United States Department of the Interior

BUREAU OF MINES

WESTERN FIELD OPERATIONS CENTER
EAST 360 3RD AVENUE
SPOKANE, WASHINGTON 99202



August 1, 1985



TO: Richard Lee, Project Officer
Geotechnical Branch
Division of Waste Management

SUBJECT: LETTER REPORT FULFILLING WORK DIRECTIVE FOR TASK ORDER #002 OF INTERAGENCY AGREEMENT NRC-02-85-004

FIN #D1018

In response to your July 11, 1985 memorandum, Subject: Work Directive under Forthcoming Task Order #002 of Interagency Agreement NRC-02-85-004; please find enclosed a letter report (six copies) containing comments on six technical documents authored by the Texas Bureau of Economic Geology (OF-WTWI-1983-5, OF-WTWI-1983-6, OF-WTWI-1983-8, OF-WTWI-1983-9, OF-WTWI-1983-14, and OF-WTWI-1984-46).

As per our July 30, 1985 telephone conversation, this deliverable is being forwarded directly to you from the Western Field Operations Center due to the quick turnaround time required. Future deliverables will be routed through Minerals Availability Field Office (for review), and the Division of Minerals Availability Program Manager prior to transmittal to the NRC Project Officer.

for John Reuss, Program Manager
Manager of Planning and Analysis
Division of Minerals Availability

Enclosure



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DOCUMENT REVIEW: OF-WTWI-1983-5

Document Title: Texas Panhandle Mineral Assessment: Summary Report

Author(s): Dr. Victor L. Arnold, Jay Zarnikau, Susan Goodman, Marguerita Chapman, University of Texas at Austin

## SYNOPSIS OF FACTUAL DATA

### Mineral Aggregates

Two naturally occurring mineral aggregates are currently produced in the Panhandle region; crushed stone (including caliche) and sand and gravel. The economic value of the region's mineral aggregates is tied closely to a given deposit's location in relation to interstate highway projects and other deposits. Thus, the most valuable deposits occur in the central area of the Panhandle (including Swisher, Lubbock, and Randall Counties) where two large highway projects are currently underway.

Most of the economically exploitable sand and gravel deposits occur within dry creek beds and in tributaries of the Canadian River. Crushed stone is produced from either caliche, limestone, or dolomite. Because transportation costs normally exceed production costs when aggregate is transported in excess of 48 kilometers (km), pits and quarries generally serve markets in their own geographical vicinity.

Of the 31 pits and quarries selected for the study, the Shisher #1, located between Amarillo and Lubbock, was judged the most valuable for the 1980 and 1981-1985 time periods.

### Petroleum Reserves in the Panhandle

In 1981, the Panhandle's two districts (8A and 10) were estimated to contain a combined total of 2,645 million barrels of proved crude oil reserves and an additional 249 million barrels of indicated reserves. Proved reserves of dry natural gas during the same period were estimated at 7,300 billion cubic feet; natural gas liquids at 699 billion cubic feet. For the same year, Panhandle reserves constituted 32.7 pct of the proved reserves for the State of Texas. The percentages for dry natural gas and liquid natural gas were 14.4 pct and 26.5 pct, respectively.

### Petroleum Production in the Panhandle

Crude oil production has been declining in the region, and at a higher rate than the State average. The Panhandle's share of Texas production slipped from 31.5 to 29.4 pct during the period 1980-1982, while gas well gas production declined from 15.5 to 14.8 pct. Production is still significant, however. Crude oil production constitutes nearly 30 pct of the state's total; gas well gas nearly 15 pct.

Crude oil production is heavily concentrated in the southern counties of the region. In 1982, production in 7 southern counties that produced over 10 million barrels each, accounted for over 202.76 million barrels. Ten counties (primarily in the northern Panhandle) accounted for more than 40 billion cubic feet of natural gas during the same year.

## Price and Production Forecasts

Notwithstanding the recent decline in crude oil prices, most analysts project significant petroleum price increases through the end of the decade. This may be expected to increase the attractiveness of exploiting petroleum resources which are currently marginally economic and result in increased application of secondary and tertiary recovery methods.

Natural gas and crude oil production may exhibit a gradual decline in production through the end of the century and beyond. During this period, however, the reserve base may be increased through intensive drilling and enhanced recovery.

## Uranium Production Potential

Geologic data compiled for the National Uranium Resource Evaluation were used to determine the production potential for uranium in the Panhandle. The data were examined and applied in a set of calculations to determine the uranium oxide selling price necessary to render an extraction program economically desirable.

Profiles of six of the more likely sites for uranium production were compiled. Since the profiles are based on a very small number of samples, the results should be considered preliminary with regard to grade, thickness, and ore body depth at these locations.

Geologic and economic data were used as input in a comprehensive FORTRAN program. Using net present value analysis, the program considers grade, dimensions, and depth-to-thickness ratio of an ore body to calculate the minimum selling price for a reasonable rate of return on an investment. Two of the six deposits may be profitable if tonnage requirements are ignored for the present.

## Other Resources

Over one quarter of the Nation's helium resources are found in Texas, the vast majority of which are in the Panhandle oil and gas field. The U.S. Bureau of Mines manages the world's largest helium storage facility at the Cliffside gas field outside of Amarillo. The use of helium in advanced energy and national defense systems is expected to dramatically increase the element's value in the future.

Copper resources exist in the Permian Basin. Although all past copper mining ventures in this area have been financial failures, modern extractive technology make the widespread copper-bearing shales of the Cedar Mountain system potentially attractive exploration targets. However, depressed copper prices and demand serve to discourage copper mining ventures in the near future.

Clay, volcanic ash, gypsum, and potash resources have been identified in the Panhandle area. Salts of sodium, potassium, and magnesium are currently produced in Deaf Smith County. For each of these resources, available information appears to be inadequate to develop meaningful economic evaluations.

## SUMMARY OF FINDINGS

The absence of any major highway projects in the later years of this decade may lead to sand and gravel pit and stone quarry shutdowns and a general decline in the value of the region's mineral aggregate wealth in the future.

Petroleum production in the Panhandle is expected to decline, but the industry's prominence should be maintained due to rising oil prices.

In the past, uranium has been mined to only a very limited extent. The most important factor prohibiting economic extraction of uranium ore is the limited volume of the area's deposits.

Lack of data prohibits meaningful economic evaluations of clay, volcanic ash, gypsum, potash, and salt brine resources in the Panhandle.

## REVIEWER'S COMMENTS

The Bureau of Mines is in concurrence with the conclusions drawn by the authors with the following exception: Regarding the economic analysis of uranium resources, the authors state, "Two of the six deposits may be considered profitable <u>if tonnage requirements are ignored for the present</u>". It is not understood how any meaningful economic evaluation can be effected in which tonnage requirements are ignored.

In the statement,"The absence of any major highway projects in the later years of this decade may lead to sand and gravel pit and stone quarry shutdowns and a general decline in the value of the region's mineral aggregate wealth in the future.", what does the word "wealth" mean? Does it mean "resource" or something else?

DOCUMENT REVIEW: OF-WTWI-1983-6

Document Title: Texas Panhandle Mineral Assessment: The Petroleum Industry

Author: Jay Zarnikau, University of Texas at Austin

Reviewer's Note: This document provided background data for the petroleum section of the document entitled "Texas Panhandle Mineral Assessment: Summary Report" (OF-WTWI-1983-5). To aviod repetition, the two documents were compared for consistency and only conflicting statements or additional findings not discussed in document OF-WTWI-1983-5 have been addressed.

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## SUMMARY OF FINDINGS

Districts 8A and 10 contain over 30 pct of the state's proven crude oil reserves and production.

These districts also contain over 25 pct of the liquid natural gas reserves and 14 pct of the dry natural gas in the State. Production has been low in comparison to its share of reserves.

The northern Panhandle region (district 10) produces primarily natural gas, while crude oil production is concentrated in district 8A.

Operating costs for gas wells in the Panhandle are generally lower than the national average.

The Panhandle's share of the State's crude and natural gas production has declined since 1981.

Oil and gas prices are expected to increase through the turn of the century with gas rising faster than oil.

Excluding Palo Duro Basin, production of petroleum is expected to greatly exceed current reserve estimates.

Oil and natural gas production is expected to gradually decline over the next 35 years.

## REVIEWER'S COMMENTS

The Bureau of Mines is in concurrence with the conclusions drawn by the author.

The only conflicting statement is minor. Document 1983-5 states "15 pct of the dry natural gas reserves" and Document 1983-6 states "14 pct of the dry natural gas reserves."

DOCUMENT REVIEW: OF-WTWI-1983-8

Document Title: Mineral Resources of the Palo Duro Basin and Surrounding Areas, Texas Panhandle

Author: Allan Kolker, University of Texas at Austin

SYNOPSIS OF FACTUAL DATA PRESENTED

Caliche, crushed stone, and sand and gravel are presently produced in the Palo Duro Basin; Pleistocene lacustrine clay deposits have been worked in the past. While large gypsum deposits are present in Permian evaporites, production has been limited to exposures east of the basin. With the exception of a single well in Deaf Smith County, there has been no production from brine deposits.

Several small, peneconcordant sandstone-type uranium deposits in the Dockum Group (Triassic) have yielded less than 907 metric tons (mt) of ore at greater than 0.1 pct $U_3O_8$. Alluvial fan deposits of the Canyon and Cisco series (Upper Pennsylvanian) and Lower Permian Wichita Group (Wolfcampian Series) are considered favorable hosts for sandstone-type uranium deposits in the Palo Duro Basin. Other Permian formations are generally considered unfavorable. Though not generally suited for deposits, Pliocene-Pleistocene ash may be an important source of uranium for underlying units.

Thick sequences of granite wash in Oldham and Deaf Smith Counties may be favorable hosts for uranium deposits.

Bedded manganiferous nodules have been identified in the lower Dockum group in Palo Duro Canyon. The areal extent and resource potential of these nodules has not been evaluated.

Uraniferous asphaltite nodules occur in and around the Panhandle oil and gas field. The average uranium (metal) content of 26 samples from the Panhandle field was reported at 0.4 pct. The samples are also enriched in arsenic (3.0 pct), cobalt (0.2 pct), nickel (0.3 pct), and iron (0.4 pct). Lesser amounts of copper, silver, lead, vanadium, bismuth, molybdenum, and rare earth elements are also present in the asphaltite.

Stratigraphic and facies equivalents of chalcocite-rich shales of a major strataform copper deposit at Creta, Oklahoma, occur within the Palo Duro Basin. Ore microscopy of Creta ores indicate that some chalcocite was formed by the replacement of pyrite. Palo Duro sulfides (mainly pyrite) are widely scattered with the greatest concentration (locally up to 3 pct) in the Lower and Upper San Andres Formations, and the Wichita Group.

## SUMMARY OF FINDINGS

A realized potential for caliche, crushed stone, and sand and gravel exists in the Palo Duro Basin; these commodities are presently produced. A potential resource for brines, volcanic ash, and diatomaceous earth exists within the basin.

Potential uranium resources exist in the Dockum Group, Canyon and Cisco Series, and in units underlying Pliocene-Pleistocene ash deposits.

Uraniferous asphaltic nodules are considered a speculative potential resource.

The resource potential and areal extent of bedded manganese deposits in Palo Duro Canyon have yet to be evaluated.

While the Basin contains units equivalent to those of the stratabound copper deposit at Creta, OK, trace-metal analyses of sulfide-bearing core samples show no enrichment in copper. Detailed ore microscopy is needed before the copper resource in the Palo Duro Basin can be properly evaluated.

## REVIEWER'S COMMENTS

1. Exploration drilling in units underlying the Pliocene-Pleistocene ash deposits may suggest a potential uranium resource.

2. Potential manganese resources in Palo Duro Canyon and the speculative resource potential represented by metal-bearing asphaltites should be fully evaluated.

3. Figures 1 and 2 (selected mineral occurrences and compilation of uranium occurrences, respectively) are missing from the reviewer's copy.

4. The Bureau of Mines is in concurrence with the conclusions drawn by the author.

DOCUMENT REVIEW: OF-WTWI-1983-9

Document Title: Hydrocarbon Resources of the Palo Duro Basin, Texas Panhandle

Author: S. P. Dutton, University of Texas at Austin

## SYNOPSIS OF FACTUAL DATA PRESENTED

The Palo Duro Basin is situated between two hydrocarbon producing basins, the Midland and the Anadarko. Although the Palo Duro Basin itself remains an "exploration frontier", oil and gas is currently produced around the basin margins.

Granite-wash production from the Palo Duro Basin margins comes from wells in Cottle, Oldham, and Potter Counties. The Lambert field in Oldham County had produced nearly 700,000 barrels (bbl) through 1980 and discovery wells in Oldham and Potter Counties produce at rates ranging from 150 to 650 bbl of oil per day (bo/d).

Shelf-margin carbonate production is derived from the southeastern margin of the Palo Duro Basin and along the Matador Arch from Pennsylvanian carbonates. A 1982 discovery was made in Pennsylvanian limestones from the center of the Palo Duro Basin (Briscoe County).

Production from Upper Permian rocks (Post-Wolfcampian) is, in the most part, from the lower Clear Fork and San Andres Formations. Production in Lamb and Hale Counties comes from lower Clear Fork dolomite. San Andres Formation production comes from a porous dolomite where the oil has been trapped by either structural closure or porosity pinch-out. Some San Andres Formation production extends into the Palo Duro Basin in Lamb County. The porous nature of dolomites in both formations decreases to the north toward Deaf Smith County because of replacement of the carbonates by secondary anhydrite and occlusion of pores by halite.

Natural gas in the Texas and Oklahoma Panhandles contain greater than 1.0 pct helium. The main gas producing horizon is the Brown dolomite (Wolfcampian).

## SUMMARY OF FINDINGS

The Palo Duro Basin exhibits the necessary elements for the generation and entrapment of oil (source rocks, appropriate thermal history, reservoirs, and traps). Pennsylvainian and Wolfcampian basinal shales contain up to 2.4 pct total organic content (TOC) and are poor to very good source rocks. Thermal history is the weakest link; however, thermal-maturity indicators show source beds to have reached the threshold of the oil-generation window. Discoveries in the basin provide the evidence that oil was generated and additional oil discoveries in the basin are likely.

Potential for oil production from post-Wolfcampian rocks is low. The porous dolomites of the lower Clear Fork reservoirs grades into tight anhydrite-dolomite and anhydrite having poor reservoir quality in the Palo Duro Basin. The porous dolomite beds of the San Andres Formation pinch out and interfinger with anhydritic dolomite, anhydrite, and salt moving northward from the Matador Arch to the Palo Duro Basin.

## REVIEWER'S COMMENTS

1. The document utilizes production history to demonstrate the potential for additional oil discoveries from Pennsylvainian and Wolfcampian rocks in the Palo Duro Basin.

2. The probable absence of oil in Permian rocks is well documented.

3. The Bureau of Mines is in concurrence with the conclusions drawn by the author.

DOCUMENT REVIEW: OF-WTWI-1983-14

Document Title: Hydrocarbon Resources of the Palo Duro Basin, Texas Panhandle

Author(s): S. C. Ruppel and S. P. Dutton, University of Texas at Austin

## SYNOPSIS OF FACTUAL DATA PRESENTED

### Pre-Pennsylvanian Rocks

No production has occurred in pre-Pennsylvanian rocks of the Palo Duro and Dalhart Basins. Numerous shows, however, indicate hydrocarbons have been generated in the area. Pre-Pennsylvanian rocks in the Palo Duro and Dalhart Basins lie at depths of 8,000 feet or more. Thermal maturity (based on vitrinite reflectance measurements and kerogen color) indicate these units are at or near the minimum level of thermal maturity necessary for hydrocarbon generation. Seventy-five percent of the samples studied were classed as immature-mature; the remaining 25 pct classed as mature.

Porosity of the pre-Pennsylvanian rocks is relatively low; however, all units have sufficient porosities to serve as potential reservoir rocks. The Ellenburger Group (Ordovician) and Chester Group (Mississippian) have the highest porosities.

### Pennsylvanian and Permian Rocks

The primary source of data relating to the existence of hydrocarbons in Pennsylvanian and Permian rocks is from cores from the Stone and Webster #1 Zeeck well in Swisher County (approximately 60 miles southeast of eastern Deaf Smith County) and the #1 Mansfield well in Oldham County (about 20 miles north of the Deaf Smith County line).

All samples from the Zeeck and Mansfield wells showed a total organic content (TOC) greater than 0.5 pct. Pennsylvanian shales in both wells are from the northern arm of the basin facies which regionally contain the best source rocks in the Palo Duro Basin. Total organic content values in Deaf Smith County range between 0.2 pct near the center of the county and 1.0 pct in the northeast corner. Total organic content values indicate both Pennsylvanian and Wolfcampian shales in the areas of the wells contain sufficient organic matter to act as hydrocarbon source rocks.

Vitrinite reflectance measurements suggest that shales below about 7,000 feet are within the peak oil-generation zone. Shales deeper than 7,000 feet in both wells appear to be thermally mature and have probably generated hydrocarbons. Shales in the Mansfield well indicate sufficient maturity to act as source beds.

If interbedded shales sourced the reservoirs in Oldham County, stratigraphically equivalent shales could have generated hydrocarbons along other parts of the basinal-shale trend; eastern Deaf Smith County lies within this trend. If this is the case, additional oil discoveries would be expected in reservoirs adjacent to these source rocks.

## SUMMARY OF FINDINGS

Mississippian Osage Group rocks have sufficient organic content and thermal maturity to produce hydrocarbons. The Meramec Group (Mississippian) and the Ellenburger Group (Ordovician) had the lowest TOC of the pre-Pennsylvanian units and are not likely source rocks. Insufficient TOC data from the Chester Group (Mississippian) disallowed characterization of this group's source rock potential. Ellenburger and Chester Groups have sufficient porosities to serve as reservoir rocks.

Wells in Swisher and Oldham Counties suggests a trend of hydrocarbon generation that encompasses the eastern half of Deaf Smith County.

## REVIEWER'S COMMENTS

1. Conclusions drawn by authors are well documented.

2. Figures 1-5, and 7 are missing.

DOCUMENT REVIEW: OF-WTWI-1984-46

Document Title: Potential for Petroleum Resources in the Palo Duro Basin Area, Texas Panhandle

Author(s): S. C. Ruppel and S. P. Dutton, University of Texas at Austin

SYNOPSIS OF FACTUAL DATA.

## Pre-Pennsylvanian Units

### Source Rock Potential

Hydrocarbon shows have been reported from both Ordovician and Mississippian rocks in the Palo Duro Basin indicating that oil has been generated. The source of this oil, however, is unknown.

In general, the total organic content (TOC) of the pre-Pennsylvanian carbonates in the basin is low. The average TOC value is 0.107 pct, below the minimum usually required for carbonate source rocks (0.12 to 0.30 pct TOC).

Although TOC values are generally low in the pre-Pennsylvanian, local areas with at least minimal amounts of organic matter do exist. The average value for the Osage Group (0.16 pct TOC) is marginally above the minimum value required for carbonate rocks. However, 41 percent of the Osage samples contained more than 0.16 pct TOC and 16 pct contained more than 0.20 pct TOC. Highest TOC values in the Osage are found in the northeastern and eastern margins of the Palo Duro Basin. These areas generally coincide with those areas thought to represent deeper, more open-marine conditions.

### Organic Matter Type

Organic matter indices (OMI) indicate that the best organic matter assemblages occur in the Osage Group. A geographical plot of these values reveals a relationship between the interpreted depositional setting of the Osage Group and the distribution of organic matter. The highest percentages of sapropelic kerogen are found in the eastern part of the Palo Duro Basin where apparently deeper water depositional conditions prevailed. A similar relationship between water depth and kerogen type was observed in Pennsylvanian rocks. Although the Osage Group contains the most oil-prone organic matter among pre-Pennsylvanian carbonates, values obtained for younger (Pennsylvanian and Permian) shales are generally better.

## Thermal Maturity

The thermal history (temperature/time relationship) of a source rock is the most important factor in hydrocarbon generation. Nearly all of the pre-Pennsylvanian deposits in the area have reached at least the minimum temperature necessary to generate hydrocarbons. Since, in most areas of the Palo Duro Basin, the Mississippian is overlain by at least 2,135 meters (m) of Pennsylvanian and Permian rocks, most pre-Pennsylvanian deposits acquired temperatures sufficient to generate significant quantities of hydrocarbons ($65^{o}$ C) at least 230 million years ago. Thermal alteration index (TAI) values suggest, however, that these rocks are transitional between immature and mature. The TAI data also suggest that most rocks in the Palo Duro Basin have not matured beyond this transitional stage.

## Other Potential Sources

Pennsylvanian and Permian shales in the basin have source rock potential as they contain up to 1.0 pct TOC and above. These rocks also appear to be slightly more mature than older rocks.

## Porosity and Permeability

With the exception of the Meramac Group, all pre-Pennsylvanian carbonates in the Palo Duro Basin contain sufficient porosity to act as petroleum reservoirs. In general, permeabilities of pre-Pennsylvanian rocks in the basin are comparable with those observed in producing horizons in the Hardeman Basin.

## Pennsylvanian and Lower Permian Units

Analyses of core and cuttings from three wells indicate the Pennsylvanian shales have reached temperatures sufficient to enter the oil-generation zone, but Wolfcampian shales have not. However, Pennsylvanian shales have not matured sufficiently to be able to generate wet gas.

## SUMMARY OF FINDINGS

Most pre-Pennsylvanian rocks probably contain insufficient TOC to be potential source rocks. The Osage Group may be an exception, especially in the northeast and eastern parts of the Palo Duro Basin where some of these rocks have TOC values of 0.2 pct and higher. The potential for pre-Pennsylvanian-sourced hydrocarbons elsewhere in the Palo Duro (or in the Dalhart) Basin is very low.

Pyrolysis data from the Zeeck, Mansfield, and J. Friemel wells suggest that Pennsylvanian and Wolfcampian shales have reached sufficiently high temperatures to generate oil from sapropelic organic matter. However, it appears that much of the kerogen in the Palo Duro Basin is relatively low in hydrogen and rich in oxygen. This type of kerogen will generate gas at high temperatures, but it does not appear that the Palo Duro shales have reached temperatures necessary to generate gas.

## REVIEWER'S COMMENTS

1. The Bureau of Mines is in concurrence with the conclusions drawn by the authors.