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Roy W. Foster and James G. Jensen

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CARBON DIOXIDE IN NORTHEASTERN NEW MEXICO

by

ROY W. FOSTER

and

JAMES G. JENSEN
New Mexico State Bureau of
Mines and Mineral Resources

INTRODUCTION

At normal pressure and temperature carbon dioxide is a heavy, colorless, odorless gas. It is extremely soluble, particularly in cold water, and has a very low sound velocity. At a critical temperature of 31.1° C. carbon dioxide can be liquified by pressure alone and if then allowed to expand rapidly it sublimes to form a solid similar to snow. Carbon dioxide as a gas, liquid, or solid has a wide variety of uses in refrigeration, beverages, cryogenics, as an inert shield, and more recently in secondary recovery of oil.

As of 1971 New Mexico led in the production of natural carbon dioxide although this accounted for only a small percentage of the gas used commercially in the United States. Most of the gas consumed is obtained as a byproduct of waste gases from industrial plants (Pierce, 1965). Recent plans for a carbon dioxide-miscible flood at the Kelly-Synder (Sacroc unit) field in Scurry County, Texas will utilize much more gas than is produced in New Mexico. Gas to be used at the Sacroc and North Crossett units will come from natural gas wells in the Val Verde basin that contain from 18 to 53 percent carbon dioxide. The flood project will use 240 MMcfd (million cubic feet per day) and over the life of the project a total of 600 billion cu ft (cubic feet) will be required (West, 1971). The total production in 1968 of natural carbon dioxide in New Mexico amounted to 749 MMcf.

OCCURRENCE

Carbon dioxide is known to occur in many parts of northeastern New Mexico. The main producing areas include the Bueyeros field in Harding County, Des Moines field in Union County, and Estancia field in Torrance County (Fig. 1). In recent years production has been limited to the Bueyeros field. Wildcat oil tests also have encountered carbon dioxide in Colfax, Mora, and San Miguel Counties and in other parts of Union, Harding, and Torrance Counties. Altogether records at the New Mexico State Bureau of Mines and Mineral Resources show that up to April of this year 73 wells have found carbon dioxide in this part of the state.

Geologically the gas occurs in rocks of Triassic, Permian, Pennsylvanian, Mississippian, and Precambrian (?) age. It is found in sandstone and conglomerate of the Triassic Chinle and Santa Rosa Formations; dolomite, sandstone, siltstone, and arkosic conglomerate of the Permian Alibates, San Andres, Glorieta (?), Yeso, and Sangre de Cristo Formations; sandstone of the Pennsylvanian Sandia Formation; carbonates of Mississippian age; and if reported producing depths are correct, Precambrian schist and quartzite.

Well potentials range from less than 1Mcfd (thousand cubic feet per day) to several million cubic feet per day. The gases are 67 to more than 99 percent carbon dioxide. Other gases occurring with carbon dioxide include nitrogen, oxygen, helium, and hydrocarbons (Tables 1 and 2).

Apparently the first discovery of carbon dioxide in northeastern New Mexico was in the California No. 1 Floersheim-State test in Colfax County. The well was plugged and abandoned in 1925 after encountering a reported 500 Mcfd of gas containing 67 percent carbon dioxide. Drilling of the American Producers Corp. No. 1 Bueyeros began in 1916 but drilling was intermittent through 1931 when it blew out. The estimated flow was 25MMcfd and the well blew wide open for a year before finally being plugged April 5, 1932. In 1950 the plug was removed and the well completed for 425 Mcfpd. Some 36 wells have been drilled in the Bueyeros area from 1931 to the present with most of the development drilling taking place in the 1930's and 1940's.

The Estancia field was discovered in 1928 with the completion of the Chief No. 1-A Pace well rated at 60 Mcfd of carbon dioxide. Most of the wells in this area were drilled in the 1930's, but two wells finding additional carbon dioxide were drilled as late as 1963. The Des Moines field was discovered in 1935 by the Sierra Grande No. 1 Rogers and the remaining four wells in this field were drilled in the 1950's. Other early discoveries of carbon dioxide were the Arkansas No. 1 Kruse in Mora County (1926) and the Con-O-Kull No. 1 Stevenson in San Miguel County (1932).

ORIGIN

There are several theories of the origin of natural carbon dioxide gas; volcanic emanations, breakdown of limestone adjacent to igneous intrusions, ground-water solution of limestones, and bacterial or thermal decomposition of organic matter.

As documented by White and Waring (1963) carbon dioxide is usually the most abundant of the active gases excluding H_2O, O_2, N_2 and Ar) associated with volcanic emanations and is secondary only to H_2O. Shepherd (1938) studied gases in rocks and found that CO_2 was relatively more abundant in gases from andesite, basalt, and granite, than from obsidian. Lang (1959) in his study of the origin of natural carbon dioxide gases used C-12/C-13 isotopic abundance ratios to determine the source of the carbon dioxide. With the exception of Saratoga Springs, New York, his studies were limited to volcanic areas. Lang concluded that the source of the carbon was marine limestones which contain more of the heavier isotope of carbon. This conclusion was based primarily on the work of Craig (1953). Additional investigation by Silverman and Epstein (1958) substantiated the findings of Craig. They

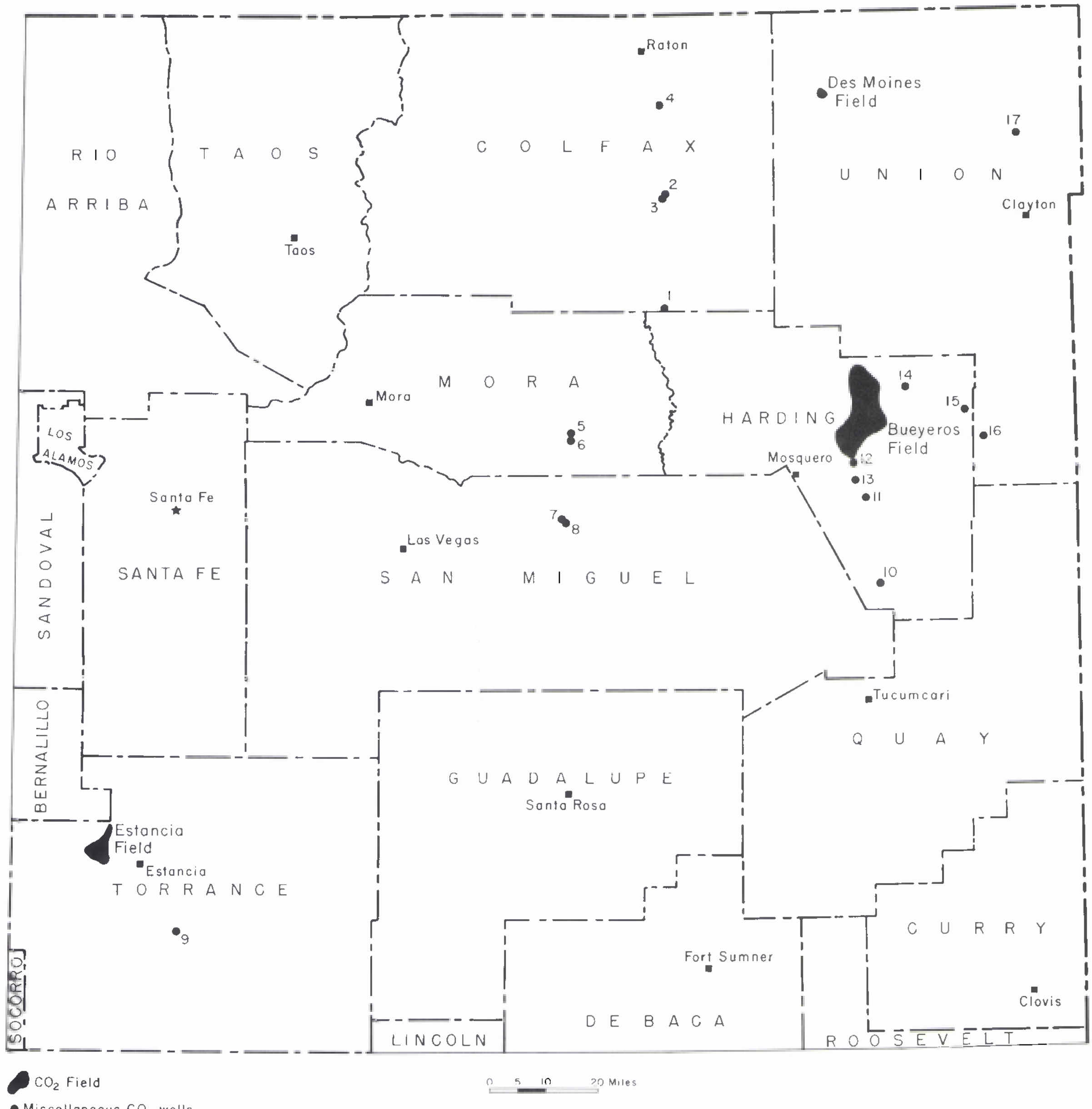

Figure 1. CO_2 Occurrences in northeast New Mexico.

report that C-13/C-12 ratios of marine organisms average about 10 per mil higher in C-13 content than non-marine organisms. Lang thus supported the theory that the carbon dioxide gas of such areas as the Bueyeros field originated from the breakdown, by thermal decomposition, of limestone in contact with or adjacent to igneous intrusions. He also noted that in some areas this "would require the dissociation of an enormous quantity of calcium carbonate and poses the question of what becomes of the remaining oxide."

An igneous-limestone source of the type suggested by Lang would seem reasonable for the occurrences in Colfax, Mora, San Miguel, Harding, and Union counties where there has been considerable intrusive and extrusive igneous activity. However, there are still some serious problems in the application of this theory. In discussing the Bueyeros area Lang with reference to Miller (1937) states that the "geologic section contains many limestones," whereas in fact, the section contains a very small percentage of carbonate rocks. Carbonates are restricted to thin dolomite beds in the San Andres, Alibates, and Yeso Formations of Permian age, and to similarly thin and impure limestone in the Chinle Formation of Triassic age. Carbonates are even less prominent in the section in the Des Moines area where a few thin limestone beds are found in the Morrison Formation (Jurassic age) and in the Chinle; what dolomite there is in the San Andres Formation is impure. Carbon dioxide occurs in Colfax, Mora, and San Miguel Counties along the west flank of the Sierra Grande arch where limestone is even rarer in the stratigraphic section. Much of the sandstone and mudstone has carbonate cement but it would seem doubtful that this could be a source for such large quantities of carbon dioxide gas.

The theory of a direct source from gases associated with igneous intrusions, although not advanced by Lang, is possibly inferred in his statement that "carbon dioxide derived from other sources, if held for sufficient time within a limestone reservoir, might acquire by fractionation sufficient heavy

Table 1: Carbon Dioxide Fields

Harding County (Bueyeros Field)

Well	Location sec., T(North)R.(East)	Comp	Potential (Mcfpd)	Pressure (psi)	Prod. Interval(ft)	CO_2 %	Other Gases	Prod. Fm.*	Lithology**
1 Carbonic No. 4 Mitchell	660N, 660E, 13-19-29	1943	710					Py(?)	
2 Carbonic No. 5 Mitchell	1980N, 660E, 24-19-29	1943		400	1,902	99.9			
3 Carbonic No. 6 Mitchell	660S, 660W, 8-19-30	1946	1,500	520	2,035-2110	99.8			
4 Clay No. 1 State	660N, 1980W, 9-19-30	1938	783	39	583-625			Trc	"sand"
5 Harding No. 1 Hayes	1650N, 2310E, 12-19-30	1939	none	none	shows			Trc-Trs	
6 Carbonic No. 11 Mitchell	660S, 1980W, 17-19-30	1955	2,740						
7 Carbonic No. 3 Mitchell	660S, 660E, 18-19-30	1939	4,051	289	1,760-1,775	99.8		Py	
8 Carbonic No. 8 Mitchell	1980N, 660E, 18-19-30	1950	210	565	1,920-2,045			(L)Py-Psc(?)	
9 Carbonic No. 10 Mitchell	2310N, 1070E, 19-19-30	1951	2,470	550	1,837-2,047			(L) Py-Psc	
10 Carbonic No. 2 Mitchell	660S, 660W, 20-19-30	1938	2,337	335	1,730-1,740	99.8		(U) Py	s/st
11 Carbonic No. 12 Mitchell	660S, 1980W, 20-19-30	1955							
12 Carbonic No. 7 Mitchell	660S, 660W, 29-19-30	1946	1,797	565	1,950-1,990				
13 Carbonic No. 9 Mitchell	1085N, 341W, 29-19-30	1950							
14 Carbonic No. 13 Mitchell	660S, 1986E, 29-19-30	1955	3,120						
15 Danube No. 1 Beller	660S, 1980E, 1-20-30	1937	308	34	840-877			Trs	"sand"
16 Neill No. 1 Smith	660S, 660W, 1-20-30	1947	1,500	40	850-888			Trs	"sand"
17 Neill No. 1 Frank	1980S, 1980E, 2-20-30	1948	none						
18 Waddell No. 1 DeBaca	1320N, 1320W, 19-20-31	1936	132	388	1,700-1,706	99.4	N 0.6	(U) Py	"red sand"
19 Schwartz No. 1-X Libby	1637N. 1650E. 30-20-31	1956	3	510					
20 Colo.-Mex. No. 2 F.C. DeBaca	984N, 1965E, 31-20-31	1938	1,056	578	2,027-2,041			(L)Py(?)	slst
21 Iceco No. 1 State	1650N, 1650E, 31-20-31	1950	1,500	520	2,000-2,048			(L) Py	slst
22 Schwartz No. 2-Y Libby	1047N, 1971E, 31-20-31	1969	1,000		2,101-2,109			Psc	ark.
23 Iceco, No. 2 Libby	1980N, 660W, 32-20-31	1950	425	520	2,000-2,500			Psc	ark (?)
24 Neill No. 1 Gallagher	660S, 1980N, 9-21-30	1937	1,504	36	795-815			Trc (?)	ss
25 Adams No. 2 Gonzales	400S, 675E, 9-21-30	1961	1,855	39	908-928			Trs	ss
26 Adams No. 1 Minerals	990N, 1930E, 16-21-30	1950	1,289	38	818-847			Trs(?)	ss
27 Neill No. 1 State	2580S, 2580W, 27-21-30	1937	889	38	920-965	99.6		Trs	ss
28 Neill No. 1 Gonzales	660S, 660W, 28-21-30	1937	1,447	34	860-910	99.6		Trs	ss
29 Adams #1 Gonzales "A"	1980N, 660E, 32-21-30	1944	1,850					Trs(?)	ss
30 Neill No. 1 Harris	660N, 1980E, 32-21-30	1947	380	39	905-15			Trs	ss
31 Timmons No. 2 Kerlin	$SW\frac{1}{4}$, $NW\frac{1}{4}$, 33-21-30	1944	1,000					Trs(?)	ss
32 Kummbaca No. 1 Kerlin	2620N, 2620W, 34-21-30	1931	3,656	38	960-988	98.2	0 0.4 N 1.4	Trs	ss
33 Powers No. 1 Timmons	1980S, 1980E, 34-21-30	1954	1,000	520	1,870-1,890	99.7	N 0.2 He 0.01	(U) Py	slst
34 Carbon No. 1 Tinsley	660S, 1980W, 31-21-31	1933			350, 700, 1,065			Trc-Trs	ss
35 Carbon No. 2 Tinsley	660S, 2475W, 31-21-31								

Union County (Des Moines Field)

Well	Location sec., T(North)R.(East)	Comp	Potential (Mcfpd)	Pressure (psi)	Prod. Interval(ft)	CO_2 %	Other Gases	Prod. Fm.*	Lithology**
1 Gruemmer No. 2 Gruemmer	660N, 1980E, 3-29-29	1954	290 60	5 200	1182-1192 2550-2605			Pal-Psc	dol-ark
2 Knight No. 1 Schmitt	660S, 660E, 4-29-29	1955	1		1188				
3 Sierra Grande No. 1 Rogers	1980S, 1980W, 4-29-29	1935	50 1000		2,060-2,080 2,245-2,280	98.6	0 0.4 N 1.2	Pal-Psc	dol-ark
4 Gruemmer No. 1 Black	660S, 660E, 33-30-29	1954	200	64	2,216-2,224 2,304-2,310 2,412-2,442			Psc	ark
5 Nelson No. 1 Fee	170S, 2470E, 33-30-29	1952	488	210	2,060-2,600			Psc	ark

Torrance County (Estancia Field)

Well	Location sec., T(North)R.(East)	Comp	Potential (Mcfpd)	Pressure (psi)	Prod. Interval(ft)	CO_2 %	Other Gases	Prod. Fm.*	Lithology**
1 Meyers No. 1 Milbourne	660N, 1980W, 11-6-7	1963						IP	
2 Chief No. 1-APace	1980S, 660W, 12-6-7	1928	60		1,640?-1,760?	99	N 0.97 He 0.03	IP	
3 Chief No. 1 Pace	1420S, 2300E, 12-6-7	1938	1,000		1,704			IP	
4 Meyers No. 1 Smith & Pace	1700S, 550W, 12-6-7	1963						IP	
5 Sinoco No. 2 DeHart	1100S, 2300W, 12-7-7	1934	660	415	1,240-1,251	99		IP	
6 Estancia No. 2 DeHart	2560N, 2335E, 12-7-7	1934	648	415	1,208-1,215	99		IPs	
7 Estancia No. 3 DeHart	1644N, 2187E, 12-7-7	1936	710		1,204-1,264			IPs	"sand"
8 Estancia No. 4 DeHart	2310S, 2612E, 12-7-7	1936	100		<1,236			IPs	
9 Estancia No. 5 DeHart	1931N, 1646E, 12-7-7	1937	250		1,233-1,258			IPs	"sand"
10 Estancia No. 1 Kellogg	1000N, 1892E, 12-7-7	1935	860	405	<1,268			IPs	
11 Estancia No. 1 Roland	600S, 600E, 12-7-7	1934	show		1,214			IPs	
12 Estancia No. Kutchin	355N, 1347W, 13-7-7	1937	150		<1,428			IPs (?)	
13 Estancia No. 1 Crawford	990N, 330E, 32-7-7	1939	show		450 & 634				
14 Drice No. 1 Garland	1650N, 330E, 32-7-7	1940	show		1,965			p€ schist	
15 Lee No. 1 Milburn	660S, 1020W, 36-7-7	1941	50		varies from 1,722-2,000			p€ schist	
16 Lee No. 1 Milburn		1926	show		1,027-1,032			p€	

*Trc Chinle Formation
Trs Santa Rosa Sandstone
Pal Alibates Dolomite
Psa San Andres Limestone
Pg Glorieta Sandstone
Py Yeso Formation
Psc Sangre de Cristo formation
Ps Sandia Formation
Tr Triassic

P Permian
IP Pennsylvanian
M Mississippian
p€ Precambrian
U Upper
L Lower

**slst siltstone
ark arkose
ss sandstone
dol dolomite

Table 2: Miscellaneous Occurrences of Carbon Dioxide

Colfax County

Well	Location sec., T(North)R. (East)	Comp	Potential (Mcfpd)	Pressure (psi)	Prod. Interval(ft)	CO_2%	Other Gases	Prod. Fm. *	Lithology**
1 California No. 1 Floersheim	250S, 250W, 15-23-24	1925	500		1,509-1,560	67.2	O 4.1 N 28.24 He 0.46	Pg(?)	ss
2 York No. 1 Tex-Mex	400N, 400W, 2-26-24	1939	250	128	1,515-1,525	99.8		Trs	ss
3 Neill No. 3 Sauble	1980S, 660E, 3-26-24	1947	133	145	1,525-1,560			Trs(?)	ss
4 Eureka No. 1 Moore	NW¼, SW¼, 10-29-24	1927	2,000(?)	1,040	3,142-3,172			Psc	

Mora County

Well	Location sec., T(North)R. (East)	Comp	Potential (Mcfpd)	Pressure (psi)	Prod. Interval(ft)	CO_2%	Other Gases	Prod. Fm. *	Lithology**
5 Arkansas No. 1 Kruse	2310N, 330E, 11-19-21	1926	26.5		various 1,160-2,225	92.2	O 1.1 N 7.65 He 0.15	Tr-P	ss
6 Fulton No. 1 Santa Fe	330N, 330E, 14-19-21	1931	600		1,050-1,135		Hydro-carbon	Tr	ss

San Miguel County

Well	Location sec., T(North)R. (East)	Comp	Potential (Mcfpd)	Pressure (psi)	Prod. Interval(ft)	CO_2%	Other Gases	Prod. Fm. *	Lithology**
7 Southwest No. 1 Conchas	NW, NE, 34-17-21	1941	show		1,830			Trs	ss
8 Con-O-Kull No. 1 Stevenson	385N, 2320E, 34-17-21	1932	show		918-937			Trc	"sand"

Torrance County

Well	Location sec., T(North)R. (East)	Comp	Potential (Mcfpd)	Pressure (psi)	Prod. Interval(ft)	CO_2%	Other Gases	Prod. Fm. *	Lithology**
9 Bluehall No. 1 Kistler	585N, 638W, 7-4-10	1929	show		1400				

Harding County

Well	Location sec., T(North)R. (East)	Comp	Potential (Mcfpd)	Pressure (psi)	Prod. Interval(ft)	CO_2%	Other Gases	Prod. Fm. *	Lithology**
10 Waddell No. 1 Peters	1980N, 660E, 31-15-31	1939	shows		various 1,675-2,025			Psa-Pg-Py	dol-ss
11 Law No. 1 Baca	1900S, 1900E, 11-17-30		show					Tr	
12 Waddell No. 1 Mitchell	330N, 330W, 9-18-30	1938	250-500		various 545-1,650			Trc-Trs	ss
13 S. E. C. No. 15 Mitchell	1980N, 3305W, 28-18-30	1971	?		1,948-2,108(?)			Py	slst
14 Amoco No. 1 State - EM	1980S, 1980W, 36-21-33	1972	?		1,825-1,877(?)				
15 Amoco No. 1 State-EN	1980S, 1980E, 23-20-33								

Union County

Well	Location sec., T(North)R. (East)	Comp	Potential (Mcfpd)	Pressure (psi)	Prod. Interval(ft)	CO_2%	Other Gases	Prod. Fm. *	Lithology**
16 Amoco No. 1 New Mexico State	1650S, 450W, 16-19-34	1971	770	375	2,200-2,528				
17 Skelly No. 1 New Mex. VanPelt	1989S, 660W, 9-28-35	1958	5	1,180	3,778-3,793			M	dol

*Trc	Chinle Formation	P	Permian	**slst	siltstone
Trs	Santa Rosa Sandstone	Ᵽ	Pennsylvanian	ark	arkose
Pal	Alibates Dolomite	M	Mississippian	ss	sandstone
Psa	San Andres Limestone	p€	Precambrian	dol	dolomite
Pg	Glorieta Sandstone	U	Upper		
Py	Yeso Formation	L	Lower		
Psc	Sangre de Cristo formation				
Ps	Sandia Formation				
Tr	Triassic				

Bacterial action on organic material releases carbon dioxide, and above certain temperatures organic material breaks down and also gives off carbon dioxide. With the exception of the Estancia area, the rocks in which carbon dioxide occurs in northeastern New Mexico are low in organic material. However, the gas could have migrated from adjacent basins to the south, east, and southwest that are richer in organic material. As can be seen in Tables 1 and 2 there are few chemical analyses for the gases. If organic material were the source it would seem that more hydrocarbon gases would be present isotopes to convert the abundance ratio to one representative of a limestone origin." Based on the results obtained from analyses of the gases he doubts that this has happened. Again the problem is a lack of limestone reservoirs. With the exception of minor amounts of carbon dioxide found in dolomite of Mississippian age and in the Alibates and San Andres Formations, reservoir rocks in northeastern New Mexico are of the sandstone-conglomerate type.

Langs theory of origin is based primarily on the carbon isotope ratios. Unfortunately he does not present data for volcanic gases or gases from igneous rocks, his igneous group being restricted to carbon found in graphite, a meteorite, and diamond.

with the carbon dioxide than are indicated unless there has been fractionation of the gases during migration. The difference in solubility in water between carbon dioxide and hydrocarbon gases might account for this fractionation. In 100 ml (milliliters) of water at 20°C and one atmosphere of pressure, carbon dioxide has a solubility of 0.1688 gms (grams) whereas the solubility of methane is 0.002319 gms.

This possible method of fractionation plus the inert character of carbon dioxide might explain the absence of other gases that would be associated with igneous activity. Most of these gases have solubilities considerably below that of carbon dioxide; the only exception being hydrogen sulfide. However, this gas is not stable and with few exceptions does not exceed 20 percent of the gases emanating from volcanoes. At a wide range of temperatures and with a limited supply of oxygen the hydrogen combines with oxygen and sulfur is precipitated. This reaction is common around fumaroles and sulfur springs.

The nearest known igneous activity to the Estancia field is 25 miles to the north at South Mountain; 45 miles to the southeast in the Gallinas Mountains; 30 miles south at the north end of Chupadera Mesa; and 20 miles northeast, north of the Pedernal Mountains. These intrusive bodies are of Tertiary age. It would be hard to explain the conditions for accumulation of carbon dioxide from these sources considering the structural conditions of the area. The carbon dioxide at Estancia does not appear to occur in carbonate rocks; however, thick limestones dip east off the Manzano Mountains and the gas may have formed from solution of limestone and subsequent trapping in minor flextures or stratigraphic traps in the sandstone intervals.

The north-south alignment of carbon dioxide wells in Colfax, Mora, and San Miguel Counties is striking (Fig. 1). These wells appear to be located on the western flank of the Sierra Grande arch and the traps may be fault controlled. Although there are only three analyses of gases in this area it is noteworthy that two have lower percentages of carbon dioxide than the wells to the east on the higher parts of the uplift. The main constituent other than carbon dioxide in these two wells is nitrogen, a gas common in volcanic emanations.

Obviously the origin of carbon dioxide gas found in wells is not fully understood. Considerable work needs to be done, particularly with carbon isotope ratios, chemical analyses of the gas, and more careful evaluation of the geologic setting. The gas may originate from a single source or may vary from one area to the next. This requires a broader study that can be accomplished with the carbon dioxide occurrences of northeastern New Mexico.

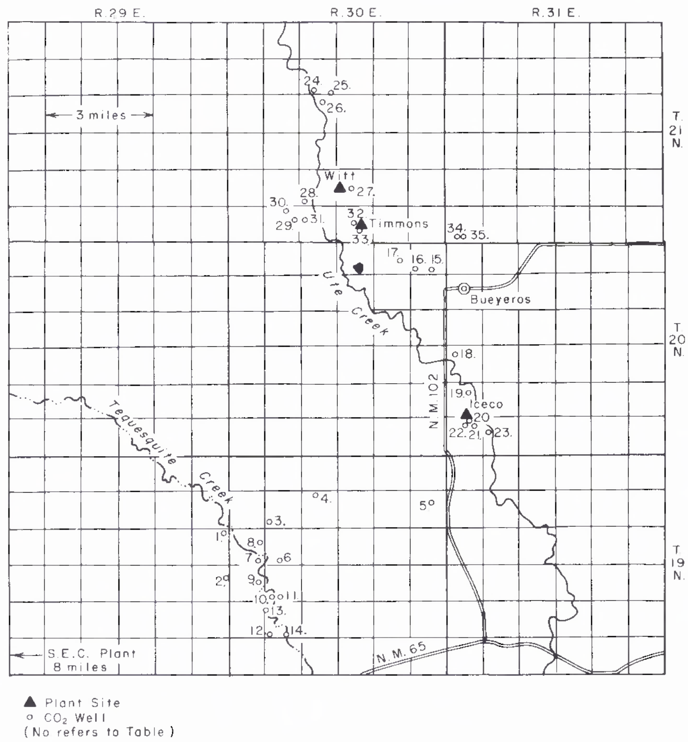

Figure 2. Bueyeros field.

BUEYEROS FIELD

The stratigraphic section in the Bueyeros area includes in descending order the Dakota Sandstone (Cretaceous); Morrison Formation and Exeter Sandstone (Jurassic); Chinle Formation and Santa Rosa Sandstone (Triassic); and Bernal Formation, San Andres Limestone, Glorieta Sandstone, Yeso Formation and Sangre de Cristo Formation of Permian age. The Sangre de Cristo Formation overlies Precambrian granites. Most wells in the area were spudded in the Triassic and only these sediments and the underlying strata will be considered.

The Chinle Formation consists of gray to red, fine- to coarse-grained sandstone, green and red mudstone and siltstone, and gray limestone pellet conglomerate. The contact with the underlying Santa Rosa Sandstone is gradational through a sequence of interbedded mudstone and light-gray, medium- to coarse-grained sandstone and conglomeratic sandstone. The total thickness of the Triassic is 900 to 1,000 feet; thinning to the north.

The Bernal Formation is about 150 feet thick and includes orange, red, and green mudstone and siltstone. The carbonate and evaporite beds present in this interval elsewhere appear to be lacking although sample quality is usually too poor in this sequence to rule out the presence of thin carbonates such as the Alibates Dolomite. About 250 feet of interbedded dolomite and anhydrite with minor green and red mudstone make up the San Andres Limestone. Anhydrite is more abundant in the upper part of the section. There appears to be a rather sharp break in this area between the dolomites in the lower part of the San Andres and the underlying 100 feet or so of clean medium- to coarse-grained sandstone of the Glorieta. Similar to other areas on the Sierra Grande uplift, evaporites and carbonates make up only a small percentage of the Yeso Formation. Here the section is primarily light-gray and orange very fine to fine-grained sandstone, orange siltstone, and dark-red mudstone.

Near the base of the Yeso is a 10 to 20 foot interval of evaporites correlated with the Cimarron Anhydrite. This unit makes an excellent marker bed that can be traced over a considerable area in northeastern New Mexico. The Yeso is only about 500 feet thick in the southern part of the Bueyeros field and thins to the north. The Sangre de Cristo Formation is on the order of 100 feet thick and consists of minor coarse arkosic conglomerate, and red sandy, arkosic mudstone.

Carbon dioxide occurs in two northwest trending areas. The western production is found along Tequesquite Creek and comprises a series of 12 wells located primarily in T. 19 N., R. 30 E. (fig. 2). The eastern producing area of 19 wells is along Ute Creek and extends from T. 20 N., R. 31 E., across the northeast corner of T. 20 N., R. 30 E., into T. 21 N., R. 30 E.

The wells in the Tequesquite area supply gas to the SEC plant approximately 18 miles to the west near Solano. This is the only plant presently operating in the Bueyeros area. Most of the gas in this part of the field, based on limited well completion data, occurs in an orange, very fine-grained sandstone to siltstone in the lower part of the Yeso Formation (fig. 3). Production appears to be obtained from both above and below the Cimarron Anhydrite. Some gas also may be recovered from the underlying thin arkosic conglomerates of the Sangre de Cristo Formation, and some shows of gas have been reported from sandstones in the Chinle Formation and Santa Rosa Sandstone. The average reported potential from these wells is 1,500 Mcfd at a flowing pressure of over 500 psi.

In the somewhat isolated part of the eastern field south of Bueyeros in T. 20 N., R. 31 E. six wells were drilled to supply carbon dioxide to the Iceco (Schwartz) plant. Here also the main pay zone is in the lower part of the Yeso and possibly the Sangre de Cristo Formation. Shows occur in the Chinle and Santa Rosa intervals. The average potential and pressure is 1,000 Mcfd at 520 psi; thus the area is similar to that along Tequesquite Creek.

Gas production to the north along Ute Creek in T. 21 N., R.

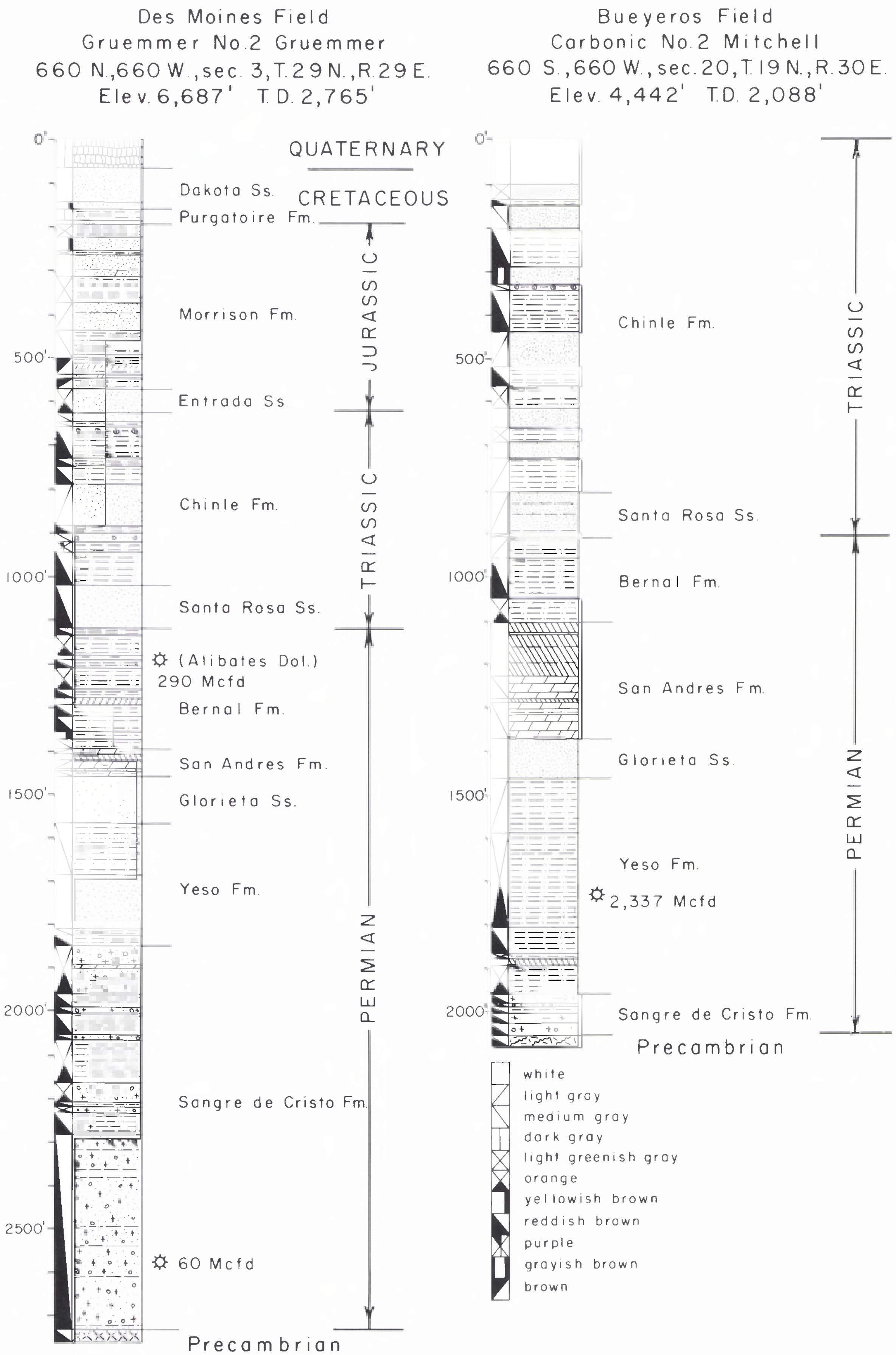

Figure 3. Stratigraphic sections of CO_2 wells.

30 E. was almost entirely from the Santa Rosa Sandstone with minor amounts possibly coming from the lower part of the Chinle Formation. Depth to the producing zone is less than 1,000 feet. The average potential of the wells was 1,540 Mcfd at an average pressure of 38 psi (pounds per square inch). Only one well in this area produced from the Yeso Formation. The pay interval was an orange siltstone at 1,870 feet and the potential was 1,000 Mcfd at 520 psi. The wells in the south part of this area apparently are located on the Baca anticline.

The two wells drilled just north of Bueyeros in sec. 31, T. 21 N., R. 31 E. and the two between the Tequesquite and Iceco fields had shows in the Chinle and Santa Rosa intervals. The wells near Bueyeros in T. 20 N., R. 30 E. tested gas from the Santa Rosa Sandstone at from 308 to 1,500 Mcfd at pressures of from 34 to 40 psi. There also were shows in the Chinle Formation.

DES MOINES FIELD

The occurrence of carbon dioxide was discovered in the Sierra Grande No. 1 Rogers oil test drilled in 1935 (Fig. 4 and Table 1). An estimated 1,000 to 6,000 Mcfd was reported at depths of 2,060 to 2,080 feet, and from 2,245 to 2,280 feet. Four additional wells were drilled between 1952 and 1955 and a plant producing liquid carbon dioxide was placed in production in 1955 and operated intermittently to at least 1966. The plant was modified some time after 1957 and when visited during the New Mexico Geological Society field conference in the fall of 1966, dry ice was being produced. Gas from the Sierra Grande well consisted of 98.4 percent carbon dioxide, the remainder being nitrogen and oxygen (Anderson and Hinson, 1951). Apparently this small amount of other gas caused some problems in processing.

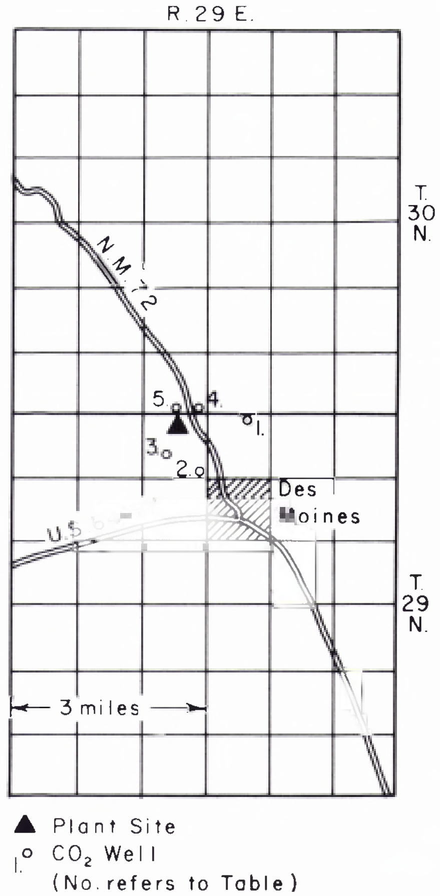

Figure 4. Des Moines field.

At Des Moines basalts and the Dakota Sandstone are at the surface and are underlain by the Morrison Formation and the Exeter Sandstone (fig. 3). The Jurassic section is slightly over 500 feet thick. The Triassic sequence is lithologically similar to that at Bueyeros, but considerably thinner, being only 500 feet thick. The contact between the Chinle Formation and the Santa Rosa Sandstone is sharp but the basal Triassic sands of the Des Moines area are not as clean as at Bueyeros. The Bernal Formation is about 200 feet thick and consists mostly of siltstone and mudstone. It contains some gypsum in the lower part and about 10 feet of dolomite believed to be correlative with the Alibates Dolomite of the Panhandle of Texas. The San Andres Limestone is about 70 feet thick and consists of minor gypsiferous dolomite and dolomitic siltstone. The Glorieta Sandstone is about 100 feet thick and the lithology is like that in the section at Bueyeros. The Yeso interval is quite different being made up of gray siltstone, white, coarse-grained sandstone and minor dark-red mudstone. It is less than 300 feet thick. The Sangre de Cristo Formation is much thicker than at Bueyeros, consisting of over 800 feet of interbedded orange to pink arkosic conglomerate and coarse arkosic sandstone, and dark-red, commonly sandy and arkosic mudstone. As at Bueyeros, the Sangre de Cristo directly overlies Precambrian granite.

Reported depths of producing intervals indicate the bulk of the gas occurs in the Sangre de Cristo Formation. Pay zones are thin (20 to 30 feet) intervals of arkosic conglomerate with red mudstones at the top and base apparently acting as a seal. As far as can be determined the gas-bearing intervals vary from one well to the next as would be expected from the lenticular nature of the conglomerates. Producing depths are from 2,060 to 2,600 feet.

A shallower occurrence of gas has been reported in three wells and has previously been considered to occur in the Triassic Santa Rosa Sandstone. However, the intervals given are from the Alibates Dolomite (Permian) in two of the wells and just below this interval in the third. The only reported pressure for this shallow pay is 5 psi whereas pressures from the deeper gas horizons range from 64 to 210 psi.

ESTANCIA FIELD

Carbon dioxide in the Estancia field has been found in two main areas about five miles apart (fig. 5 and Table 1). In the southern area carbon dioxide was reported from four wells drilled in secs. 11 and 12, T. 6 N., R. 7 E. Very little information is available for these tests but apparently the gas occurs in the lower part of the Pennsylvanian—probably from sandstone in the Sandia Formation. Pennsylvanian strata are overlain by a cover of alluvium and directly overlie Precambrian metamorphics at a depth just below 1,800 feet.

Reported potentials for two of the wells (Table 1) were 60 and 1,000 Mcfd; no pressures were given. Talmage and Andreas (Bates, 1942) reported that the gas was 99 percent carbon dioxide. Anderson and Hinson (1951) give a producing depth of 1,640 feet for one of the wells in sec. 12 and an analysis of from 98.4 to 99.0 percent carbon dioxide, 0.97 to 1.56 percent nitrogen, and 0.03 to 0.04 percent helium.

In the northern part of the field eight wells drilled on the

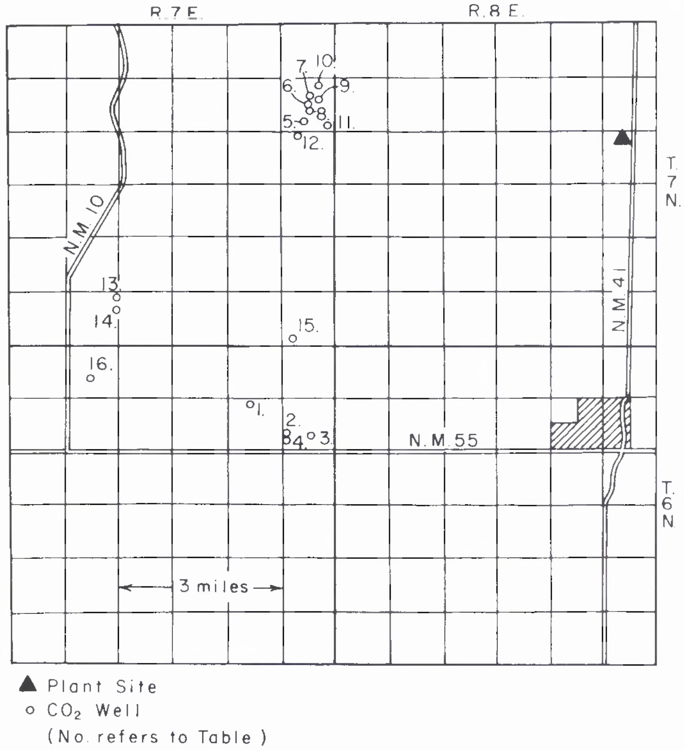

Figure 5. Estancia field.

Wilcox anticline had reported potentials ranging from 150 to 860 Mcfd. The few pressures reported are slightly greater than 400 psi and the gas is about 99 percent carbon dioxide. As near as can be determined the gas occurs in the lower part of the Sandia Formation (Pennsylvanian) and probably in sandstone.

If the reported gas intervals are correct for the two wells drilled in the southern part of T. 7 N. (Table 1, wells 14 and 15) the carbon dioxide occurs in Precambrian schist or schistose quartzite. The Lee well in sec. 36 was reportedly deepened in 1941 from 1,860 to 2,000 feet and the potential at this time was estimated to have increased from 50 to 12,000 Mcfd.

MISCELLANEOUS CARBON DIOXIDE WELLS

Colfax County

Four wells discovered carbon dioxide in Colfax County (Table 2 and fig. 1). Reported potentials range from 133 to 2,000 Mcfd although some reports list the 2,000 Mcfd as 2 Mcfd. Carbon dioxide content from two of the wells is 67.2 and 99.8 percent. The California-Florsheim test had over 28 percent nitrogen and 0.46 percent helium. Available data for these wells is very sketchy but the gas seems to have been found in Santa Rosa and Glorieta sandstone and possibly from conglomerate in the Sangre de Cristo Formation.

Mora County

Carbon dioxide has been reported from two wells in Mora County. The Arkansas-Kruse test drilled on Wagon Mound anticline south of Wagon Mound encountered gas from 1,160 to 1,190 feet; 1,420 to 1,425 feet; at 1,670 feet and 1,795 feet; and from 2,220 to 2,225 feet. There is some confusion regarding the potential of this well probably from the use of "M" for 1,000 cubic feet. Talmage and Andreas (Bates, 1942) reported 26,000 Mcfd, Anderson and Hinson (1951) 12,000 Mcfd, and scout data 26.5 Mcfd. Anderson and Hinson give two analyses of the gas taken two months apart. These are carbon dioxide-92.2 percent, oxygen-1.1 percent, nitrogen-6.55 percent, helium-0.15 percent; and carbon dioxide 90.0 percent, oxygen-2.2 percent, nitrogen-7.65 percent, and helium-0.15 percent.

It is difficult to determine from available data the part of the section containing gas. The intervals from 1,160 through 1,795 feet are unquestionably in the Triassic, but the lowermost zone probably is Permian, perhaps the Glorieta Sandstone.

The Fulton-Santa Fe test encountered an estimated 600 Mcfd of gas from 1,050 to 1,135 feet and a show at approximately 1,540 feet. This well was located one mile south of the Arkansas test and drilled on the same structure. At the depth of the indicated carbon dioxide zone the test was in the Triassic. Scout data states that the well was not a commercial carbon dioxide well because of the presence of hydrocarbon gas.

San Miguel County

Shows of carbon dioxide have been reported from two oil tests drilled on the Cherry Vale dome. The Southwest-Conchas show may have been in rocks of Permian age instead of the indicated Santa Rosa Sandstone (Table 2). Details of the stratigraphy of this part of the section have not been adequately worked out. The show in the Con-O-Kull-Stevenson test is from sandstone in the Chinle Formation.

Torrance County

The Bluehall well in T. 4 N., R. 10 E. apparently had a show of carbon dioxide at 1,400 feet; probably in rocks of Pennsylvanian age.

Harding County

Other occurrences of carbon dioxide have been discovered in six wells drilled to the south and east of the Bueyeros field. In the Waddel-Peters test (Table 2, well 12) shows of carbon dioxide were found between depths of 1,675 and 2,025 feet. Tops for this well are: Chinle Formation-surface, Santa Rosa Sandstone-850 feet, Bernal Formation-1,285 feet, San Andres Limestone-1,540 feet, Glorieta Sandstone-1,800 feet, and Yeso Formation-1,980 feet. Thus the shows occur somewhere from the San Andres Limestone into the upper part of the Yeso Formation. No estimate was made of the amount of carbon dioxide present.

The Law-Baca well (No. 13) had a show of carbon dioxide in Triassic sediments, and numerous shows were reported in the Waddell-Mitchell test (No. 14) drilled about three miles south of the SEC field. Most of the carbon dioxide occurred in Triassic rocks. Estimated flows were from 250 to 500 Mcfd. Still farther south the SEC-Mitchell (No. 13) found carbon dioxide apparently in the lower Yeso or Sangre de Cristo intervals. To the east the recently drilled Amoco-State EM test (No. 14) was listed as being completed as a carbon dioxide well. A drill-stem test was made from 1,825 to 1,877 feet, but no potential was reported so it can only be assumed that this is the producing interval. Similar limited data was given for the Amoco-State EN test (No. 15) drilled to a depth of 2,676 feet. The test was to be completed as a carbon dioxide well but there were no reported drill stem tests or potentials. A preliminary examination of the samples indicates the following tops: San Andres Limestone-1,650 feet, Glorieta Sandstone-1,920 feet, Yeso Formation-1,940 feet, (Cimarron Anhydrite-2,406 to 2,420 feet), and Sangre de Cristo Formation-2,610 feet.

Union County

The Skelly-Van Pelt well (Table 2, fig. 1, well no. 17) had an estimated flow of 5 Mcfd at a depth of 3,788 to 3,793 feet with a 30 minute shut-in pressure of 1,180 psi. The gas-bearing interval is dolomite in the upper part of the Mississippian.

Recently (1971) Amoco deepened the Humble New Mexico State (No. 17) from approximately 2,000 to 2,528 feet. Several drill stem tests were made on this well and carbon dioxide was reported from 1,120 to 1,210 feet, 1,702 to 1,718 feet, and 2,200 to 2,528 feet. Some oil-cut mud also was reported from the upper test. The lowest test was gauged at 770 Mcfd and according to reports the well has been completed for carbon dioxide. Preliminary tops for this well are: Ogallala Formation (?), surface; Morrison Formation, 80 feet; Exeter Sandstone, 460 feet (?); Chinle Formation, 500 feet (?); Santa Rosa Sandstone, 1,190 feet; Bernal Formation, 1,220 feet; San Andres Limestone, 1,400 feet; Glorieta Sandstone, 1,740 feet; Yeso Formation, 1,770 feet (?) (Cimarron Anhydrite-2,190 to 2,220 feet); and Sangre de Cristo Formation, 2,390 feet. The indicated shows therefore occur in the Santa Rosa Sandstone, lower part of the San Andres Limestone, and from the lower part of the Yeso Formation and upper part of the Sangre de Cristo Formation.

PROCESSING

The method of producing dry ice is fairly standard with the exception of compression of the gas where well-head pressures are below about 500 psi at 0°C. At the SEC plant near Solano gas is received at about 530 psi, liquified at -15°F, using ammonia as a refrigerant, sprayed under pressure through a nozzle into snow chambers, and compressed into blocks of dry ice at a pressure of 125 tons (Anderson, 1959).

Six plants have been constructed in northeastern New Mexico to process natural carbon dioxide gas. Four of these were located at the Bueyeros field and one each at the Des Moines and Estancia fields. The Witt Ice and Gas Co. was the initial producer of dry ice in New Mexico operating a plant from 1934 to 1942 near Estancia. According to Anderson (1959) gas pressure was too low to expel the water that seeped in through the casing and the full flow of gas could not be utilized. In 1942 the Witt Co. purchased the holdings of the Ute Carbonics Co. and produced dry ice at the plant northwest of Bueyeros. This plant had a capacity of 20 tons of ice per day. The Timmons plant, with a capacity of 10 tons of ice per day, was the first plant operated in the Bueyeros field, and produced both liquid carbon dioxide and dry ice. The Witt and Timmons operations used low-pressure gas from shallow pays and compression of the gas was required. The Iceco plant south of Bueyeros was built in 1952 and produced dry ice until recently. The plant had a capacity of 53 tons of ice per day but was expanded sometime prior to 1959.

The largest plant processing gas (and the only one now active) is the SEC operation located near Solano. The plant capacity is 125 tons of ice per day; at one time 100 tons of liquid carbon dioxide also was produced each week. Gas is delivered to the plant by a 6-inch pipeline.

Gruemmer Industries and later Liquid Carbonics Co. operated the plant 1.7 miles north of Des Moines. Gas used at the plant came from the two Gruemmer wells at pressures of 10 and 250 psi. This necessitated installation of a compressor on the low-pressure line. Only liquid carbon dioxide was produced originally but by 1966 equipment had been installed to produce dry ice.

REFERENCES

Anderson, C. C., and H. H. Hinson, 1951, *Helium-Bearing natural gases of the United States:* U.S. Bur. Mines, Bull. 486.

Anderson, E. C., 1959, *Carbon dioxide in New Mexico (1959):* New Mexico State Bur. Mines Mineral Resources, Circ. 43.

Bates, R. L., 1942, *The oil and gas resources of New Mexico:* New Mexico State Bur. Mines Mineral Resources, Bull. 18.

Craig, H., 1953, *The geochemistry of the stable carbon isotopes:* Geochim. et Cosmochim. Acta, v. 3, p. 53.

Lang, W. B., 1959, *The origin of some natural carbon dioxide gases:* Jour. Geophys. Res., v. 64, no. 1, p. 127.

Miller, J. C., 1937, *Carbon dioxide accumulations in geologic structures:* American Inst. Min. Metal. Eng., Tech. Pub. 841.

Pierce, A. P., 1965, *Mineral and water resources of New Mexico:* U.S. Geol. Survey, New Mexico State Bur. Mines Mineral Resources, Bull. 87.

Shepherd, E. S., 1938, *The gases in rocks and some related problems:* American Jour. Sci., 5th ser., v. 35-A, p. 311.

Silverman, S. R., and Epstein, S., 1958, *Carbon isotopic compositions of petroleums:* American Assoc. Petroleum Geologist Bull., v. 42, no. 5, p. 998.

West, J., 1971, *Line will move 240 MMcfd of* CO_2: Oil and Gas Jour. v. 69, no. 45, p. 53, Nov. 8, 1971.

White, D. E., and G. H. Waring, 1963, Data of Geochemistry, Sixth edition, Chapter K, *volcanic emanations:* U.S. Geol. Survey, Prof. Paper 440-K.