THE PERMIAN BASIN CO_2 SEQUESTRATION MODEL AND RIDGEWAY PETROLEUM'S ST. JOHNS PROJECT

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Abstract

The U.S. Permian Basin region of West Texas and southeastern New Mexico currently injects 1.4 billion cubic feet (80,000 tons) of new carbon dioxide each day into 50 reservoirs to produce 160,000 barrels of oil per day (bopd) of additional oil. This rate of enhanced oil recovery (EOR) production has grown from zero in 1975 to now represent approximately 15% of the oil produced from the Permian Basin. Without commercial sources of aboveground CO_2, the Permian Basin is using large quantities of subsurface (natural underground) sources of CO_2 and transporting via 250-500 mile (400-800 kilometer) pipelines to the oil fields of the Permian Basin. A critical and very large pipeline network has been constructed over the twenty five-year history of CO_2 EOR and offers tremendous advantages for future oil recovery projects.

Much can be learned from the Permian Basin experience that can be applied to other regions. This paper summarizes the attributes of the Permian Basin model for CO_2 injection and sequestration, discusses the critical nature of the past capital investment in the region, and uses the model as a basis by which to think about beginning the process in other regions and, specifically, within the San Joaquin Valley area of California. A discussion of the world-class nature of the helium resources in the St. Johns Field of eastern Arizona and western New Mexico is shown as the all-important catalyst for jump-starting the California investment in the CO_2 infrastructure for the future.

Permian Basin Enhanced Oil Recovery

In 1974, the first two large-scale carbon dioxide injection projects were started in the Permian Basin. These two floods utilized carbon dioxide separated from natural gas that was captured at gas plants, compressed, and sent along a new pipeline built especially for the task of delivering carbon dioxide to the floods. After a period of observation and confirmation of the CO_2 EOR process, three new pipelines from three large underground sources were started in the early 1980's. These can be seen on Figure 1. These new pipelines were built with capital investment dollars resulting from the high prices of the oil boom years of the late '70's and early eighties and were justified using the $50/barrel oil price projections of the time.

Construction of the CO_2 source field pipelines led to a dramatic acceleration of the use of CO_2 starting in 1984. Figures 2-4 track the growth of CO_2 supply deliveries, CO_2 flood projects, and enhanced oil recovery production through this period.

Coordinated with the growth of new projects was the development of a significant network of pipelines for distributing the CO_2 to the oilfields. Figure 5 displays the current status of the CO_2 floods and pipelines serving those fields.

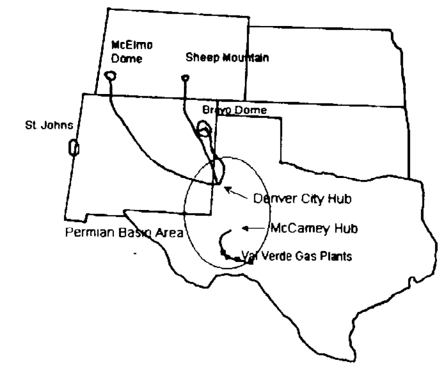


FIG. 1 - CO_2 SOURCES AND PRIMARY PIPELINES FOR THE PERMIAN BASIN

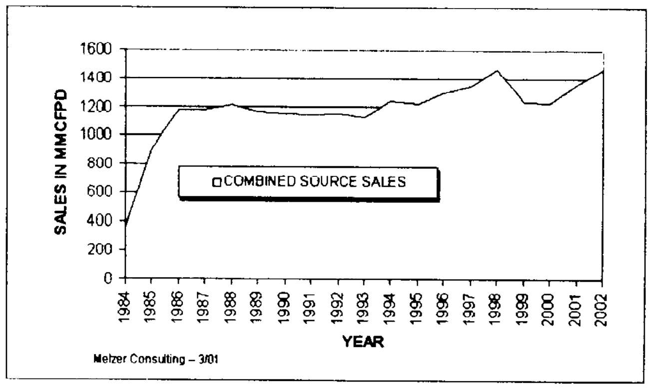
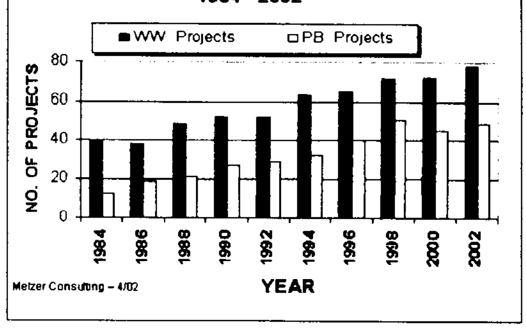


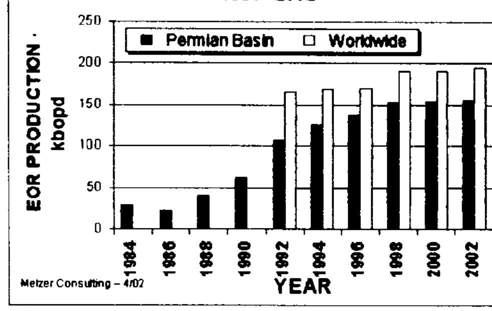
FIG. 2 - PERMIAN BASIN CO_2 SUPPLY GROWTH - 1984 to 2002

FIG 3 - GROWTH OF PERMIAN BASIN & WORLDWIDE CO2 PROJECTS 1984 - 2002



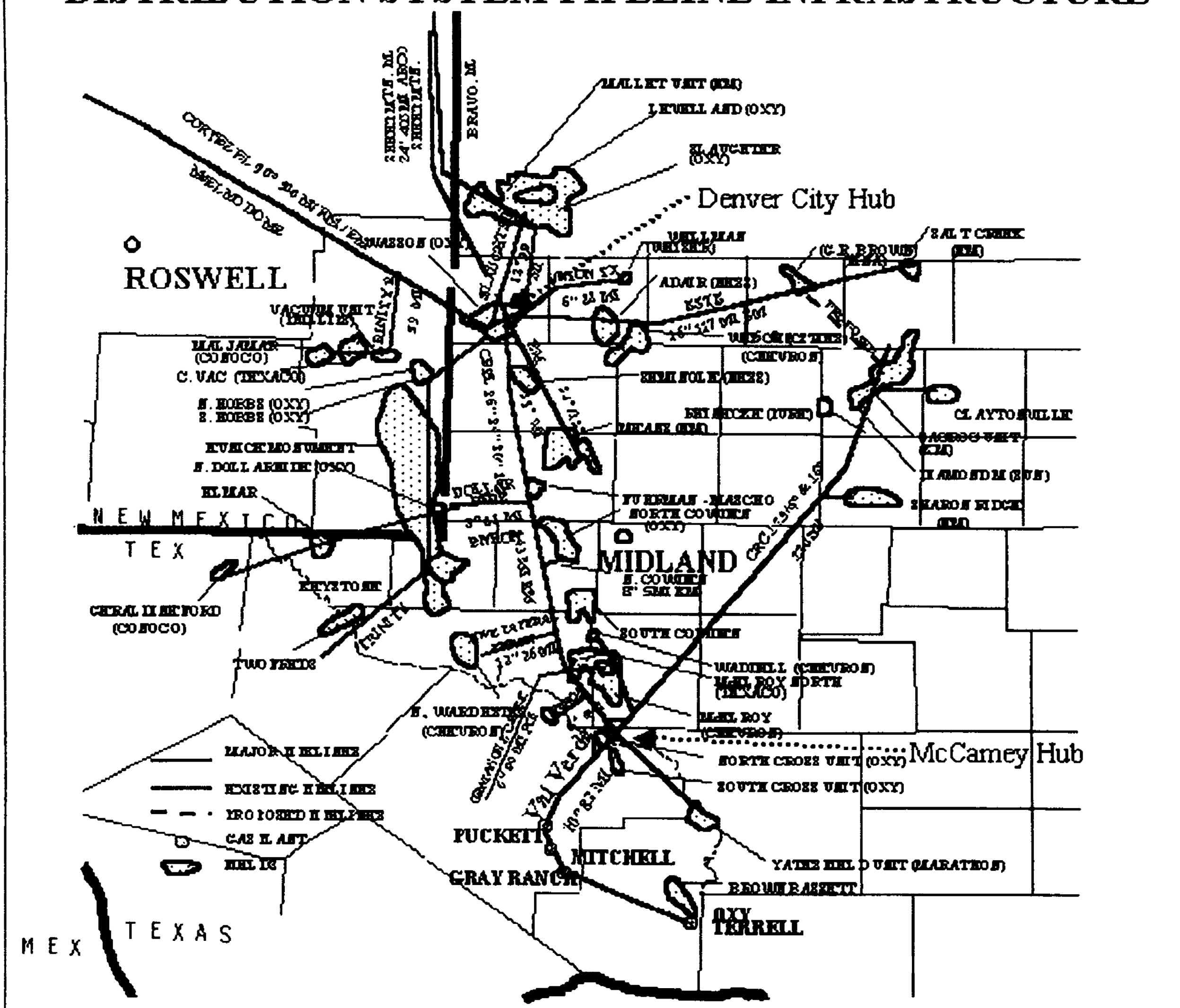
As the role of CO_2 flooding in the Permian Basin began to be recognized for its economic importance, a large effort was undertaken in the 90's to assist the industry with the transfer of the complex technology associated with successfully conducting a CO_2 injection project. Prior to the early 90's, nearly all CO_2 injection was conducted by a small group of major oil companies including Amoco, Exxon, Mobil, Shell, Chevron, Arco, Texaco and Amerada Hess. Their important research and subsequent development of field-tested procedures for handling, processing, and re-injection of produced CO_2, together with flood monitoring and surveillance methods were worked out over the course of many years. The technology transfer initiative was headed by the University of Texas of the Permian Basin but critically supported by the Shell, Mobil, and the U.S. Department of Energy's National Energy Technology Laboratory. As a part of the technology transfer effort, a series of shortcourses was developed by which the techniques developed by the majors were made available to the rest of the industry. Nine short courses, covering most aspects of CO_2 handling and flooding, have been conducted since 1995; the shortcourse manuals are available to the public and can be ordered via the Internet at: http://www.utpb.edu/ceed/index.htm

FIG. 4 - GROWTH OF WW & PERMIAN BASIN CO_2 EOR PRODUCTION 1984 - 2002



In addition to the availability of the technology, access to a large network of CO_2 delivery systems is critical to the growth of CO_2 flooding and sequestration. Studies conducted as a part of the continuing series of CO_2 shortcourses have shown that the most important variable controlling economic success of CO_2 floods (using discounted rate of return as the measure) is the distance of the flood (i.e., CO_2 sink) to the CO_2 source/pipeline connection. The Permian Basin has handled this difficulty through the aggregation of several large fields thus the cost of the main

FIG. 5 - THE PERMIAN BASIN CO_2 SOURCE AND DISTRIBUTION SYSTEM PIPELINE INFRASTRUCTURE



pipeline is amortized using the large reserves available via these "anchor" fields. Smaller fields near the large anchor fields then become viable CO_2 floods as their distance to the new pipeline is reduced. Conversion of natural gas, water, or oil pipelines is typically not an option as CO_2 typically requires transmission at supercritical pressures (>1200 psi) where other types of pipelines are generally rated at lower pressure and are, therefore, very inefficient or unusable for CO_2 service.

A list of the major pipelines in the Permian Basin is given in Table 1. Given our rule of thumb estimator for the cost of construction of these pipelines of $25,000/inch-mile, these pipelines represent a cumulative capital investment in today's dollars of just over one billion dollars. Coupling 1) the huge sums required to provide transport of CO_2 and 2) the primary controlling variable determining economically successful CO_2 floods of distance to the source of CO_2 (i.e., cost of a pipeline), one clearly needs to find ways to encourage those capital investments. Tax abatements are one way; emission credits for CO_2 sequestration could be another. But, whatever the economic incentive(s), viability of the performing flood provides the profit motive and thereby can insure the rapid growth of CO_2 flooding/sequestration projects. Underground sources of CO_2 may be desirable initially to assure flooders that the CO_2 necessary for their floods will be predictably available; however, capture of surface (stack-sourced CO_2) should begin to compete and would begin to complement the underground sources. In this manner, producing oil from CO_2 flooding/sequestration is the best mechanism for maximizing CO_2 vent stack capture and, eventually, minimizing the environmental cost of hydrocarbon fuel use.

TABLE 1: LIST OF MAJOR PERMIAN BASIN CO_2 PIPELINES

PIPELINE	Length (km)	Length (mi)
Cortez	805	500
Sheep Mountain	657	408
Bravo	402	250
Central Basin	286	178
Canyon Reef Carriers	222	138
Transpetco	177	110
Val Verde	134	83
Comanche Creek	134	83
Big Three	97	60
West Texas	92	57
Llano	85	53
Este II - to Salt Crk Field	72	45
Este I - to Welch, Tx	64	40
Anton Irish	64	40
Slaughter	56	35
El Mar	56	35
Pecos County	42	26
Wellman	40	25
Dollarhide	37	23
Ford	19	12
Cordona Lake	11	7
TOTAL	3553	2208

The Permian Basin is now quite mature with its infrastructure; however, for areas with oil production new to CO_2 injection, what is needed to begin the process is the aforementioned anchor project. This can be one or a combination of two or three projects where connecting the source of CO_2 with the flood appears economically attractive for all parties, i.e., flooder, pipeliner, CO_2 provider, and government. In the formation stage for the Permian Basin, three of the parties were all the same entity, a major oil company. In today's climate, it is more likely an alliance of at least two or three entities in addition to the government, all informed about the business and profit of the others, is what will create the anchor project to jump start the process.

Ridgeway's St. Johns Field

As the result of an initial discovery well in 1994 and an extensive leasehold acquisition program, Ridgeway Petroleum Corp. (RGW) of Calgary, Alberta, Canada is the owner of approximately 280,000 acres (113,000 hectares) of a field of world-scale reserves of helium and carbon dioxide in Arizona and New Mexico within the eastern portion of the Holbrook Basin (Figure 6). The rights come through mineral leases from the U.S. Bureau of Land Management, the States of Arizona and New Mexico, and a handful of private owners in both States.

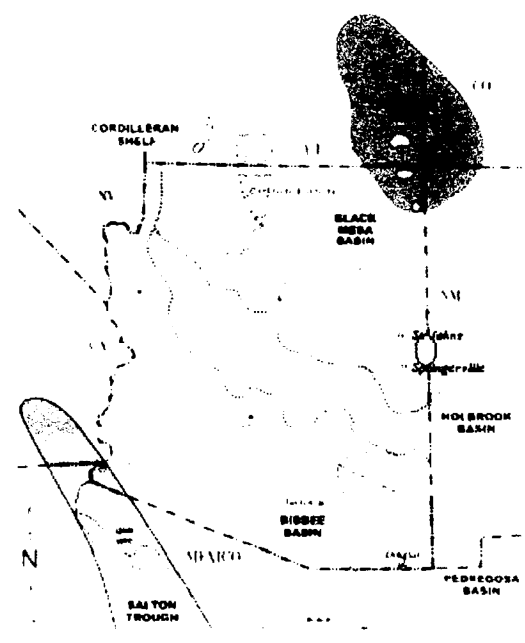


FIG. 6 - AZ/W N.M. PALEOBASINS ILLUSTRATING THE LOCATION OF THE ST. JOHNS PROJECT

During the course of the last five years, a series of delineation wells was drilled to define the stratigraphy, structure and extent of reserves in the two-state area. Figure 7 displays the pertinent stratigraphic section present in the area - note that the productive intervals (noted by zone numbers) are three. The uppermost (Zone #1) is a dolomitic interval called the Ft. Apache which averages 30 meters in thickness (12m of pay thickness {net}) and averaging 460 meters in depth. The next zone is a series of sandstones and siltstones interbedded with shales and identified as the Amos Wash formation. The average gross interval thickness is 120m with a net thickness of 25m and at a depth of 550m. A generally non-productive interval called the upper Abo underlies the Amos Wash. The upper two zones have been averaged together to obtain gas composition data. The average CO_2 composition is 93.7% CO_2, 5.4% nitrogen and 0.6% helium.

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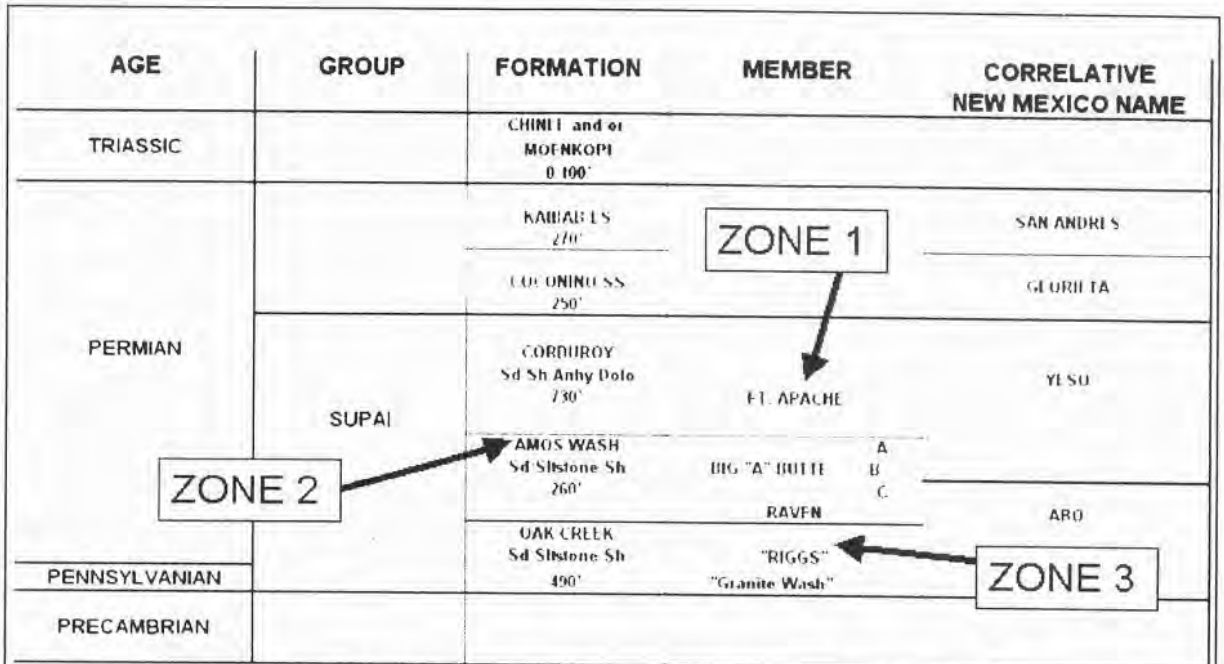

FIG. 7 - ST. JOHNS STRATIGRAPHIC SECTION AND ZONE (FORMATION) TERMS OF INTEREST

The lowermost zone is a combination granite wash and weathered granite interval just above basement rock which has been dubbed the Riggs zone. This interval varies in thickness dramatically throughout the field but can be 30m thick and is at 670m depth near the center of the field. The zone differs compositionally from the upper two in that it is nearly pure CO_2 with an average helium composition of 0.14%. Figure 8 summarizes some of the important reservoir characteristics for the three productive intervals.

FORMATION	PERMEABILITY (MILLIDARCIES)	POROSITY	NET PAY THICKNESS (FEET)	BH PRESSURE (PSI)	BH TEMP (DEGREES F)
[illegible]	0.5-20	13	40	400	86
[illegible]	0.5-100	20	83	480	88
[illegible]	2	11	50	690	120

FIG. 8 - AVERAGED RESERVOIR CHARACTERISTICS OF THE THREE PRODUCTIVE ZONES AT ST. JOHNS

Figure 9 outlines the structural extent of the St. Johns anticline using structural contours on the middle productive interval, the top of the Amos Wash Formation. The anticlinal nature of the trap is interrupted by a northwest-southeast trending reverse fault with approximately 150m of throw near the highest point of the field.

In a detailed engineering study of the field, the independent consulting firm of William M. Cobb & Associates, Inc. of Dallas, Texas, dated May of 1999, estimated the original gas in place for the planned unit area at 420 billion cubic meters (14.8 trillion cubic feet) of which 1.8 bcm (64 bcf) is helium with 390 bcm (13.9 tcf) of CO_2, with the balance of some 23.6 bcm (836 bcf) being predominately nitrogen.

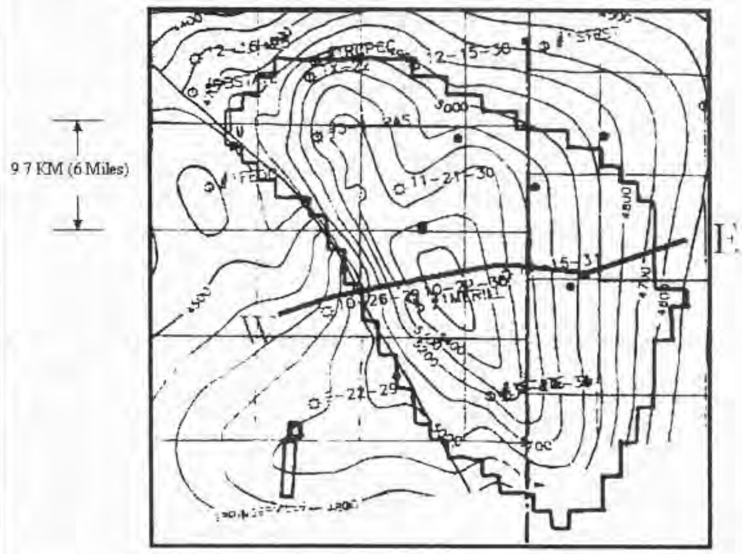

FIG. 9 - AREA SUBSURFACE CONTOUR MAP ON THE AMOS WASH FORMATION w/ PROPOSED UNIT BOUNDARY

A crossectional view of the field is shown in Figure 10. The three reservoir zones are shown highlighted in blue. A particularly notable characteristic of the field is the presence of carbon dioxide in the shallow aquifers near the surface and to the west of the structure. Some strong evidence exists for active migration of CO_2 from depth feeding into the trapping reservoirs, spilling into the fault zone where it intersects the reservoir beds, and moving vertically to the shallower formations near surface. The main corroborative evidence is the fact that many water wells on the west side of the structure produce quantities of CO_2. Using this as a hypothesis, i.e., that the subsurface is actively producing CO_2 and making St. Johns an active trap, producing CO_2 from the St. Johns structure would, in fact, curtail the ongoing spillage of CO_2 and reduce natural atmospheric CO_2 emissions in the region.

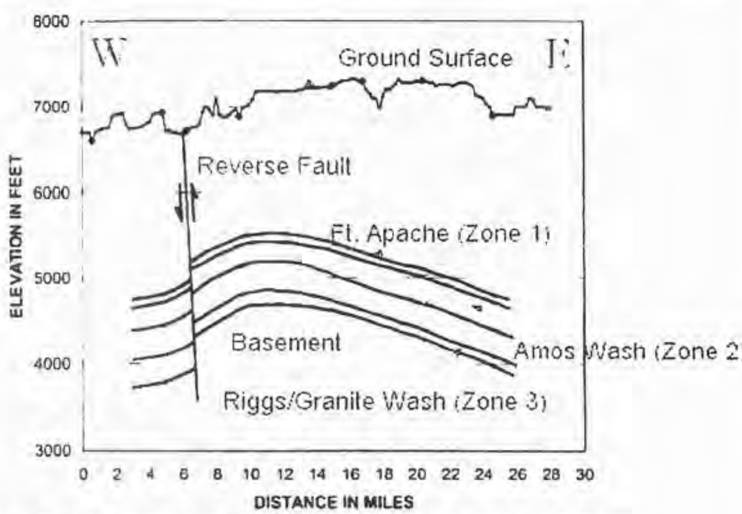

FIG. 10 - STRUCTURAL CROSSECTION OF THE ST. JOHNS FIELD

California Initiative

Figure 11 provides a map of the U.S. showing the location of the St. Johns Field, the Permian Basin area and a proposed route of a pipeline from St. Johns to the San Joaquin Valley area near Bakersfield, California. This region of California produces approximately 570 thousand barrels of oil per day (mbopd) or 82.5% of the 692 mbopd from onshore California and 68% of the 840 mbopd of onshore plus offshore California production. This San Joaquin oil production also represents just over 10% of the U.S. Domestic oil production. Much of the San Joaquin production is a result of enhanced oil recovery but comes from shallow reservoirs and uses steam to heat the oil. This steam-drive EOR works effectively for heavy oil (<20 degrees API) reservoirs and those

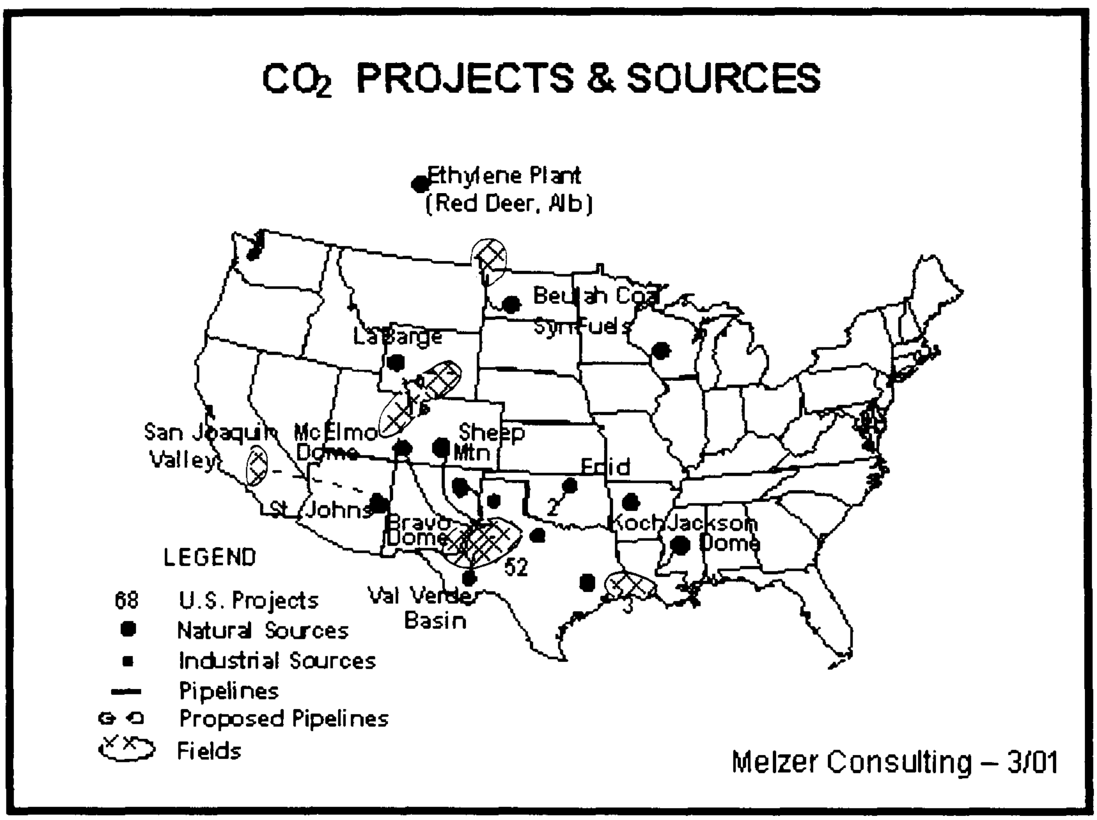

FIG. 11 - MAP OF THE U.S. ILLUSTRATING THE NORTH AMERICAN CO2 SOURCES AND LOCATION OF ST. JOHNS FIELD

shallower than 2000 feet (600 meters). For many of the lighter oils and reservoirs deeper than 2000 feet, CO_2 EOR would be applicable. Figure 12 provides a map of the southern San Joaquin Valley area illustrating the many oilfields present within a small area. Several successful CO_2 flood pilot projects have been conducted since the early 80's but the limiting factor for any large-scale application of CO_2 has always been the availability and cost of sufficient volumes of CO_2.

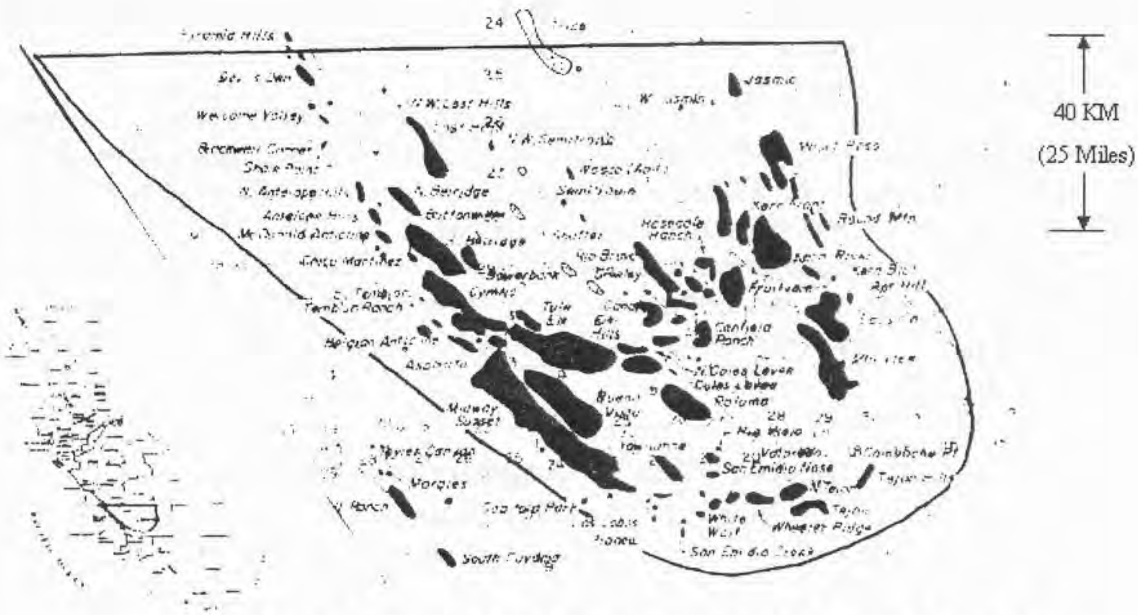

FIG. 12 - MAP OF THE SOUTHERN SAN JOAQUIN VALLEY AREA OF CALIFORNIA

Figure 13 provides a schematic look at the St. Johns to California project. The plant for processing CO_2 and crude Helium would include a liquid helium plant to process the

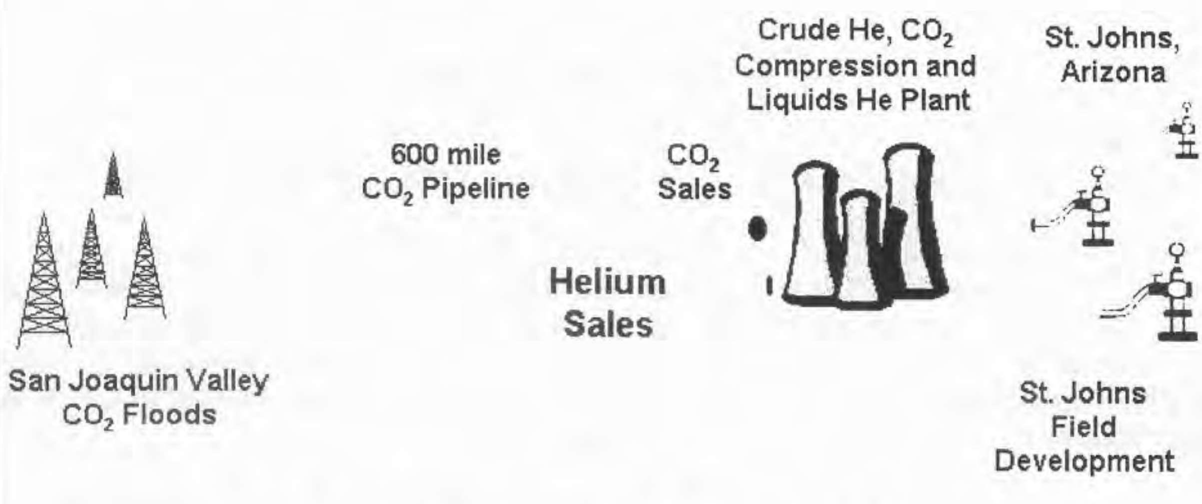

FIG. 13 - SCHEMATIC LOOK AT THE ST. JOHNS PROJECT

helium to the required purity for commercial sales. In addition to the plant compression requirements, additional compression of the tailgate CO_2 is necessary to elevate the pressure of the CO_2 to its supercritical state for delivery into the pipeline. It should be noted that the field lies in close proximity to two coal burning power plants which will likely offer access to the large power needs of the plant facilities.

The challenge of California CO_2 flooding is economic justification of transporting, via pipeline, a large source of CO_2 to the Bakersfield area. St. Johns is geographically advantaged but the cost of the 970 km (600 mile) pipeline is a hurdle of major proportions. Fortunately, the helium present in the gas at St. Johns provides additional revenue which can be applied to the cost elements of the field development and pipeline project. Finding the "anchor" project(s) is the second hurdle as the demand volumes of CO_2 will dictate the pipeline size and cost of CO_2. Figure 14 provides a

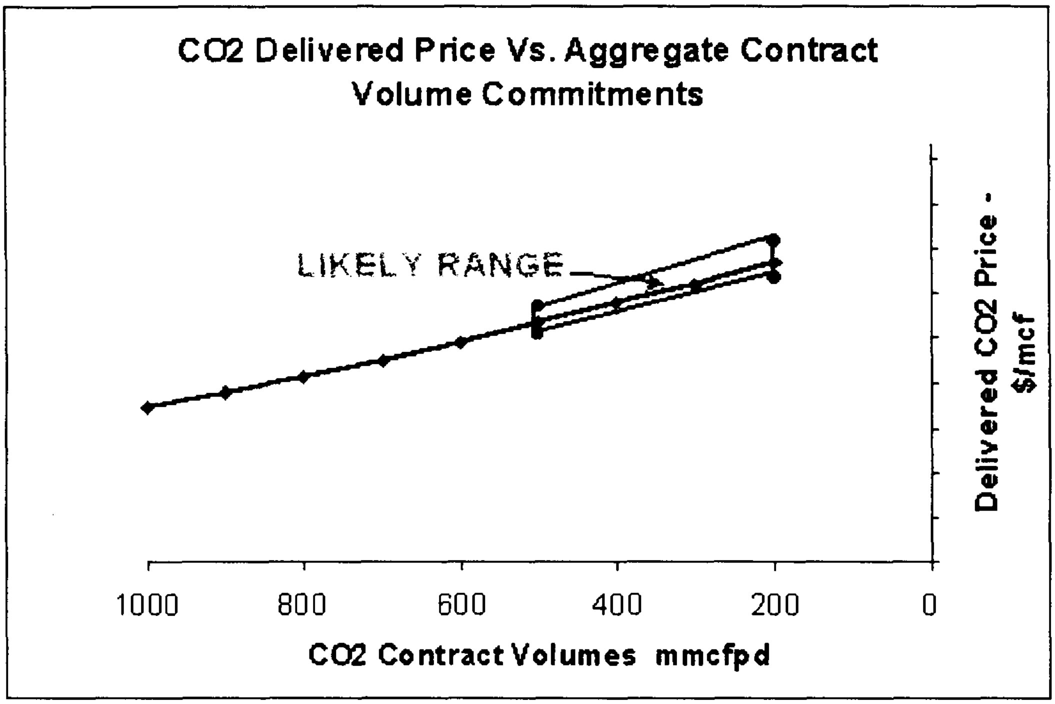

FIG 14 - CO_2 DEMAND VOLUME VS. DELIVERED PRICE

qualitative look at the demand volume dependency on CO_2 price. Clearly, the larger the demand volume for CO_2 the less expensive the delivered price will be; however, the demand volumes and delivered price are dependent variables. In other words, the lower the cost of CO_2, the greater the number of fields which are economically attractive for CO_2 flooding and the higher the demand volumes will be. The initial set of floods will have to carry the cost of the 600-mile pipeline from Arizona.

Studies are currently underway by Ridgeway to examine the economic viability of a standalone helium project at St. Johns. Venting of the large volumes of CO_2 would appear to provide an economically tempting project; however, it has been the position of Ridgeway's management that CO_2 venting is neither acceptable from an environmental perspective nor is it an acceptable business strategy. Reinjection of the CO_2 volumes may make economic sense although the first look economics are marginal at best. Clearly the optimal strategy is to find a market for the CO_2 and California is the market of choice.

Summary

Approximately 75,000 tons per day (27 million tons per year) of CO_2 are injected each day in the Permian Basin area of West Texas and southeastern New Mexico. The pipeline infrastructure required to distribute the CO_2 consists of over 2200 miles of pipeline valued at a (year 2001) construction cost of over $1 billion. The pipelines have been justified with the oil revenue produced through the use of the CO_2. Given that a source and sink(s) for CO_2 are 100 miles or more apart, the pipeline infrastructure is the key financial hurdle for creating sequestration opportunities in other regions.

Ridgeway's St. Johns project in eastern Arizona and western New Mexico has world-class reserves of both helium and carbon dioxide. Ridgeway's California initiative would produce helium to a sufficient purity for commercial sales and transport and sell by-product CO_2 for use in enhanced oil recovery projects in the San Joaquin Valley of California. The development of the St. Johns project would add 850+ million cubic meters (30+ bcf) of helium to the worldwide reserves and would add approximately one billion barrels of oil to the U.S. domestic production base.

Worldwide demand for helium, together with the demand for CO_2 in the southern San Joaquin Valley area of California for enhanced oil recovery, makes for a business model for the St. Johns project which would work as alliance of corporate entities. A major pipeline company has already joined the team and active contact is ongoing with several oil producers, helium retailing companies, and the Arizona governmental authorities. Crude and/or liquid Helium production, CO_2 production and compression, power provision, governmental cooperation, CO_2 transportation and CO_2 EOR production are the primary components of the alliance.

Finally, experience in the Permian Basin demonstrates that CO_2 enhanced oil recovery is a relatively proven and cost efficient process for CO_2 sequestration. It has been demonstrated there that large volumes can be injected and stored in mature oil reservoirs while producing additional oil to pay for sequestration project operations and infrastructure construction. Incentives to accelerate the building of pipelines and capture of vent stack CO_2 may be necessary to jump start sequestration in areas where no existing infrastructure exists.