THE MANCOS FORMATION
of the
RANGELY OIL FIELD
RANGELY, COLORADO

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This paper will update and evaluate the potential of future oil production in the Mancos shale formation, part of the Upper Cretaceous age group in the Rangely Area. The Rangely Mancos shale has produced in excess of 15,000,000 barrels of high gravity crude oil in the Rangely Oil Field and the surrounding area in it's 95 years of production. I have been involved in the Mancos shale drilling and production business for the last 40 years drilling my first Mancos shale well about 1958. Before that I work for my father in the same business here in Rangely with a company he owned, Twin Arrow Oil and Gas.

The Mancos Shale Formation with production from the upper Mancos shale, the three benches of the Niobrara section and the top of the Carlile shale have all produced oil at one time or another on the Rangely Anticline. Production in the upper Mancos shale is common to Rangely in Northwest Colorado, with about half of the Rangely Mancos shale production coming from that zone.

The over all thickness of the Rangely Mancos shale in Rangely is 4200 ft. The upper Mancos shale consists of a dark gray to a blue gray, soft, thinly bedded, slightly calcareous, plastic marine shale with intermittent calcite seams running adjacent to faulting in this area. Oil shows and production have been common in this section.

The three Niobrara benches consist of Gypsum in the form of selenite and calcite geodes that are common throughout this section. Oil shows and production have been common in all three zones of the Niobrara Section.

The Carlile Shale below the Niobrara consists of a gray, occasionally silvery-gray, firm, slightly calcareous, very slightly silty shale. Oil production from this section has been produced on the southeast and south flank of the Rangely anticline in the past.

As early as 1902, oil was discovered in open fractures in the Cretaceous Mancos formation high up on the south side of Rangely Anticline in Section 5, Township 1 North, Range 102 West. The remote location and lack of a local market suppressed development until about 1919. About this time Raven Oil and Refining Co. started operations in the Rangely area. They provided a integrated service company (from the oil well to the gasoline tank so to speak). They provided gasoline and fuel oil for western Colorado and Eastern Utah in the 20's and 30's. In the early 50's Twin Arrow drilled a number of mancos wells in Sections 29 and 28, 2 North, 102 West at a depth of 1500 to 2000 feet. Three or four of these wells made 250 BOPD and in five to six years the accumulative was about 160,000 bbls. In the early 50's sporadic drilling, mostly around the crest of the anticline brought in an occasional well, some of which paid out, while others were sub-commercial. Continued development of the fracture reservoir idea pointed to the greater potential of down - flank locations based on surface mapping of calcite lined fractures. As the more obvious locations in the Rangely "basin" become scarce, exploration moved down the steep south limb of the fold following the faults which offset the sandstone's of the rim-rock.

These wells are deeper and stratigraphically as well as structurally lower than the "basin" wells. Several 500 BOPD wells have been completed in the Niobrara member of the Mancos from sites along the hogback rims on the South flank of the Rangely Oil Field."

One of the numerous problems of testing the Niobrara shale in Rangely was that a well would be completed for production in the upper Mancos shale before obtaining a sufficient depth to test the Niobrara or Carlile shale zone. Later after production was depleted the well very likely would be P&A with out any future drilling to a lower depth.

The precedent of discovery on the crest and flank of Rangely let gradually to the drilling of analogous locations on other structures in Northwest Colorado. The second major Mancos/Niobrara discovery was at the Tow Creek Oil Field in 1924. Except for development drilling in these two fields, there was no significant new Mancos/Niobrara exploration until 1953, at which time Moffat Dome's production was extended to the Niobrara. In 1955, renewed drilling at Rangely extended the production to the southeast and south flanks of the Rangely field and also in the lower Niobrara and Carlile shale zones.

<u>Reservoir Characteristics</u>

There is little, if any, inherent porosity or permeability in the Mancos/Niobrara formation. Production is obtained from various types of fracture or jointing systems, fault zones, or lamellar bedding separations. Since calcite seems to be common in many fractured shale reservoirs, it is believed that associated calcitized zones having a vugular ground mass may supplement ordinary fracture production.

By their nature, fracture systems may form reservoirs that are greatly varied in size and pattern. The type of tensional stress certainly has some bearing on both the areal extent and pattern of the fracture reservoir. The thickness of the competent bed also is a factor in determining the size of a reservoir. Calcite filled fracture systems were traced out by the USGS on the top of the Rangely Anticline in the 1930s and 1940s. These fractures were dug out by hand and a majority of them were found to be running Northeast/Southwest parallel to the faulting system across the Rangely Anticline. It has been known that these fracture systems to be as close as 10/50 ft' and not communicate from one fracture to the other fracture with hydrocarbons.

One of the seemingly "apparent problems" connected with fractured shale reservoirs is that the accumulation of oil in any given fracture may not necessarily have any relation to oil accumulation in other fractures. Many times producing wells have been offset by dry holes in different directions. By the same token, many wells have been successfully completed in a very near offset location to wells that had produced and been exhausted of all production or where drilled as dry holes, plugged and abandoned. For example, a fracture system caused by a specific fault may have a very limited extent, and if no major competent bed is adequately fractured near the fault, there may only be minor oil recoveries from the fracture system.

One other feature of fractured shale reservoirs is the effect of depth on the fracture system. It is believed that the greater pressures and higher temperatures associated with depth serve to enhance the favorable characteristics of a fracture system reservoir with more brittle shales near the fractured zones. "Estimates of oil in place, the recoverable oil, the pay thickness and porosity-permeability characteristics are difficult to describe because of the nature of the fracture pattern and because of lack of data on the many old wells. The actual pay zone in individual wells may be limited to a few large fractures spread over a few inches or may include minor fractures spread over several feet.

It has been known over time that many depleted oil bearing fractures have been regenerated with oil. This oil replacement could be from lower fractures or fractures nearby that were not drained or depleted. If this is true, then other fracture systems/zones in the same vicinity/area could still be stored up with producible hydrocarbon. Old fracture systems/wells that have produced and where depleted have been known to regenerate or accumulate with oil over time and where later returned to a good productive oil well. New drilling has obtained new production from the same area or fracture systems that where produce and depleted of oil before. some times the new production is better than the first time around.

Size of fracture: In association with the pressure of the reservoir, the width of the fracture void at its entrance to the well bore is the single most important factor determining the rate of production of the well. As can be imagined, there are a multitude of fracture void sizes, ranging from paper thin cracks to "cavities" of a foot or more. As an extreme example, there are numerous cases in Rangely where the drill string has dropped as much as 20 feet into a void. It is believed that the "norm" for fracture void sizes would consist of a broken or shattered area irregularly occurring in a vertical area of only a few feet, with the individual "cracks" being measured only in fractions of inches. With any given reservoir pressure, therefore, the larger the cracks, the higher the rate of production.

Pressure of the reservoir: Most producing fractured reservoirs in the Rangely Mancos shale are characterized by gravity drainage and low pressures, aided slightly by a solution gas drive. Occasionally, a low pressure gas cap structurally updip, or stratigraphically at the top of the fracture system, may provide a slight temporary gas expansion drive.

Depth of reservoir: Higher pressures have been recorded in the deeper fracture reservoirs and it has been noted that favorable characteristics of a fracture system seem to be enhanced at greater depths. The conclusion is that the deeper the fractured shale zone is pursued, the greater the production potential becomes. This is born out by the higher rates of production in the southeast and south flanks of the Rangely Anticline.

Niobrara Oil:

The source of Niobrara oil is unknown. One theory of accumulation is that the oil has migrated along fault planes into the fracture system from sand reservoirs below. The association of surface oil and gas seeps with some fracture reservoir fields would tend to support this idea. Others (as is this author) are of the opinion that the oil is indigenous to the Mancos formation and that fracturing a competent zone within this rich marine source bed provided the reservoir. The Niobrara crude oil like the upper Mancos shale is a waxy-paraffin base crude with an API gravity of 38 to 44 degrees. In Rangely when drilling with cable tools or air you could let a dry hole that had no oil shows during drilling operations set for a short time and later find a accumulation of oil in the hole. It could be the massive Mancos shale formation is the source rock that furnishes the oil to the fracture shale reservoirs. Because oil and gas (hydrocarbons) ordinarily does not occur in commercial deposits in the same rocks in which they probably originated. Migration of the hydrocarbons from source rock to reservoir rock is a question that many have tried to solve or understand for many years either by laboratory test or field experiences. It is the belief that further migration can and does take place through the reservoir rock until the hydrocarbons either escape or are caught in some type of nature trap or fracture system. The oil and gas can travel along a fault line to a fracture system like those found in the Mancos shale in Rangely.

Most likely the subsidiary breakage off of the fracture and the fracture zones are cleaner than the fault corridors. Slow movement of the migration of hydrocarbons into the fracture zone or from one fracture to another helps keep the fault trash or seam mud down to a minimum with the entry of oil into these fracture reservoirs.

If the oil and gas is produced from a well to rapidly, it can cause the movement of these fault contaminants into the producing fracture. This can completely shut down the movement of oil from the source rock into the producing fracture reservoir. In most cases a oil operator may not have but very little control over this problem.

Exploration Methods:

Many different techniques are used in the exploration for fractured Niobrara reservoirs. A general prospective area may exist anywhere the beds are folded, regionally jointed, or faulted.

In localizing the actual drill-site, many geologists attempt to intersect at depth a fault or fracture observed on the surface. After estimating the hade of fault or fracture and predicting the drift of the well bore, it is a matter of simple trig to place the drill-site such that the two will meet at the proper depth. One of the obvious fallacies of this technique, however, is when the hade of the fault or fracture changes at depth; it has been estimated that of all locations picked using this method, 50% are successful in reaching the objective fracture.

Another method used, is placing the location such that the well bore will intersect a potential fracture zone "near" a known fault; some people believing in the upthrown side and others in the down thrown side.

Much photogeology and "creekology" is used in initially determining lineations and fracture or jointing systems in a prospective area. Surface work normally supplements the photogeologic work by refining the fracture patterns. Individual locations are then picked depending on fracture densities, stronger versus weaker lineations, regional dip, and/or known directions of fracture hades.

An area of tensional stress, with the appropriate bending of the beds, is still the single most important criterion for establishing a fractured shale prospect. Of all the exploration methods used to set a new well location in Rangely, one would be the tossing of the hat more times than not.

<u>Drilling Techniques:</u>

The open cable tool hole in the early years had been the most satisfactory method of drilling into fracture zones. The majority of the wells at Rangely were drilled by the cable tool rig. With no hydrostatic pressure (other than the drilling fluid) against the fracture, the cable tool hole, in its time , furnished the best evaluation of oil shows. However, unfavorable aspects of this method are the numerous instances where the walls of the cable tool hole have been mashed and plastered, sealing off apparent commercial oil zones. Also, the slow penetration rate and the resulting high costs combine to detract from the advantages of cable tool drilling.

With conventional rotary drilling, the hydrostatic pressure of a column of mud against a fracture system can very likely plug or damage a potentially productive zone, especially at shallower depths where the reservoir pressure is low. Mud invasion into a fracture system with low pressures can occur very easily and can virtually eliminate any chance of "seeing" the oil. Also. gels in the mud may set up in the fractures and permanently damage the reservoir.

Today, rotary air drilling has become the most popular method of drilling into fracture zones. It is normally very fast, economical, and truly affords the best evaluation of any oil or gas show. The major problem encountered with air drilling is when water zones occur above the objective pay. Aerated oil, aerated mud, stiff foam, and most recently Air Mist have been used to combat water flows. It is believed, however, that any additives to the air detract greatly from the effectiveness of air drilling in fractured oil reservoirs.

The firm limy shale of the Niobrara is relatively very competent in its original state, but it can be crushed or broken into an incoherent mass when higher pressures are applied. Naturally, if the competent shale is fractured when drilled into, any abnormal pressure, whether it be fluid or air, will tend to destroy this fracture framework. For this reason, potential fracture reservoirs should be treated as gently as possible. Air mist has cut down on chances of mud/off. History has shown that the less the natural state of the fracture zone is disturbed, the better the well will be. After the productive fracture is exposed and the allowable rat hole is drilled, the well should be blown until the oil is clean of impurities. This policy has cause many wells in the past to stop with drilling ahead when production was obtained in the upper Mancos shale zones.

Air mist drilling has made it possible to drill below an oil zone keeping the chance of mud rings or mud bridges to build up in the upper hole to a minimum helping to eliminate high air pressure across the new oil zone.

Frac jobs are naturally not recommended because the high pressure tends to destroy the framework of the fractures. Also, there is no way of directing the frac energy into the proper zone.

Acid only dissolves the firm limestone matrix leaving a bentonitic-clay mush which would possibly plug the fracture voids.

Completion Techniques:

Although a few wells have been completed in the conventional porous reservoir manner, most wells in the fractured Mancos/Niobrara have been completed as open holes. Surface casing is generally set from 30 to 90 feet, depending on surface waters encountered. The hole is then drilled with air or cabletools into the fracture system. After oil entry is noted, the well is either blown or bailed clean, tubing is run, and the well put on pump. In the deeper wells in this area, a production string of casing is occasionally hung just above the pay zone with numerous baskets to protect the pay zone'(s) from cavings from up the hole.

Production and Operation:

A fractured Mancos/Niobrara well is usually one of the most trouble-free operations in the oil field. Shale wells in the Rangely Mancos shale have produced 15 to 20 years with out any down hole well service , pump change or clean outs.

Economic Considerations

Several factors combine to make a Mancos Shale well in Rangely Field relatively inexpensive to drill and complete. Some of the major factors are listed below.

1) Rangely Field is an established oil field. It is near an office of almost every major oil field supplier. Supplies and services can be secured without delays, which eliminates costly rig standby, and without excessive mileage and freight charges.

2) Because of the previous activity in Rangely Field, almost any potential well site is within a quarter-mile of an existing access road, reducing construction cost.

3) Because the Mancos Shale is the surface formation and it weathers to a clay soil without rock, road and location construction is in clay, or in unconsolidated stream deposits. Neither requires blasting or ripping, and construction costs are reduced.

4) Topography in Rangely Field is subdued. Generally it is flat to gently rolling, though the area is cut by some deep draws. Choosing a well location to conform to geologic criteria will not result in expensive construction costs as it can on the Douglas Creek Arch to the South.

5) Air drilling is the preferable method; this eliminates expensive mud programs and water hauling.

6) Since shale wells in Rangely Field are shallow, from about 500 feet to 4000 feet, drilling rigs in the lowest range of capabilities and the lowest price range can be hired.

7) Because of the stability of the Mancos Shale, a well can be left open during air drilling without causing downhole problems during holidays, periods of bad

weather, or unavoidable delays. Wells are often drilled by working during daylight hours only. A rig need not be kept on standby during long delays.

8) Because of the stability of the Mancos Shale, a well can be completed without the cost of production casing and the cementing of the production casing.

9) Normally, no mud logging, open-hole logging, or stimulation work need be included in the cost of a well.

10) Because in most producing wells there is no gas or water, no treaters, gas or water flow meters, or other gas or water equipment need be included in the well cost.

There are two significant negative factors that affect a Mancos Shale drilling prospect. Because of the uncertainty of dry holes. Approximately three holes in ten can be completed as producers. In addition, the production of a producing well can fall anywhere within a wide range. More wells will be stripper wells than will make fifty barrels a day or more.

There are considerations that help offset these negative factors. Mancos crude usually has a 40 gravity or higher, resulting in no reduction in the sales price. Colorado Western crude prices are the highest paid in the Mid-Continent EOTT crude price bulletins for many years. Rio Mesa Resources is under contract to sell oil to EOTT Operating Limited Partnership. This contract has a bonus of .45 per barrel above the current daily posted price.

The Rangely Mancos shale has always been known to have deeper possibilities for production after the shallower oil zones were depleted. Oil could always be found anywhere in the 3500 ft, in the Mancos shale above the Carlile shale. Below the Mancos shale, the Carlile shale and the Frontier sandstone have both produced oil in the past.

Many of the older wells were drilled with Cable Tools. There was an old saying in those days "that a straight hole never produced oil in Rangely." A large number of these oil wells seemed to go crooked about the depth the drilling operation was near or started to cut into a fracture system. With Cable Tools these oil zones were always hard to drill through because of the shattered or broken up shale and the seam mud located in the oil zones that would not mix with the drilling fluid used in the drilling operations. Also after drilling through the oil zone the crooked hole would try to straighten up. This same procedure would repeat each time the well was deepened to deeper production. Quite offend the deepening of a hole would be less than 50 to 100 ft. before the well was but back on production. When this happened, a number of times in a thousand feet, there was always the problem of the drilling tools key seating or the drilling line cutting a line groove in the wall of the well bore. This would bring the deepening operation of the well to a halt, basically, because you actually wore the hole out from the numerous times of deepening the well. Quite often, this type of a hole would never reach a depth that would be sufficient in obtaining production from the lower Niobrara sections.

The following is a good example of a well drilled deeper and successfully obtaining deeper production after the upper oil zone was depleted. In the 1950's we drilled a well in Sec. 28, about 2 miles east of the Chevron's Rangely Field office. This well was completed at 750 ft. making about 75 bpd. This well was drilled with Cable Tools by Twin Arrow Drilling Co. in an area that Raven Oil had produced a number of oil wells at a deeper depth in the 1940's. When Twin Arrow completed this 750 ft. well the rig was moved around to the south side of the mud pit. A second well drilled to 2500 ft. was dry. Later the 750 ft. well, exhausted all oil production at that depth, was shut in. Because of the dry hole to the south about 50 ft. and the old dry holes of Raven Oil in the same vicinity the decision was made to plug and abandon the well. When the production equipment was removed from the hole a small amount of oil was found in the hole. The well was then deepened the first time to 1100 ft. for 75/80 bpd. and later a second time to 1400 ft. for 75/80 bpd. The last time the well was deepened to 2300 ft. and put on production for 250 bpd.

During the time periods that the shallow well was being deepened two more wells were air drilled by Twin Arrow and completed in the same vicinity at a depth of about 2500 ft. These three wells along with and including the old Raven Oil wells were all in the same vicinity and on less than 10 acres. The cumulative oil production in this small area was over 200,000 barrels in the 1940's and 1950's.
In the Rangely Field, Sections 27, 28, 29, 30, 31, 32, and 33, T2N, R102W, a large number of wells were drilled and produced as shallow as 500 ft. In a few places in this area there were more than 40 holes drilled on less than 40 acres.

Air mist drilling makes it possible to continue deepening these old crooked holes when the shallower production has been depleted. There can will be times that nothing can be done to take these old holes deeper. We feel that if a well is one of those that can't be deepened, we could therefore recommend a offset and the re-drilling of that well on the same location pad.

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