A HISTORY OF THE DEVELOPMENT OF THE PICTURED CLIFFS SANDSTONE IN THE SAN JUAN BASIN OF NORTHWESTERN NEW MEXICO

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Abstract

Through the years of gas production in the San Juan basin, the Pictured Cliffs has been one of the most talked about, most sought after and least written about formations in the entire area. This paper will be an attempt to trace the history of gas development of this formation from the first discovery well through the present drilling activity.

This treatise will include its age, stratigraphic position in the section, lithology, mode of deposition, methods of completion and their effect on the development and production statistics of the various pools in the San Juan basin.

For the most part, this will be a history of El Paso Natural Gas Company's participation in the development of the Pictured Cliffs Formation.

INTRODUCTION

The purpose of this paper is to trace the history of gas development from the Pictured Cliffs sandstone in the San Juan basin of northwestern New Mexico. A short background will acquaint the reader with the Pictured Cliffs sandstone.

The Pictured Cliffs Formation was recognized and named by W.H. Holms in 1877 and substantiated by J.H. Reeside in 1924. The type section is an outcropping sandstone overlying the Lewis shale west of Farmington, New Mexico at approximately the village of Waterflow. The name Pictured Cliffs comes from the petroglyphs that adorn the rocks in this area. This is considered a form of Thirteenth Century art and/or vandalism, depending on which side of the fault you're from.

The Pictured Cliffs Formation in the San Juan basin is Upper Cretaceous, Middle Montanan in age. The sandstones in the formation are grey to greyish-white, with a salt and pepper look, fine to medium grained, well sorted, angular to sub-rounded, composed mainly of quartz with some ferromagnesium minerals and glauconite cemented with calcite and bentonite. The Pictured Cliffs is transitional with the underlying Lewis shale and the bottom of the formation is usually picked from the electric log at the base of the last recognizable sandstone.

The Pictured Cliffs is overlain by the Fruitland Formation which consists primarily of coal and shale with some sandstone stringers. These stringers, when located in the basal portion of the Fruitland, are usually tongues of the Pictured Cliffs. Since the top of the Pictured Cliffs is usually picked on the top of the first sandstone below the last coal, these tongues were often mistaken for the true top by early workers.

The Pictured Cliffs sandstones are a series of lenses or benches that were deposited as the shoreline phase of a sea that regressed northeastward across the area. These benches show a definite northwest-southeast trend and overlap one another in some areas due to short periods of transgression. They become stratigraphically higher from southwest to northeast.

The Pictured Cliffs Formation has the following general characteristics:

Depth Range	0 to 4,200'
Thickness	50 to 400'
Porosity	0 to 20%, Average approximately 15%
Permeability	0 to 150 Millidarcies

Since little structure is present in the Pictured Cliffs, it is generally accepted that the trapping mechanism is stratigraphic.

The development of this sandstone formation in relation to its natural gas production has been taking place for approximately 45 years, with early development at a rather slow pace due mostly to a lack of market. During the early phase, drilling was undertaken by Southern Union Gas Company, Amoco Production Company and several independents to supply Southern Union's pipeline to Albuquerque.

El Paso Natural Gas Company became interested in the San Juan basin gas during the latter part of the 1940's. Based on the future potential of the area, a pipeline was constructed from the basin to the California state line. This project created an immediate demand for San Juan basin gas and the Pictured Cliffs Formation played an important part in fulfilling this demand.

Figure 1 shows the San Juan basin as defined by the Pictured Cliffs outcrop. Nearly all the Pictured Cliffs production is located in San Juan, Rio Arriba and Sandoval Counties, New Mexico. There is some production in Colorado, but this paper will be confined to New Mexico.

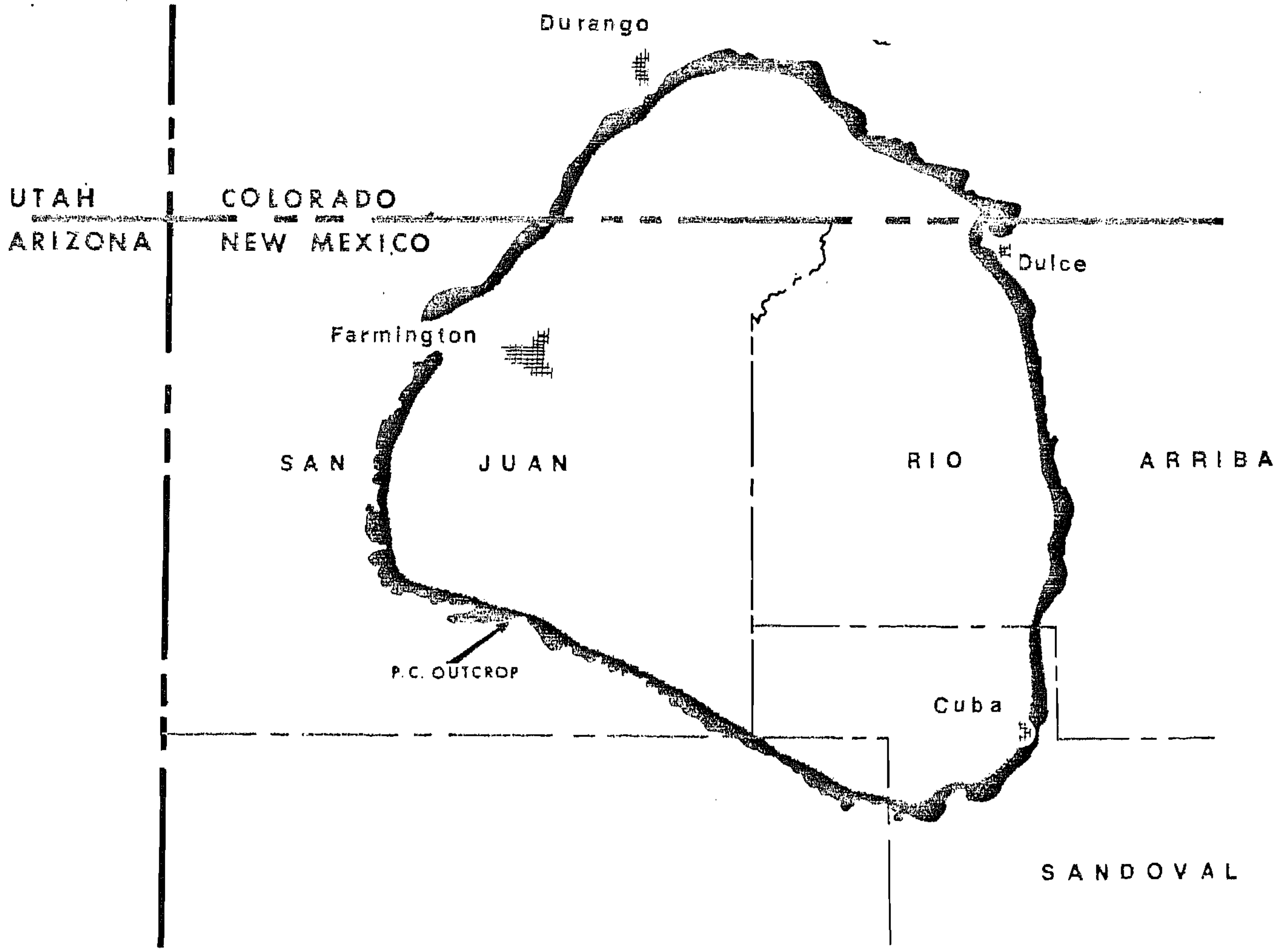


Figure 1: Central San Juan Basin as defined by Pictured Cliffs Outcrop.

It all started in Sec. 34, T. 29 North, R. 11 West, with the discovery well being completed by Congress Oil Company November 25, 1927 (fig. 2). The well had an Initial Potential of 1.5 MMcfgd from 1,910 feet. The area was known at that time as the Kutz Canyon gas field. By mid-1941 twenty development wells had been drilled here.

The second significant discovery was made approximately 4½ miles directly northwest of the Congress well. This well, the Hart No. 1 (SW¼ Sec. 11, T. 29 N., R. 12 W.), was drilled by an independent, Fred Barrett, and potentialed for 800 Mcfgd from 1,740 feet. This area was named the Fulcher Basin gas field. By mid-1941 seven development wells had been drilled in this field. These fields have since been connected and are now known as the Fulcher-Kutz gas pool. It covers the area shown on figure 2.

Very little development work was accomplished during the early and mid-1940's due to World War II and its immediate after-effects. In the late 1940's and early 1950's development of the Pictured Cliffs was greatly accelerated. This acceleration was initiated principally by El Paso Natural's pipeline to California, opening a new market for San Juan basin gas.

During the late 1940's it seemed that every Pictured Cliffs well was a new field discovery. Some of the more important discovery wells are shown on figure 3. Recognizing that some of these fields were merely extensions along the same trend, they were grouped and four new pools were created; Aztec, Blanco, Gavilan and West Kutz (see fig. 4).

With such good production at relatively shallow depths, the development wells were being drilled by practically everybody who could muster a 160 acre block. Some were well planned and some were just drilled "shotgun" style. This resulted in prolific production in some areas and little or no production in others. It soon became apparent that these sandstones were not a blanket type deposit but rather a series of lenticular beach or near-shore type deposits. From this knowledge, stepout wells were located along the suspected trends and new pool boundaries established.

The basic drilling activcty in the San Juan basin during the early 1950's was for the prolific Mesaverde Formation (Cliff House and Point Lookout). Fortunately, the wells were logged through the Pictured Cliffs in most instances and from these logs we are able to examine the characteristics of the Pictured Cliffs and pinpoint areas of superior reservoir quality.

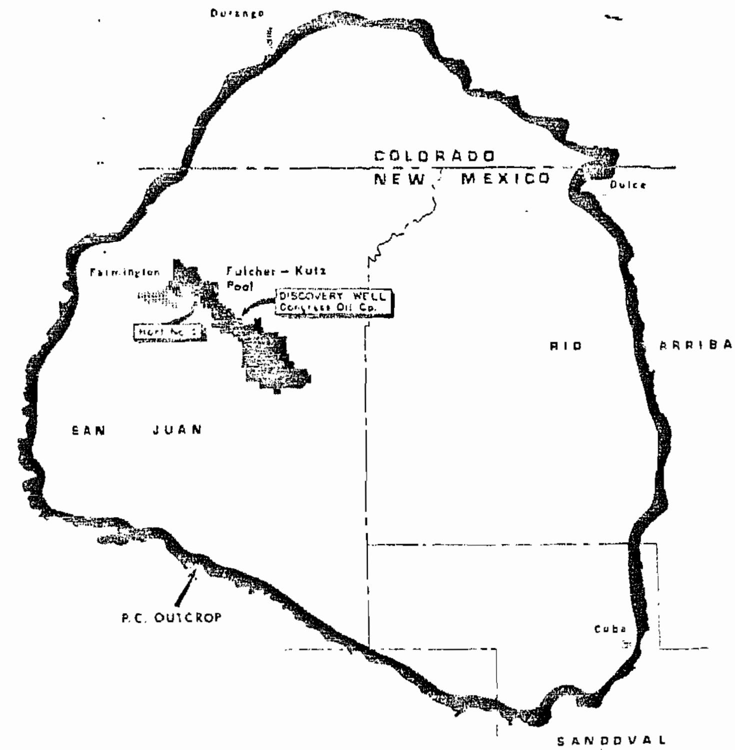
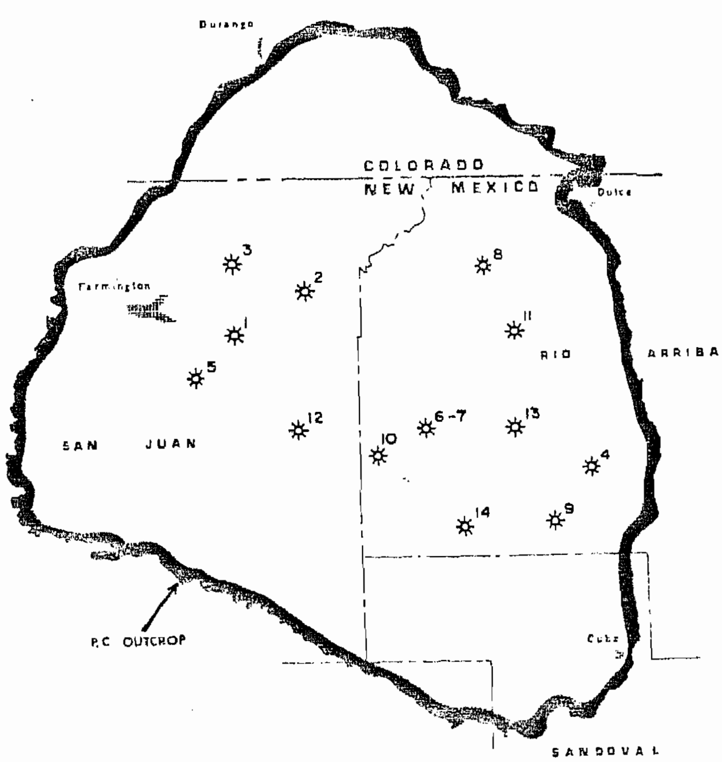


Figure 2: Fulcher Kutz Pool.



POOL	DATE	LOCATION OF DISCOVERY
1 Fulcher - Kutz	1927	Sec. 34 - 29N - 11 W.
2 Blanco	1933	Sec. 33 - 30N - 9 W.
3 Aztec	1941	Sec. 10 - 30N - 11 W.
4 Gavilan	1949	Sec. 14 - 25N - 2 W.
5 West Kutz	1950	Sec. 12 - 27N - 12 W.
6. South Blanco	1951	Sec 15 - 26N - 6 W.
7. Doggie Canyon	1951	Sec. 15 - 26N - 6 W. (now South Blanco)
8. East Blanco	1952	Sec. 18 - 30N - 4 W.
9. Hammond	1952	Sec. 22 - 24N - 3 W. (now South Blanco)
10 Canyon Largo	1953	Sec. 4 - 25N - 7 W. (now Ballard)
11. Chaza Mesa	1953	Sec 25 - 29N - 4 W.
12 Ballard	1953	Sec. 16 - 26N - 8 W.
13. Tapacito	1954	Sec 14 - 26N - 4 W.
14 Otero	1955	Sec 28 - 24N - 5 W. (now Ballard)

Figure 3: Significant Discovery Wells

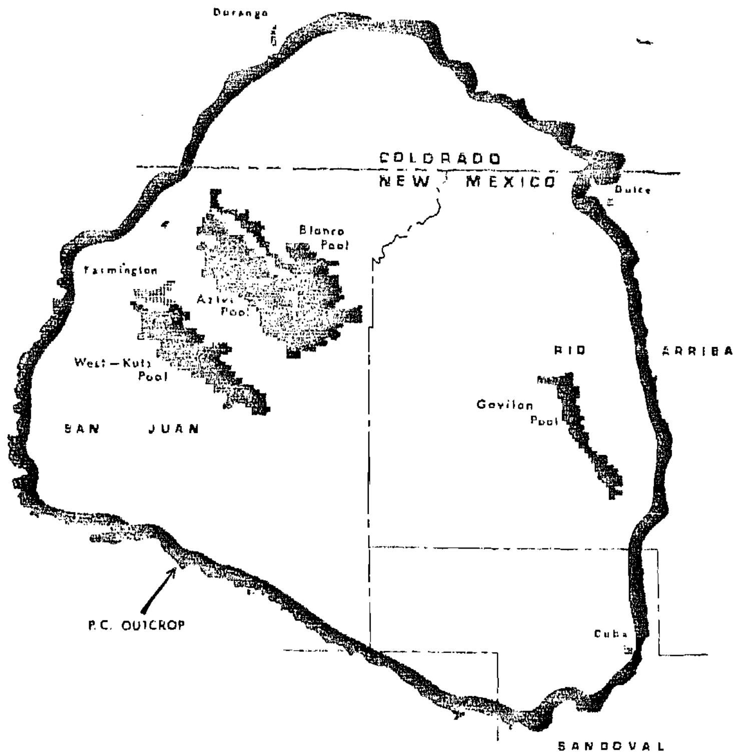


Figure 4: Aztec, Blanco, Gavilan and West Kutz Pools.

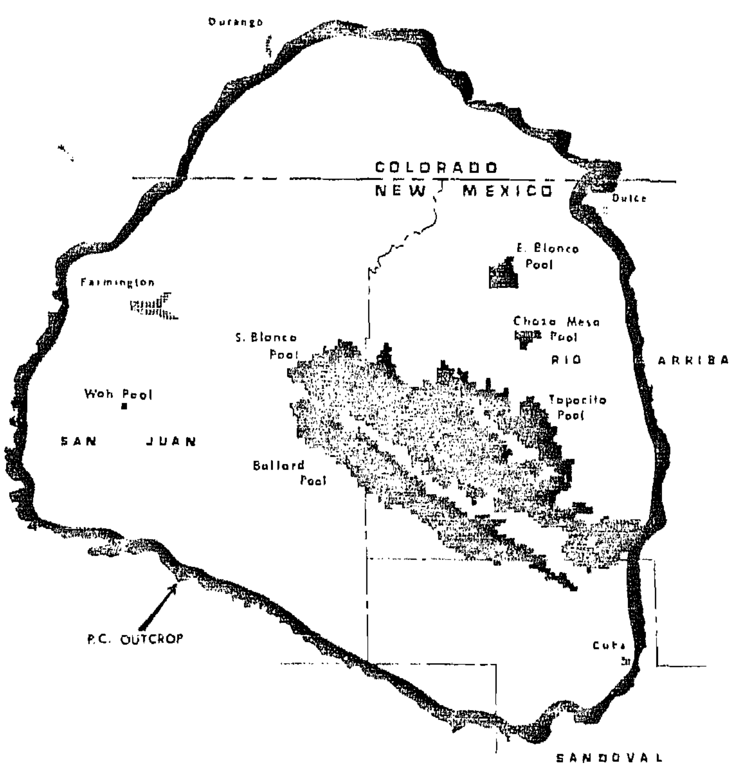


Figure 5: Ballard, Choza Mesa, East Blanco, South Blanco, Tapacito and Wah Pools.

From 1952 to 1955 the drilling of Pictured Cliffs wells was mostly in the area of T. 28 and 29 N., R. 9 and 10 W. (south end of Aztec and Blanco pools). At this time there was also a large amount of Mesaverde activity going on in this same area. The drilling of these individual Pictured Cliffs and Mesaverde wells in the same area led to the inevitable question, "why not a dual completion?" During El Paso Natural's 1955 Drilling Program approximately 50 wells were selected to be dually completed. Most of these locations were scattered throughout T. 28 N., R. 7, 8, 9 and 10 W. (north end of South Blanco pool, fig. 5). These were, for the most part, very successful and were also among the first Pictured Cliffs wells to be completed through perforations. These completions added greatly to the development in this area.

By 1955 the remaining Pictured Cliffs pools presently occupying the San Juan basin were established. These are Ballard, Choza Mesa, East Blanco, South Blanco and Tapacito. One more 160 acre field, the Wah pool, is located in T. 27 N., R. 13 W.

Notice the complete absence of production to the southwest and northeast of the established pool area (fig. 6). The sandstones to the southwest are water saturated and are believed by some workers to be from a different source than the sandstones to the north and east. The sandstones to the northeast tend to become shaly to the point that they are difficult to recognize on logs. The two isolated pools, East Blanco and Choza Mesa located in this shaly area, produce from fractures rather than the beach or bar type reservoirs in the other pools.

With this trend type development it became apparent that in some instances there could be a number of different sandstone lenses under one location. This more or less initiated the drilling of the complete Pictured Cliffs Formation in contrast to the previous practice of drilling to some predetermined intraformational depth.

Completion methods and techniques played a major, if not the major, role in the development of the Pictured Cliffs. The major changes in method that have occurred from 1950 until the present are of interest.

DRILLING METHODS

Open Hole Method

The method used by El Paso Natural for an open hole completion was to drill two feet into the Pictured Cliffs Formation, run an electrical log for correlation purposes, and set casing (usually 5½ inch or 7 inch) at this point (see fig. 7).

Cable tools were then moved in and the well drilled to a predetermined depth, theoretically through the entire pay zone of the Pictured Cliffs Formation. At this point, the well was stimulated by either shooting with nitroglycerine, sand-oil fracturing or sand-water fracturing. This stimulation was usually conducted without a log of the pay section. Therefore, a mistake in determining the top of the formation resulted in setting the casing either too high or further into the pay section than anticipated. In this respect, the intertonguing of the Pictured Cliffs and Fruitland Formation had a great effect on some of the early Pictured Cliffs wells. For instance, if a tongue of the Pictured Cliffs was encountered in the Fruitland, chances were good that casing would be set at this point and a predetermined depth set for the well. It would then be possible to drill to total depth and never reach the pay section, or drill into the Lewis shale below. This has been done in many instances.

Another method was to determine the top of the Pictured Cliffs by samples and run casing *without benefit of a correlation log*. Upon reaching total depth, a Gamma Ray-

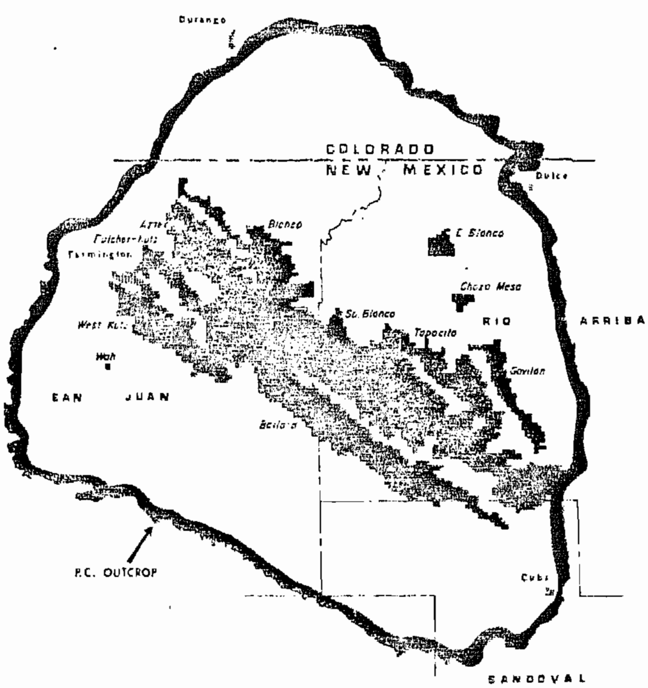
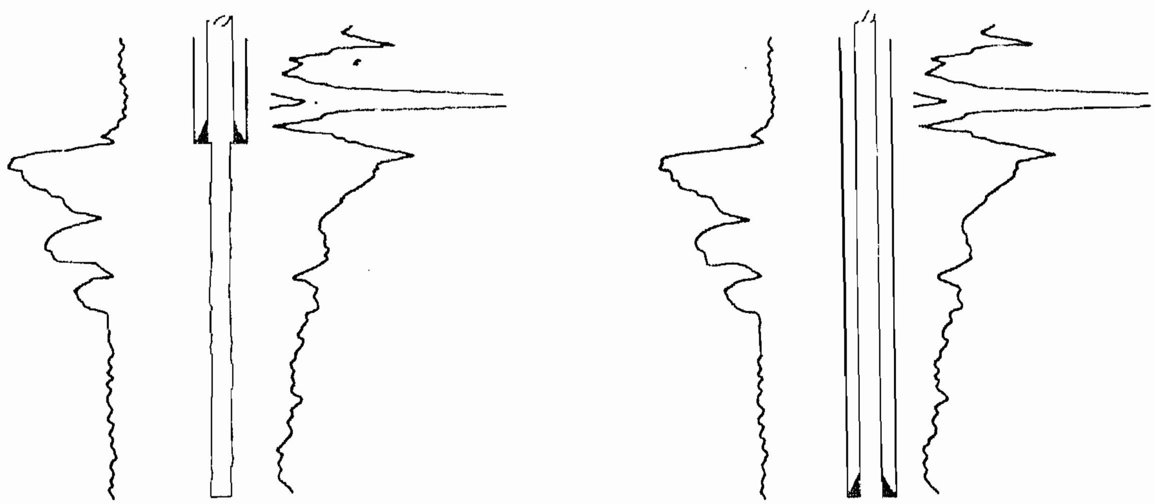


Figure 6: Present outline of San Juan Basin Pictured Cliffs Pools (The Whoooole Thing).

COMPOSITE LOG OF PICTURED CLIFFS SANDS IN THE SAN JUAN BASIN



OPEN HOLE CASED HOLE

Figure 7: Typical Pictured Cliffs Section showing open hole (left) and Cased hole (right).

POOL NAME	NO. OF WELLS	ACCUM. PROD. IN BILLION CUBIC FT.
AZTEC	435	175.1
BALLARD	519	221.1
BLANCO	261	106.4
BLANCO EAST	21	10.1
BLANCO SOUTH	1252	612.8
CHOZA MESA	8	2.1
FULCHER - KUTZ	327	175.7
GAVILAN	89	33.8
TAPACITO	197	152.1
WEST - KUTZ	201	103.7
UNDESIGNATED	15	3.1
TOTALS	3325 WELLS	1,595.9 B.C.F.

ESTIMATED ORIGINAL RECOVERABLE RESERVES =	4,000 B.C.F.
ESTIMATED REMAINING RECOVERABLE RESERVES =	2,400 B.C.F.

Fig. 8 Pictured Cliffs gas production by pool through 1971.

Neutron log was run over the entire hole — both cased and open. The interpretation of these logs is very difficult because the argillaceous matrix causes the Pictured Cliffs to log as shale. In some cases no log at all was run. Last year El Paso Natural worked over a well of this type and, after running a Gamma Ray correlation log and comparing it to the log of a nearby well, it was observed that the entire Pictured Cliffs section was behind the casing.

Different types of completions in "open hole" have been:

Shooting with Nitroglycerine

One of the three methods of open hole completion, shooting with nitroglycerine was the earliest and perhaps the least successful method. The procedure for this method was as follows:

Upon reaching the predetermined total depth, the well was killed with water. Containers of solidified nitroglycerine, called Torpedos, were then run in the hole with two preset time bombs in the top Torpedo. This filled the "open hole" from total depth to within ten feet of the casing. (Considering a perfect casing point two feet into the pay and the ten feet of "open hole", there was twelve feet of pay not covered by explosives.) A canvas umbrella was run in the hole on top of the nitroglycerine and five or six feet of pea-gravel was run in on top of the umbrella. A calseal plug was then set in the hole to fill the remaining four or five feet of "open hole" and upward through the first joint of casing. This was known as a Tamp shot. Although this plug was primarily used to contain the explosive and prevent collapse of the casing, it would also cover the top ten feet of the pay formation. In many areas, and in certain wells, this would cover a major portion of all of the pay zone of the Pictured Cliffs Formation, thus leaving the explosive to work on the shales and shaly sandstones of the basal Pictured Cliffs-Lewis shale transition.

As was previously mentioned, this method at its best was not the most potent production stimulant. It did, however, have good results in some isolated cases.

Sand-Oil Fracturing

This type of completion is done by forcing, under high pressure, a mixture of sand and deisel oil down through the casing or tubing. Theoretically, hydraulic pressure applied to the formation forces fluid into bedding planes and preexisting or newly created fractures which are scoured clean by the sand and widened by the force applied. When the pressure is released the oil flows back into the wellbore leaving the sand to prop open the fractures and bedding planes, thereby creating a passageway for the gas to enter the wellbore. The oil is recovered and the well is completed.

Sand-Water Fracturing

Sand-water fracturing works on the same principle as sand-oil except that water has been substituted for oil for a more economical and less hazardous operation.

The difficulty with sand-oil and sand-water fracturing in "open hole", is the lack of control to assure the frac-mixture penetration of the desired interval. The only recourse, once the fracture operation starts, is to continue pumping until the job is completed with the hope that the fracturing occurs in the zone containing the gas.

It is also a common belief in the case of sand-oil fracturing that in certain areas in the basin an oil-water emulsion was formed which created a permeability barrier and restricted the flow of gas into the wellbore.

Present Method

The aforementioned completion methods spanned the years 1950 to 1955. There are approximately 1,000 open hole completions in the San Juan basin.

The method used at present is to drill through the entire Pictured Cliffs Formation, run logs, usually an induction-electric, plus a porosity determination log such as gamma-density, sonic or neutron. Casing is then run to total depth. From these logs the zones to be completed are selected. These zones are then selectively perforated with a specified number of holes per foot or per zone. The well is then ready for sand-water fracturing. Here, again, different techniques are employed. Bridge plugs may be used to stage-frac different intervals or rubber ball sealers may be dropped at certain intervals during treatment to plug perforations in the already fractured zones. In either case it is assumed that all the potential productive zones have been stimulated and the gas is capable of being delivered into the wellbore.

New methods of completion are still being tried at the present time. Nuclear stimulation, where the formation is fractured by exploding a nuclear device in or slightly below the pay zone, has been pioneered at Project Gasbuggy. This technique causes a chimney (cavity) to be formed which collapses, forming a large porous area. Gas migrates along the induced fractures into the chimney area and is produced in a conventional manner out of the wellbore.

A second method is to pump a liquid chemical explosive into the formation and ignite it, again inducing fractures from which the gas is produced. Another is gas fracturing with CO_2 or some other gas.

The first two methods are still not operational at this time, but experimenting is still proceeding.

The total accumulative production from the Pictured Cliffs Sandstone as of January 1, 1972 is shown on fig. 8.

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