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A HYDROCARBON EXPLORATION MODEL FOR THE CRETACEOUS FERRON SANDSTONE MEMBER OF THE MANCOS SHALE, AND THE DAKOTA GROUP IN THE WASATCH PLATEAU AND CASTLE VALLEY OF EAST-CENTRAL UTAH, WITH EMPHASIS ON POST-1980 SUBSURFACE DATA

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NOTICE

This research was funded by the Utah Geological and Mineral Survey's (UGMS) Mineral Lease Special Projects Program, and will be available through the UGMS as an Open File Report. For information concerning the release of this project, please contact: Utah Geological and Mineral Survey, 606 Black Hawk Way, Salt Lake City, Utah, 84108, Phone: (801) 581-6831.

Included in this report is the text of the contract, and selected plates (on a greatly reduced basis) concerned with Ferron Sandstone Member deposition. The Appendix, and Plates 2-5, 7, and 13 are not included. Plates available from the UGMS are not reduced, and individual well information is more readable.

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ABSTRACT

This study incorporates subsurface, surface, structural, and stratigraphic data from the Cretaceous Ferron Sandstone Member of the Mancos Shale, and the Dakota Group into a hydrocarbon exploration model for the Wasatch Plateau and Castle Valley areas.

Deposition within a paludal environment limits the hydrocarbon potential of the Dakota Group. Prospective reservoirs lie within northeastward trending channel systems in structurally favorable areas.

Ferron production in the region is most prolific from the highly faulted Clear Creek anticline. Joes Valley, Flat Canyon, and Ferron anticlines are also responsible for significant hydrocarbon production. The future of this area lies in the development of stratigraphic traps. Areas of deltaic sedimentation have been delineated in this study which provide future exploration targets.

Cretaceous sediments were supplied by the Sevier orogenic belt, located west of the study area. The most widely accepted interpretations for the extremely complex structural relationships within the study area involve continental tectonism.

INTRODUCTION

The drilling boom of the early to mid- 1980's allowed many small operators to participate in the drilling of shallow wells in the Wasatch Plateau and Castle Valley of east-central Utah. The gas producing Ferron Sandstone Member of the Mancos Shale was the primary objective, with many operators opting to drill an additional 300 to 800 feet to also test the Dakota Group. Success was encountered within the Ferron objective in numerous wells. Unfortunately, as operators attempted to connect their wells to pipelines, they met with a depressed gas market. Hopefully, gas prices and demand will increase soon, allowing these operators to market their gas, and resume drilling.

The flurry of drilling by these small operators has produced a wealth of data that now allows deltaic systems within the Ferron to be delineated, along with potential hydrocarbon producing trends. Hydrocarbon potential of the Dakota Group has also been examined in this study.

PURPOSE AND SCOPE

This study incorporates subsurface, surface, structural, and stratigraphic data from the Cretaceous Ferron Sandstone Member of the Mancos Shale and the Dakota Group into a hydrocarbon exploration model. Using this model, specific recommendations are made for locating and drilling oil and gas wells. While numerous investigations have been conducted in the Wasatch Plateau and Castle Valley, most of these have focused on either the subsurface or the outcrop, with very few integrating both outcrop and subsurface data. Additionally, most studies have addressed either the stucture or the stratigraphy of the region, and not attempted to incorporate both into an exploration model. The existing studies are primarily oriented towards facies descriptions, coal exploration, and gross paleoenvironmental interpretations, and do not delineate potential hydrocarbon producing trends.

During the early 1980's, this area experienced a surge of drilling. Most of the operators were small companies, without extensive exploration staffs. The primary drilling objectives were the stratigraphic traps in the Ferron Sandstone Member of the Mancos Shale. Although limited success was encountered, the area is still largely unproven due to the inability of these operators to market their gas. This was caused by the surplus of gas in the mid-1980's, and the resulting downturn in gas prices.

The wealth of geologic data produced by the drilling activity in the early 1980's is incorporated into this study. It enables a much more complete interpretation of the area than previously presented. This study should prove valuable to those small operators who will undoubtedly become active again when the market improves, by providing specific recommendations for locating and drilling Ferron and Dakota wells.

PREVIOUS STUDIES

Literally dozens of investigators have studied the Wasatch Plateau and Castle Valley region. Selected publications most applicable to this study are discussed below.

Spieker (1931, 1949) was one of the earliest geologists to study the Cretaceous stratigraphy and structure in the region. Walton (1954) played an active role in the discovery and development of the Wasatch Plateau fields, and has provided interpretations of subsurface drilling data. Hale and Van de Graaff (1964), and Hale (1972) proposed the Vernal delta, Last Chance delta, and the Sanpete embayment with the accompanying Castle Valley bar. Cotter (1971, 1975a, 1975b, and 1976) performed detailed outcrop work, and integrated outcrop information and subsurface data to establish facies interpretations within the Last Chance and Vernal deltas. Ryer and McPhillips (1983), utilized both pre-1980 well data and outcrop observations to interpret the paleogeography of the Ferron Sandstone Member. They could find no evidence to confirm the existence of the Vernal and Last Chance deltas, the Sanpete embayment, and the Castle Valley bar. They support an interpretation based on numerous rivers building deltas on a much smaller scale than the Last Chance and Vernal deltas.

Young (1960, 1973) detailed the stratigraphic and depositional relationships within the Dakota Group.

Witkind (1982), Witkind and Page (1984), Standlee (1982), Villien and Kligfield (1986), and Neuhauser (1988), have all offered recent structural interpretations of the region.

METHODS USED

Subsurface data from wells within the geographic limits of Townships 12 to 25 South and Ranges 1 to 12 East in Utah was collected from the Utah Division of Oil, Gas, and Mining in Salt Lake City, Utah. Correlations were made from well to well using geophysical logs. A marker bed in the Bluegate Shale Member of the Mancos Shale, was picked from resistivity logs, and used to prepare a structural contour map for the study area. An isopach map was prepared for the interval from the Bluegate Marker to the top of the Ferron Sandstone Member. Additional isopach maps were constructed for the Ferron Sandstone Member, and the Tununk Shale Member of the Mancos Shale. Net sand maps were prepared from gamma ray logs for the Ferron, and the upper 200 feet of the Dakota Group, with sandstone lenses less than five feet thick being excluded from the net sand counts. A 200 foot slice of the Dakota Group was used because poor well control and the stratigraphic nature of the interval made it impossible to pick a reliable marker for a basal correlation point. Additionally, wells drilled to specifically test the Dakota seldom penetrated farther than the first 200-300 feet. It is also thought that the overlying Tununk may provide a source for Dakota hydrocarbons. Because of this, a 200' slice should be sufficient to determine if the Dakota has hydrocarbon potential.

Stratigraphic cross-sections support the conclusions presented in this study. These cross-sections utilize gamma ray curves, and resistivity curves in the majority of instances, and thus represent a combination of logs from each well. Spontaneous potential curves generally accompanying resistivity curves, but due to the formation water characteristics within the Ferron and Dakota, little curve deflection is observed on the spontaneous potential log. A reference map shows cross-section lines, and producing fields.

Net sandstones with greater than 8 percent porosity were calculated in the Ferron and Dakota intervals using neutron-density porosity curves. Porosity measurements, hydrocarbon shows and production, samples and sample descriptions, and drilling methodologies were analyzed to aid in outlining favorable exploration areas and drilling strategies. A fairly complete listing of pertinent well information is included in the appendix of this study.

GEOLOGIC SETTING

The study area (Plate 1) encompasses the Wasatch Plateau and Castle Valley regions of east-central Utah. Cretaceous sediments deposited in this area were derived from the Sevier orogenic belt to the west, which was active throughout Cretaceous time (Armstrong, 1968). During Dakota Group deposition, it provided source material for a depositional system that ranged from a piedmont environment west of the Wasatch Plateau, eastward through floodplain, paludal, lagoonal-estuarine, littoral, deltaic, and neritic environments (Young, 1973). Although westward trangressions of the sea caused these environmental belts to shift slightly, deposition of the Dakota Group in the Wasatch Plateau and Castle Valley areas was predominantly paludal in nature (Young, 1973). Following Dakota deposition, westward transgression of the sea inundated the study area, allowing the Tununk Shale Member to be deposited in an offshore marine environment. Deposition of the Ferron Sandstone Member of the Mancos Shale occurred when the sea regressed, and channel systems from the Sevier highlands flowed westward, depositing sediments in river dominated deltaic systems. Another transgression of the sea signaled the end of Ferron deposition, and the Bluegate Shale Member of the Mancos Shale was deposited in an offshore marine environment.

DEPOSITIONAL HISTORY AND FACIES INTERPRETATION

Dakota Group

Young (1973) proposed the term Dakota Group to include the Dakota and Cedar Mountain Formations. The contact between the two formations is very difficult to establish in the subsurface, due to similar lithologies and the intertonguing of the two formations in some parts of the study area. Because of this, it was not possible to pick a regional marker to use as a correlation point at the base of the Dakota. Therefore, a 200 foot "slice", or the uppermost 200 feet of the Dakota Group was focused upon in this study.

The Dakota Group in the study area was deposited in a paludal environment (Young, 1973). Facies within this environment include eastward flowing braided and meandering channels, interchannel facies, and coal swamps. Lithologies consist of conglomeratic sandstones, mudstones, shales, coals, and bentonites. The coals and bentonites make drilling and exploration in the area extremely difficult by causing the drill holes to slough, cave, and swell, and by greatly affecting porosity log values.

Plate 2 is a net sandstone/paleogeographic map for the uppermost 200 feet of the Dakota Group. Most operators in the area did not penetrate into the Dakota, and thus, well control is sparse. Net sand values calculated from gamma ray logs do appear to show some thickness trends. Facies relationships are also evident from studying the stratigraphic cross-sections (Plates 3-7) included with this study. By using these in conjunction with show and production information, and sample descriptions, two channel systems have been delineated which fit the trend direction and width of Young's model. These two systems flow in an east-northeast direction. The uppermost channel system shown in Plate 2, appears to demonstrate the beginning of a deltaic system in the extreme eastern edge of the study area. This increase in net sand is further demonstrated in Plate 5, where the gamma ray curve in well number 67 is beginning to show profiles common to delta front sequences.

Hydrocarbon production within the Dakota Group is extremely limited in this area. A detailed discussion of the production and interpreted hydrocarbon potential, is provided later. Additionally, the coals and bentonites have the potential to create serious drilling problems. These are also discussed later, along with recommended drilling methodologies.

Tununk Shale Member of the Mancos Shale

Subsidence of the area allowed the Cretaceous sea to transgress across the study area, and marked the end of Dakota Group deposition and the beginning of Tununk sedimentation in an offshore marine environment. Lithology of the unit is fine silt and mud. Plates 3-7 demonstrate the nature of the contacts between the underlying Dakota Group, and the overlying Ferron Sandstone Member. The Dakota-Tununk contact is generally sharp, indicating rapid subsidence of the area. The overlying contact between the Tununk and the Ferron is gradational, with the boundary being drawn where the highly resistive beds of the Ferron end. The nature of this contact indicates gradual withdrawal of the Cretaceous seaway. Subsequent deposition of the Ferron demonstrates a sediment regime composed of regressive deposits.

Plate 8 is an isopach map of the Tununk Shale Member. Since the Cretaceous seaway was towards the east, with the Sevier orogenic belt in the west, it would be expected that thickening of the Tununk shale would occur in an easterly direction. However, the isopach map demonstrates a southwestward thickening section. This appears to be related to the rapid subsidence of the axis of the foreland basin, which was developing east of the Sevier orogenic belt. A more detailed discussion of the structural history of the area is given later.

Some very limited hydrocarbon potential within the Tununk has been demonstrated in the Miller Creek area (Plate 1). It seems doubtful, however, that significant hydrocarbon production can be established within the offshore marine sediments of the Tununk.

Ferron Sandstone Member of the Mancos Shale

Ferron deposition has been extensively studied by numerous investigators. This study differs from others in that it utilizes post-1980 subsurface data and delineates areas with the greatest hydrocarbon producing potential.

Cotter (1975b) and Ryer (1981a, 1981b) identified and described five facies from outcrops of the Ferron: offshore marine, prodelta, delta front, delta plain, and alluvial plain. Plates 3-7 demonstrate facies relationships within the Ferron in the study area. Offshore marine deposition is typified by the dark shales of Tununk and Bluegate. The lowermost Ferron and uppermost Tununk are composed of prodelta deposits, which grade upward into a regional delta front sandstone. Above this, are deltaic plain and alluvial plain deposits. Differences between delta-plain and alluvial-plain sediments are summarized by Ryer and McPhillips (1983). Delta plain deposits on outcrop are distinguished from alluvial plain deposits by the presence of brackish-water trace and body fossils in delta plain deposits. Channel geometry within the delta-plain facies demonstrate channels that are lens-shaped in cross section parallel to depositional strike. Channels in the alluvial plain facies are more sheet-like, reflecting lateral migration within meander belts. The delta-plain and alluvial-plain facies are very difficult to separate in the subsurface, and are combined by Ryer and McPhillips (1983) into one facies: the delta-plain/alluvial-plain facies. This terminology is maintained in this study. Lithologies within the delta-plain/alluvial-plain facies are interbedded sandstone, shale, and coal.

Plate 9 is an isopach map of the Ferron Sandstone Member of the Mancos Shale. In general, the Ferron thins towards the eastern edge of the study area. Utilization of post-1980 well data allows for a much more detailed interpretation than presented by other studies. Several embayments are present which are indicative of interdeltaic areas. Eastward projections of Ferron thicks indicate deltaic areas; these are prime targets for hydrocarbon exploration.

Deltaic systems were mapped using the model established by Ryer and McPhillips (1983), who proposed that the Ferron was deposited by numerous deltaic systems in the Castle Valley area, and not by the hypothetical Last Chance and Vernal deltas. They explain the paleogeography of the Ferron as being dependent on the interplay between sediment input from the Sevier orogenic belt, basin subsidence from both regional tectonics and sediment loading, and eustatic rise and fall of sea level.

Plate 10 is a net sand/paleogeographic map of the Ferron, and further depicts areas of deltaic sedimentation, and thus increased hydrocarbon potential. By mapping areas of high net sandstone concentrations, several deltaic systems at the seaward (east) edge of the study area can be delineated. A fairly large delta is shown building in the area of Clear Creek field. Three lobes surround the field, with the field itself being located in an interdeltaic area. Sample and geophysical logs are extremely scarce in this field, but those available indicate that the Ferron sandstones are very poorly developed, and very tight. It is proposed that the intense fracturing and structural position of the Clear Creek Field has allowed it to produce such prolific amounts of gas from the poorly developed reservoirs. A more seaward lobe of the "Clear Creek" deltaic system is evident west of the Miller Creek Field. Another deltaic system is mapped in the Flat Canyon/Indian Creek field area, and extends east and south. Much of the post-1980 drilling success has been centered in this area. Cross-sections (Plates 3-7) show thick sandstone sequences that are interpreted as deltaic-plain sandstones. A third deltaic sequence is interpreted as being present in the Ferron field area. Ferron field appears to be more seaward than the previously described deltas. Cross sections (Plates 4 and 7) demonstrate that the lowermost Ferron delta front sandstone in the Ferron Field is becoming shaley (marine), and the coaly middle Ferron (delta plain) is becoming an upward-coarsening, clean delta front sandstone. A fourth deltaic system appears to be building south of the Ferron field, in the vicinity of the Last Chance anticline. This system shows a northeastward flow direction, and is consistent with outcrop studies in the area (Cotter (1976), Ryer (1981b), and P.B. Anderson (Personal Communication, 1989).

Cotter (1971, 1975b, 1976) described the delta system present in the Ferron outcrop belt in the southern part of the study area (Last Chance). These interpretations may be used as a model for individual river and deltaic systems in the subsurface of the Wasatch Plateau and Castle Valley. Cotter's Ferron River was about 300 feet wide and 25 feet deep. It was highly sinuous, with meander lengths of 2500 to 4100 feet. He estimated a drainage area of 6000 to 8000 square miles, with two percent of the total river load as bedload. The river dominated delta built by Cotter's Ferron River is classified as a high-constructive lobate delta (terminology after Fisher et al., 1969). There was sufficient marine reworking of the delta front to produce an essentially continuous fringe of sand.

Net sandstone and porosity values are high on the west edge of the study area, indicating alluvial plain sedimentation. However, there is no production and no shows are reported in these sediments. The intertonguing with marine shales in the deltaic sequence appears to provide the source for the hydrocarbons. When these shales are not present, as in the western portion of the area, hydrocarbons are not encountered.

Cotter (1975a) described the northern Castle Valley Ferron outcrop units in detail and interpreted them as having been deposited by southwestward longshore drift from a delta system (the Vernal delta) towards the north. Ryer and Lovekin (1986) acknowledge a seaward bulge of the Ferron shoreline in the area of the Vernal Delta. It is interpreted by them as being caused by differential subsidence in the area of the Uinta Mountain uplift. As in Ryer and McPhillips' 1983 model of the Castle Valley area, Ryer and Lovekin demonstrate the presence of numerous rivers and deltaic systems within this shoreline bulge. In the northeastern portion of the study area, the trend of the Ferron net sandstones (Plate 10) is northeast/southwest; there is no indication of deltaic systems building out into this area, which is consistent with Cotter's findings in the Ferron outcrop belt, approximately six miles to the east. Examination of Plates 4 and 5 demonstrates the absence of the regional delta front sandstone unit, and the presence of thinner, more marine sandstones. It thus appears that not only have the northern Castle Valley outcrop units been affected by longshore drift from the northern deltaic systems, but the most northeastern subsurface units have been affected as well.

Bluegate Shale Member of the Mancos Shale

Renewed subsidence in the Wasatch Plateau and Castle Valley areas allowed the Bluegate Shale Member of the Mancos Shale to be deposited. Plate 11 is an isopach map of the interval from the Bluegate Marker to the top of the Ferron. The Bluegate Marker was picked by this investigator, and is a thin marker bed of unknown lithology which is continuous throughout the study area, and can be easily picked from the conductivity curve on geophysical logs.

It is very difficult to identify the marker bed on the stratigraphic cross-sections (Plates 3-7), due to the reduced scale of the logs, and the diminished amplitude of the resistivity curve in comparison with the conductivity curve. The isopach map illustrates an eastward thinning of the unit; as with the Tununk, this is believed to be related to the the subsiding foreland basin. A very interesting feature is an area of thickening, or an embayment, indicating greater subsidence, in the area slightly west of the Clear Creek field. This trend continues southwestward into the Sanpete Valley, around Manti. Some indication of this feature can be seen on the Tununk isopach west of the Clear Creek area, but it is much more pronounced and larger within the Bluegate horizon. No indication of this feature is present in the Ferron (Plates 10 and 11). This trend appears to be caused by a zone of weakness which allows for greater subsidence; it corresponds to the location of the the axis of the subsiding foreland basin. A more detailed discussion concerning the structural history of this area is found in the next section.

STRUCTURAL HISTORY

Plate 12 is a structural contour map based on the Bluegate Marker (Plates 3-7). Subsurface well control and published geologic maps of Walton (1954), Witkind et al (1987), Witkind and McGimsey (1979), and Williams and Hackman (1971) were used in its compilation. Additional information from Spieker (1949) and various consulting geologists' reports in the well files at the Utah Division of Oil, Gas, and Mining in Salt Lake City, also proved to be of great value.

Numerous geologic features are apparent within this highly folded and faulted area. Major structural components of the region are briefly discussed below, as they occur from west to east.

The Gunnison Plateau is the westernmost feature, and contains north-trending grabens that are broken by secondary faults. This complex of smaller faults, break and disrupt the downdropped blocks in the grabens.

Sanpete Valley lies between the Gunnison and Wasatch Plateaus. The Wasatch monocline determined the form of the Sanpete Valley, and extends south from Milburn (approximately 10 miles north of Mount Pleasant) for a distance of approximately 55 miles to Salina Canyon in the southwest corner of the study area

(Spieker, 1949). The Musinia graben system separates the Sanpete Valley from the Wasatch Plateau, and forms the westernmost edge of the Wasatch Plateau.

The Wasatch Plateau covers an area about 80 miles long and 25 miles wide. It trends approximately north 20 degrees east, and separates Sanpete Valley on the west from Castle Valley on the east. Hydrocarbon production has been established within the folded and highly faulted structures of Clear Creek, Joes Valley, and Flat Canyon. Joes Valley graben is the most spectacular feature on the Plateau, and extends in a north-south direction for 75 miles from a point not far north of Cleveland Reservoir (Township 14 South, Range 6 East), to the Paradise fault zone in the southern part of the study area (Spieker, 1931). Pleasant Valley graben on the north end of the Wasatch Plateau spans from approximately Township 10 South to Township 14 South where it curves to meet the Joes Valley graben. Gordon Creek fault zone is easternmost on the Plateau. Faulting is not of a graben type, but is more diverse. (Spieker, 1931, 1949; Witkind et. al., 1987).

Castle Valley contains the anticlinal folds of the Huntington and Ferron anticlines, and is devoid of the graben type faulting that typifies the Wasatch Plateau. Updip to the east is the San Rafael Swell, and the Ferron Sandstone Member outcrop.

Numerous investigators have attempted to unravel the complex structural relationships in this area. A brief description of their ideas is given below.

Spieker (1931, 1949) delineated 14 episodes of crustal movement involving thrusting, normal faulting and folding. Since then, his students have added two more episodes of localized movement (Gilliland 1951, 1952).

Stokes (1952, 1976) proposed salt movement as being a dominant force in the shaping of the region. This was furthered by Baer (1976), and Witkind (1982). Witkind attributes almost all the structural complexity in the Sanpete Valley area to episodes of diapirism involving the repeated growth and collapse of salt diapirs.

The most recent theories about the structural history of the area support Spieker's concept of regional compression followed by extensional events. Diapirism is thought to be of local significance only. Sevier style thrusting has been demonstrated as far east as the eastern edge of Castle Valley. Seismic lines have enabled some of the complex relationships to be delineated. Allmendinger and Jordan (1981), Standlee (1982), Villien and Kligfield (1986), and Neuhauser (1988) all support a theory of continental tectonism to explain the relationships within the study area.

Subsurface data from this study may offer some support for a tectonic origin of the area. As previously discussed, a large embayment, or area of increased subsidence is present on the Bluegate Marker isopach map (Plate 11). This area lies within the Sanpete Valley, and corresponds to the area of the Wasatch monocline and Musinia graben system. Villien and Kligfield (1986) interpret the structural relationships within the Sanpete Valley, and demonstrate the existence of an axis of subsidence in the area of the Bluegate embayment. Thrust emplacement in the hinterland caused tectonic loading in the foreland, which produced a subsiding foreland basin with a correlative forebulge (the San Rafael Swell). The Bluegate embayment appears to correlate very closely with Villien and Kligfield's axis of subsidence in the foreland basin. Additionally, episodes of active tectonism along the western margin of the seaway appear to correlate with eustatic changes in sea level, which produce transgression (Villien and Kligfield, 1986). Standlee (1982) also shows subsidence in the same area as the Bluegate embayment in his figure 14. He locates the axis of subsidence between the Mobil #1 Larson well in Section 1, Township 17 South, Range 2 East (well number 119), and the Phillips #1 U.S. "E" well in Section 27, Township 19 South, Range 3 East (well number 145).

Neuhauser (1988) and G.L. Hunt (Personal Communication,1989) have demonstrated Sevier style thrusting along the northwestern San Rafael Swell. Subsurface evidence from this study demonstrates a thrusted Ferron section in well number 65 (Plate

4), located in Section 31, Township 14 South, Range 10 East; approximately 200 feet of section in the lower Ferron is repeated (Plate 5).

HYDROCARBON PRODUCTION AND POTENTIAL

Plate 1 summarizes the major areas of hydrocarbon production in the Wasatch Plateau and Castle Valley areas. Significant production to date is associated with anticlinal structures.

The largest structure is the Clear Creek anticline, which has produced approximately 114 billion cubic feet (BCF) of gas. The field is still active, with 16 producible wells as of February, 1989. Geophysical logs and sample descriptions are extremely sparse, because the vast majority of wells in this field were gas drilled. The little information available seems to indicate the sands are tight with very low permeability. It is thought that extensive faulting and fracturing has greatly aided the production at Clear Creek.

The future of hydrocarbon production in this area is dependent on the successful delineation of stratigraphic traps. Plate 13 is an exploration summary map of the study area, and delineates prime areas for Ferron and Dakota exploration, based on the structural and stratigraphic relationships established in this study.

Dakota Group production has been limited to three wells in the study area. Two wells at Joes Valley produced approximately 2.2 BCF from the Dakota, and one well at Flat Canyon produced approximately 284,000 mcf of gas from the Dakota from June, 1953 until October, 1957 when it was recompleted in the Ferron Sandstone, due to water production in the Dakota.

The paludal depositional environment of the Dakota, limits the potential for favorable facies deposition. The best potential reservoirs would be found in the channel facies. Two channels have been portrayed on Plate 2 . Unfortunately, it also appears that structural position plays a significant role in the entrapment of gas within the Dakota in the study area. High net sandstone values found in the Dakota near the northeast corner of the study area indicate good potential reservoirs. However, analysis of hydrocarbon shows in the Dakota Group demonstrates a lack of hydrocarbons in the northeast corner of the study area, where the highest values of net sandstone are located.

Oil and gas shows in the Dakota Group are found at Gordon Creek. Drilling of the Dakota at Clear Creek field has been limited (Plate 2). Only four wells (#31, 32, 36, and 38) penetrated to the Dakota; no shows have been reported. These factors, in conjuncion with production from Joes Valley and Flat Canyon, and net sand values, has led to the interpretation of a channel system flowing through Joes Valley, Flat Canyon, and the southern portion of Clear Creek Field, into Gordon Creek. The southern extent of Clear Creek Field is thus outlined as a potential Dakota producing area. The prime area is in the southwest corner of Township 14 South, Range 7 East, and the northwest corner of Township 15 South, Range 7 East. Structural considerations (Plate 12) have been used to outline these areas in addition to net sand values, shows, and production.

A second Dakota Group channel system has been interpreted in the Ferron Field. A drill stem test of well number 190 (Plate 3) in Section 16, Township 21 South, Range 6 East recovered 181 feet of mud, 188 feet of mud cut water, and 1350 feet of gas cut, salty water. This well is downdip from Ferron field. There appears to be a sand build-up (73 feet of net sand) in one well in the southern portion of Ferron Field. No tests or shows were reported in this well (#203) in Section 9, Township 21 South, Range 7 East. Based on these facts, and considering structural position (Plate 12), a potential Dakota producing area is outlined in the south-central and north-central portion of the Ferron field in Townships 20 and 21 South, Range 7 East.

Very minor Tununk production has been established in the Miller Creek Field (Township 15 South, Range 10 East). The majority of this production is from the prodelta sequence separating the Tununk and Ferron Members. Some Tununk production is also co-mingled with very minor Dakota production (see Appendix for well locations, and initial potential (IP) information). These wells are not connected to a pipeline; it is doubtful that production could be sustained for long enough to make these wells an economic success. The marine shales of the Tununk do not form acceptable reservoirs, but they may be important source beds for hydrocarbons within the Dakota Group. As was mentioned previously, it appears that marine shales within the Ferron itself are the source for hydrocarbons from the Ferron.

Ferron exploration areas are also portrayed on Plate 13. Two areas have been outlined for potential Ferron exploration. These outlines correspond with: higher initial potential rates (IPs) in recent wells, prime deltaic areas as outlined on Plate 10, and higher concentrations of net sandstone with greater than 8 percent neutron-density cross-plot porosity (see Appendix). Other possible exploration areas are present, but these are associated with productive fields, and it is possible that much of the gas would have been drained from these areas.

While the Ferron is mainly gas productive, numerous oil shows have been recorded (see Appendix). Oil is being produced by Vortt Exploration in its recently discovered Indian Creek field south of Flat Canyon. Hopefully, more Ferron oil production will be established in the future.

As more wells are drilled, deltaic trends will be more closely delineated; it must be expected that non-productive acreage will be found within the prime exploration areas that have been outlined on Plate 13. It must also be expected that some production may be established outside of the prime acreage. The delineated exploration trends are presented as a guide to the best potential acreage that can be outlined from the interpretations made in this study, with the data currently available; these outlines must not be construed as a guarantee of production.

RECOMMENDATIONS FOR DRILLING METHODOLOGY

Numerous methods have been used over the years to drill wells in the Wasatch Plateau and Castle Valley areas; these are summarized in the Appendix. A review of the drilling histories, mediums used in drilling, and established production trends produces one very important fact: the Ferron, and especially the Dakota, are very susceptible to formation damage.

Clear Creek field wells were originally drilled using natural gas. The top of the Ferron was tagged, and casing was run. The remainder of the Ferron was then drilled out. Tubing was set in the open hole and absolute open flow tests were run. Some of the wells developed problems with caving shales and bentonites, resulting in lost production. Because of this, light, low water-loss mud was used after the mid-1950's to drill the wells. After the well was logged, casing was then run, and the well was perforated. This enabled more information to be gained from geophysical logs, samples, and cores. (Edson et al, 1954.) The reason Clear Creek wells were originally drilled with gas was to avoid formation damage; it was felt that the low water-loss mud would not cause appreciable formation damage. Much can be learned from this early example.

In the 1970's, Pease drilled several wells in the northeastern part of the study area. A report by W. Don Quigley (1973) in the well file of the Pease Price # 1 well in Section 35, Township 13 South, Range 10 East (well number 21) details the problems encountered in drilling the Ferron and Dakota Group in this area. Air was originally used in the Price #1 well, but due to water in the zones above the Ferron, use of mist was necessitated. When the Dakota section was encountered, severe sloughing and caving of the hole required changing to mud drilling, which in turn damaged the overlying Ferron. This pattern of trouble is present throughout the area, and has been experienced by numerous operators.

Recent successful wells have been drilled with KCl mud, or have been air drilled. Brine drilling (KCl, $CaCl_2$, and NaCl) acts to inhibit absorption of water by the clay. Additionally, clay stabilizers can be used to control fines migration which can clog the pore throats (Farina, 1984). By using KCl mud, the well can be evaluated extensively through samples, geophysical logs, and drill stem testing. Air drilling limits well evaluation.

Several wells in the study area have good Ferron reservoir development, and probably would have produced if they had not been drilled with fresh gel mud. Areas outlined as potential producing areas may have dry holes included in them which were drilled with fresh mud; it is believed these wells would have produced if air or a KCl based mud had been used.

CONCLUSIONS

Potential reservoirs in the Dakota Group are limited to channel facies within a paludal depositional environment. These channels must be located within structurally favorable areas.

The Ferron Sandstone Member of the Mancos Shale was deposited by eastward flowing rivers from the western Sevier orogenic belt. These rivers formed numerous river dominated deltaic systems in the eastern part of the study area. Isopach maps, net sandstone maps, and stratigraphic cross-sections aid in the delineation of these deltaic trends, which are primary targets for hydrocarbon exploration.

The structural history of the region is extremely complex, with the most widely accepted interpretations relying on continental tectonics to explain the relationships present. Thrust emplacement in the hinterland caused tectonic loading in the foreland, and created a subsiding foreland basin; the axis of this basin is evident on isopach maps of the Tununk and Bluegate Shale Members of the Mancos Shale. Additionally, evidence for Sevier style thrusting is present in the eastern portion of the study area.

Both the Dakota Group and the Ferron Sandstone Member reservoirs contain bentonites, which are extremely susceptible to formation damage by fresh mud systems. Successful wells will be drilled with air or a KCl based mud system to avoid formation damage.

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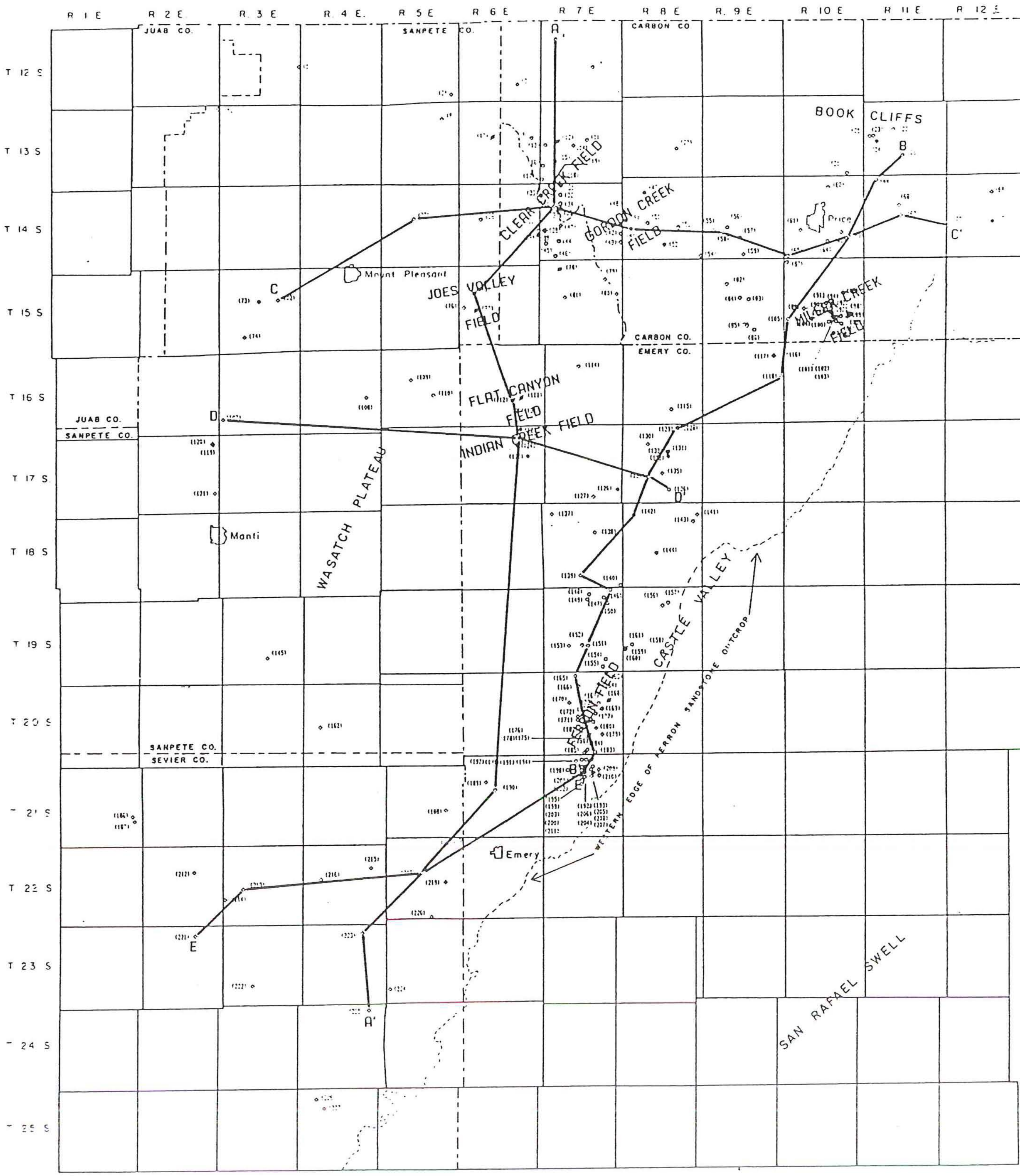


SCALE

5 0 5 10 Miles

0 5 10 Kilometers

1: 250,000

(###) Denotes drill hole number. Refer to well reference table for well interval.

EXPLANATION OF DRILL HOLE SYMBOLS

- GAS WELL- PRODUCTION FROM FERRON-DAKOTA SECTION
- OIL WELL- PRODUCTION FROM FERRON-DAKOTA SECTION
- GAS AND OIL WELL- PRODUCTION FROM FERRON-DAKOTA SECTION
- GAS SHOW IN FERRON-DAKOTA SECTION
- OIL SHOW IN FERRON-DAKOTA SECTION
- GAS AND OIL SHOW IN FERRON DAKOTA SECTION
- DRY HOLE- NO SHOWS IN FERRON DAKOTA SECTION
- PLUGGED GAS WELL- PRODUCTION FROM FERRON-DAKOTA SECTION

SUMMARY OF WASATCH PLATEAU AND CASTLE VALLEY FIELDS

FIELD	DATE DISCOVERED	PRODUCTIVE HORIZON	CUMULATIVE PRODUCTION AS OF FEBRUARY, 1989	# OF ACTIVE WELLS	DATE ABANDONED
CLEAR CREEK	1951	FERRON	[illegible]	[illegible]	
GORDON CREEK	1948	[illegible]	[illegible]		[illegible]
JOES VALLEY	1958	FERRON AND DAKOTA	[illegible]		[illegible]
FLAT CANYON	[illegible]	FERRON AND DAKOTA	[illegible]		[illegible]
INDIAN CREEK	[illegible]	FERRON	[illegible]	1	
MILLER CREEK	1983	FERRON, TUNUNK, DAKOTA, AND CEDAR MOUNTAIN	[illegible]	[illegible]	
FERRON	[illegible]	FERRON AND [illegible]	9.5 BCF; 28,5[illegible] BO	11	

PLATE 1

REFERENCE MAP

C. N. TRIPP. 1989

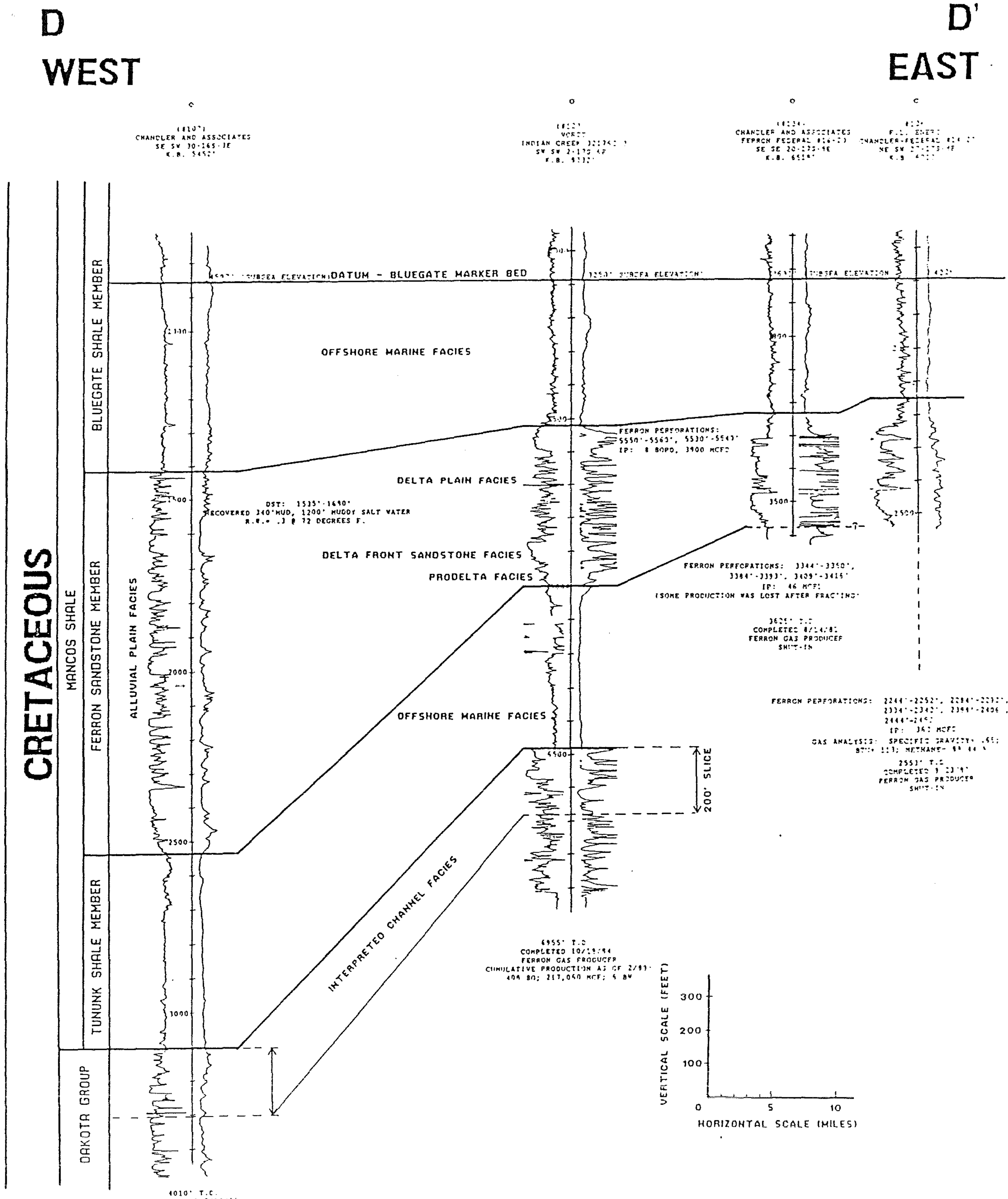
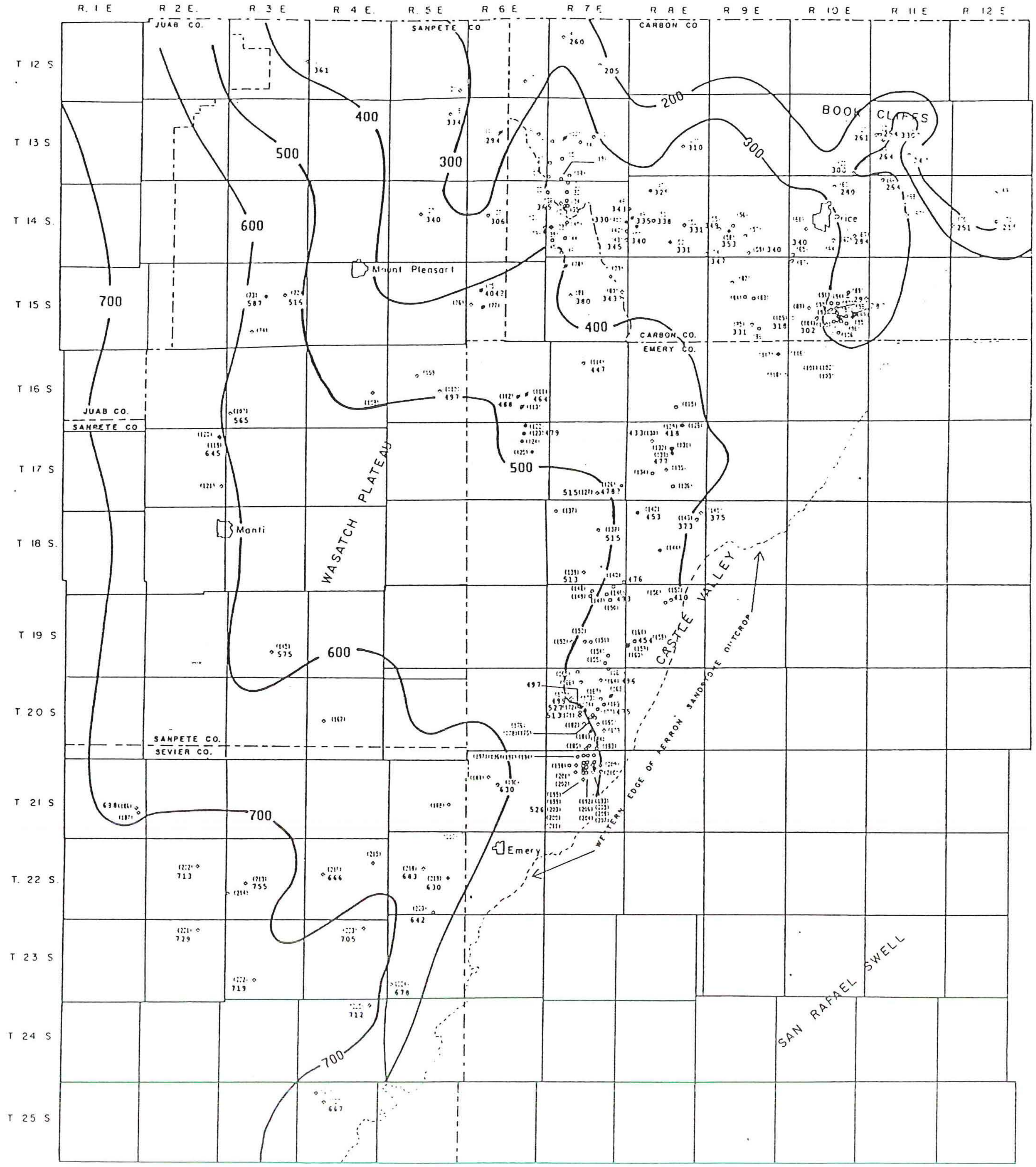


PLATE 6 STRATIGRAPHIC CROSS SECTION D-D' C. N. TRIPP, 1989

SEE PLATE 1 FOR REFERENCE MAP



SCALE

5 0 5 10 Miles

0 5 10 Kilometers

1: 250,000

CONTOUR INTERVAL: 100'

WELL SYMBOL
(115)-DRILL HOLE #
489—TUNUNK ISOPACH VALUE (FEET)

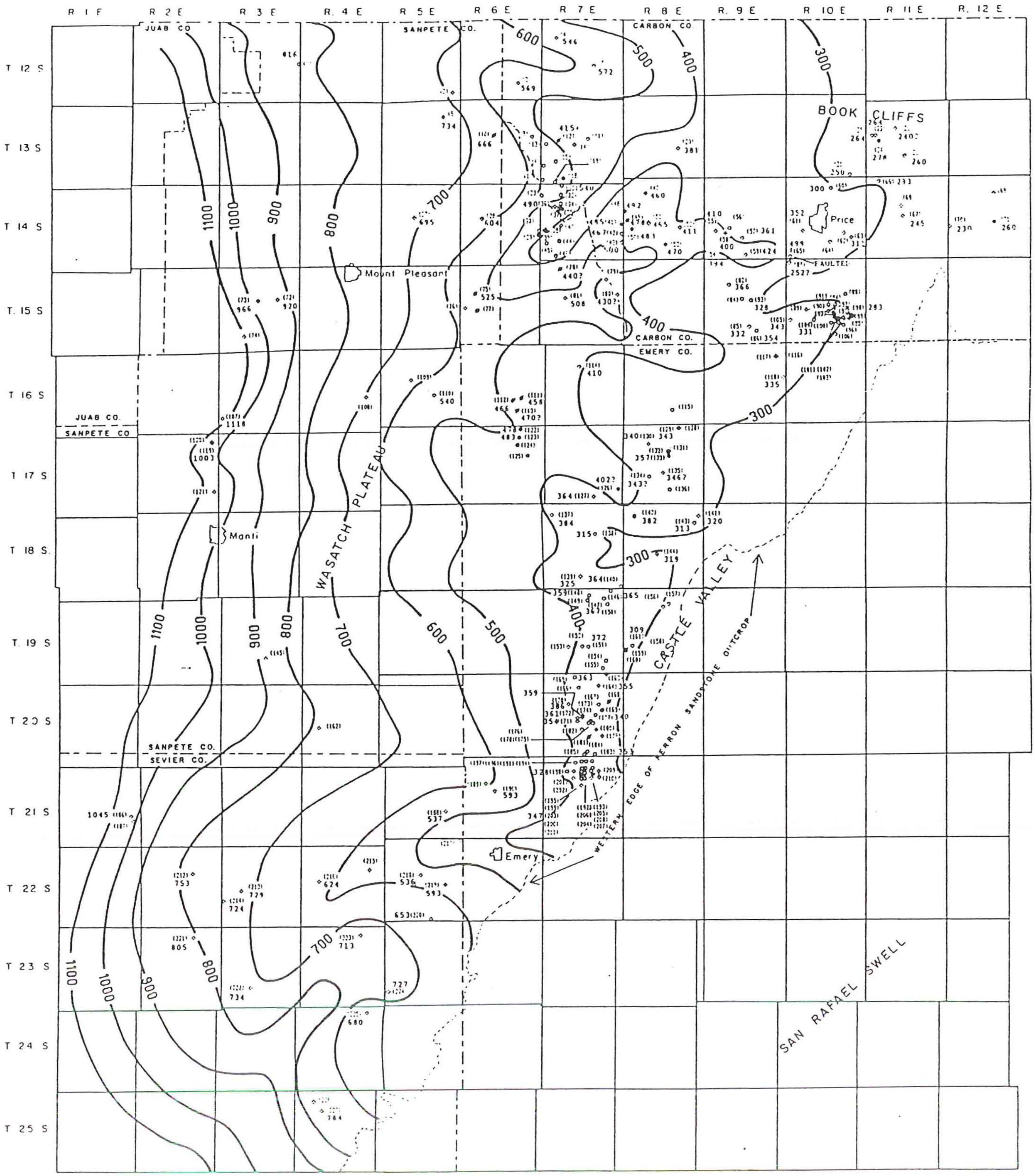
EXPLANATION OF DRILL HOLE SYMBOLS

- GAS WELL- PRODUCTION FROM FERRON-DAKOTA SECTION
- OIL WELL- PRODUCTION FROM FERRON-DAKOTA SECTION
- GAS AND OIL WELL- PRODUCTION FROM FERRON-DAKOTA SECTION
- GAS SHOW IN FERRON-DAKOTA SECTION
- OIL SHOW IN FERRON-DAKOTA SECTION
- GAS AND OIL SHOW IN FERRON-DAKOTA SECTION
- DRY HOLE- NO SHOWS IN FERRON-DAKOTA SECTION
- PLUGGED GAS WELL- PRODUCTION FROM FERRON-DAKOTA SECTION

PLATE 8

TUNUNK ISOPACH MAP

C. N. TRIPP, 1989



SCALE

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0 5 10 Kilometers

1: 250,000

CONTOUR INTERVAL: 100'

WELL SYMBOL
(188)—DRILL HOLE #
537—FERRON ISOPACH VALUE (FEET)

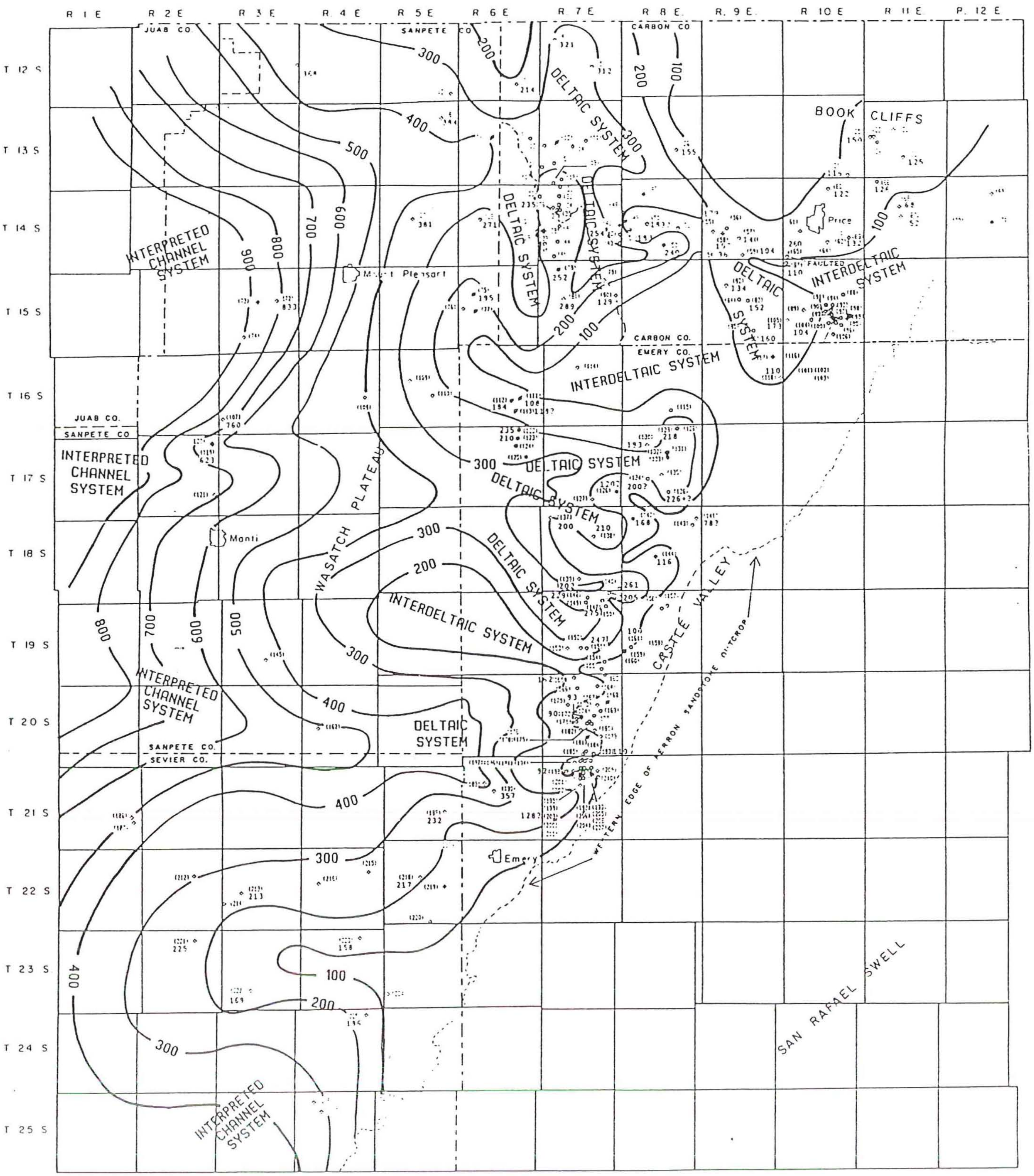
EXPLANATION OF DRILL HOLE SYMBOLS

- GAS WELL- PRODUCTION FROM FERRON-DAKOTA SECTION
- OIL WELL- PRODUCTION FROM FERRON-DAKOTA SECTION
- GAS AND OIL WELL- PRODUCTION FROM FERRON-DAKOTA SECTION
- GAS SHOW IN FERRON DAKOTA SECTION
- OIL SHOW IN FERRON DAKOTA SECTION
- GAS AND OIL SHOW IN FERRON DAKOTA SECTION
- DRY HOLE- NO SHOW IN FERRON DAKOTA SECTION
- PLUGGED GAS WELL- PRODUCTION FROM FERRON DAKOTA SECTION

PLATE 9

FERRON ISOPACH MAP

C. N. TRIPP, 1989



SCALE

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0 5 10 Kilometers

1 : 250,000

CONTOUR INTERVAL: 100'

WELL SYMBOL
(1444)—DRILL HOLE #
232—NET SANDSTONE IN FERRON SANDSTONE MEMBER (FEET)

CHANNEL SYSTEMS, DELTAIC, AND INTERDELTAIC ENVIRONMENTS WERE INTERPRETED USING NET SANDSTONE VALUES, POROSITY MEASUREMENTS, AND HYDROCARBON SHOW AND PRODUCTION INFORMATION

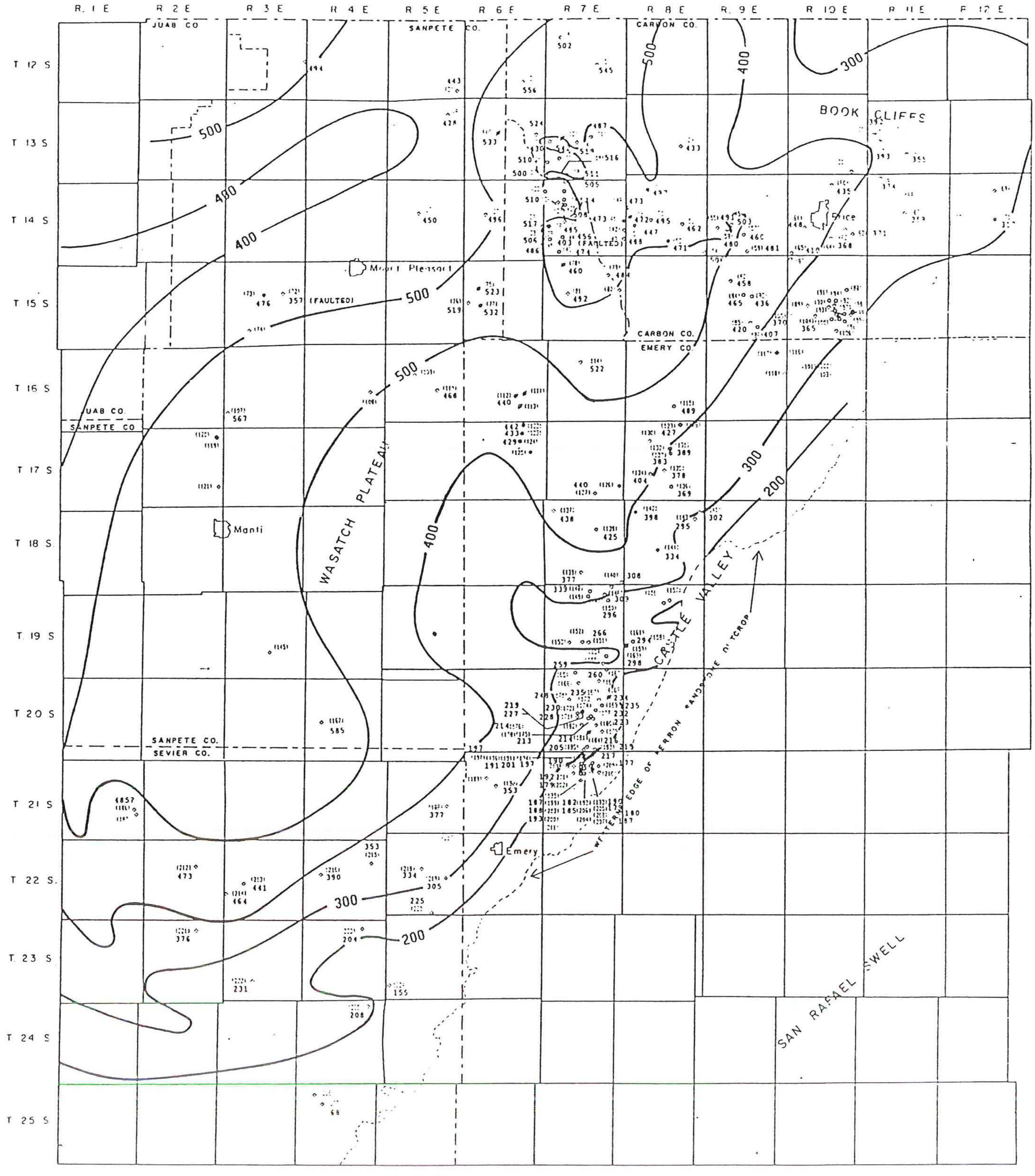
EXPLANATION OF DRILL HOLE SYMBOLS

- GAS WELL - PRODUCTION FROM FERRON-DAKOTA SECTION
- OIL WELL - PRODUCTION FROM FERRON-DAKOTA SECTION
- GAS AND OIL WELL - PRODUCTION FROM FERRON-DAKOTA SECTION
- GAS SHOW IN FERRON DAKOTA SECTION
- OIL SHOW IN FERRON DAKOTA SECTION
- GAS AND OIL SHOW IN FERRON DAKOTA SECTION
- DRY HOLE - NO SHOWS IN FERRON-DAKOTA SECTION
- PLUGGED GAS WELL - PRODUCTION FROM FERRON DAKOTA SECTION

PLATE 10

FERRON NET SANDSTONE AND PALEOGEOGRAPHIC MAP

C. N. TRIPP, 1989



SCALE

5 0 5 10 Miles

0 5 10 Kilometers

1 250,000

CONTOUR INTERVAL: 100'

WELL SYMBOL
(1441)—DRILL HOLE #
334—BLUEGATE MARKER ISOPACH VALUE (FEET)

INTERVAL ISOPACHED IS FROM THE BLUEGATE MARKER (SEE TEXT) TO THE TOP OF THE FERRON SANDSTONE MEMBER

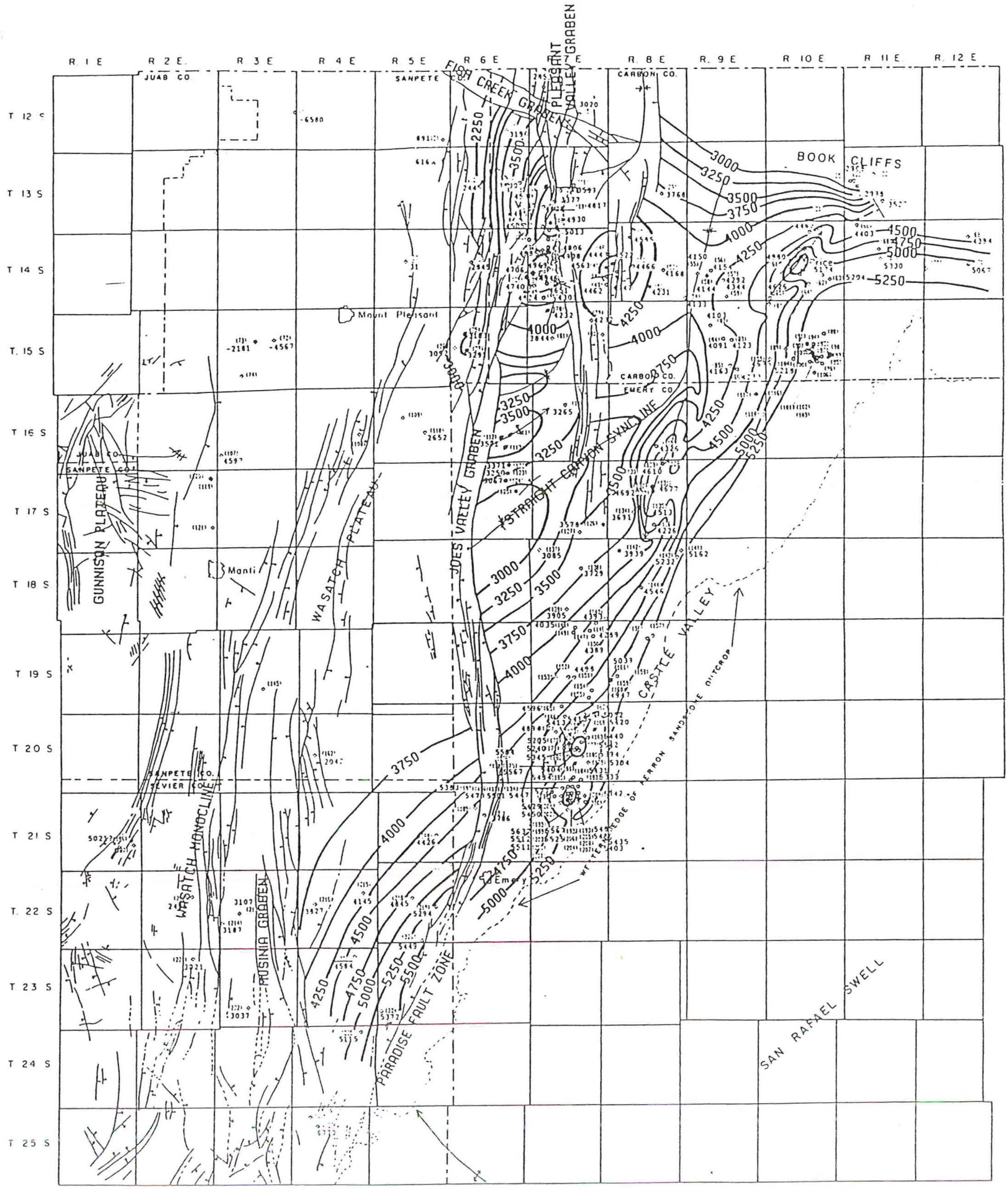
EXPLANATION OF DRILL HOLE SYMBOLS

- GAS WELL - PRODUCTION FROM FERRON-DAKOTA SECTION
- OIL WELL - PRODUCTION FROM FERRON-DAKOTA SECTION
- GAS AND OIL WELL - PRODUCTION FROM FERRON-DAKOTA SECTION
- GAS SHOW IN FERRON DAKOTA SECTION
- OIL SHOW IN FERRON DAKOTA SECTION
- GAS AND OIL SHOW IN FERRON DAKOTA SECTION
- DRY HOLE - NO SHOW IN FERRON DAKOTA SECTION
- PLUGGED GAS WELL - PRODUCTION FROM FERRON-DAKOTA SECTION

PLATE 11

BLUEGATE MARKER ISOPACH MAP

C. N. TRIPP, 1989



SCALE

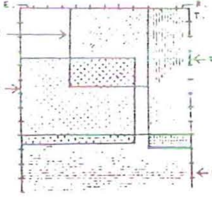
5 0 5 10 Miles

0 5 10 Kilometers

1: 250,000

CONTOUR INTERVAL: 250'

MAJOR SOURCES OF GEOLOGIC DATA
(See text References for detailed listing)



FAULT- BAR AND BELL ON DOWNTHROWN SIDE

WELL SYMBOL
(20)—DRILL HOLE #
3768-BLUEGATE MARKER SUBSEA ELEVATION (FEET)

BLUEGATE MARKER
STRUCTURAL CONTOUR MAP

PLATE 12

EXPLANATION OF DRILL HOLE SYMBOLS

- GAS WELL- PRODUCTION FROM FERRON-DAKOTA SECTION
- OIL WELL- PRODUCTION FROM FERRON-DAKOTA SECTION
- GAS AND OIL WELL- PRODUCTION FROM FERRON-DAKOTA SECTION
- GAS SHOW IN FERRON-DAKOTA SECTION
- OIL SHOW IN FERRON DAKOTA SECTION
- GAS AND OIL SHOW IN FERRON DAKOTA SECTION
- DRY HOLE- NO SHOWS IN FERRON DAKOTA SECTION
- PLUGGED GAS WELL- PRODUCTION FROM FERRON-DAKOTA SECTION

C. N. TRIPP, 1989