New Mexico Bureau of Mines & Mineral Resources

Open-File Report 89

Basic Subsurface Data
Compiled for Hydrogeologic Study
of the San Juan Basin, Northwest New Mexico

William J. Stone, Hydrogeologist
and Nancy H. Mizell, Geologist

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Contents

Illustrations

* Plates are in pocket.

INTRODUCTION

Overview of Hydrogeologic Study

In July 1972, the New Mexico Bureau of Mines and Mineral Resources undertook a study of the ground-water resources in the New Mexico portion of the San Juan Basin to determine the availability of water supplies for coal surface mining. The initial project was funded in part through a grant from the New Mexico Water Resources Research Institute and by contributions from El Paso Natural Gas Company, Peabody Coal Company, and Western Coal Company. The scope of the project was expanded in 1974 to include the entire water-resource/energy spectrum in the area, and the study was continued as a cooperative effort of the Bureau, the Water-Resources Division of the U.S. Geological Survey, and the New Mexico State Engineer.

In the present study the Bureau is responsible for characterizing the geologic framework of the Basin and helping evaluate the extent to which this framework controls the ground-water system(s) operative there. To accomplish this the Bureau part of the study has involved:

1. Preparation of maps showing elevation of top (structure), depth to top, and total thickness for all potential aquifers in the Basin.
2. Construction of a series of geologic cross sections to show the position, structure, thickness, and lateral continuity of Jurassic and younger strata in the Basin.

3. Field measurement, description, and selective sampling of representative stratigraphic sections for major rock units in the Basin.
4. Analysis of the petrography (texture, porosity, and composition) of major aquifers and selected confining layers in the Basin.

Purpose of This Report

Although much useful hydrogeologic information has already been compiled by both the U.S. Geological Survey and the Bureau, the project was scheduled to run for 5 years, and final reports may not appear before 1980. Presently there is considerable resource development activity in the San Juan Basin, and the need for hydrogeologic information is urgent. To assure that interested parties have ready access to at least the basic data of our study prior to the completion of the final report, it was decided that a series of Open-File Reports be prepared: the Survey would report the basic hydrologic data (well records and water chemistry) and the Bureau would give the basic geologic data. As outlined above, the Bureau's geologic effort has included surface and subsurface stratigraphic studies as well as various petrographic analyses. The purpose of this report is to release the basic data and preliminary results of the Bureau's subsurface stratigraphic study of the San Juan Basin. Results of the field stratigraphic study and the petrographic study will be reported in subsequent reports (OF-90 and OF-91 respectively).

The San Juan Basin

The San Juan Basin is a Laramide depression at the eastern edge of the Colorado Plateau. The Basin covers about 30,000 mi^2 in northwestern New Mexico and southwestern Colorado (figure 1). Structural relief in the Basin amounts to about 6,000 ft; monoclines are the most prominent structures. Faults are known to be abundant along the southern margin of the Basin, but the occurrence of soft shales at the surface of much of the area hinders recognition of faulting outside this area.

The hydrogeologic study of the San Juan Basin has focused mainly on the Morrison Formation (Jurassic) and overlying rock units because 1) except in a narrow belt near the outcrop, underlying deposits are generally too deep in most of the Basin to be economically useful as aquifers, 2) the hydrologic and geologic characteristics of the deeper units are too poorly known, and 3) present energy development, specifically uranium mining, directly involves no units deeper than the Morrison. The stratigraphic framework and nomenclature of the deposits of interest in the present study are given in figure 2. In general, this sequence of deposits reflects a shift from largely continental deposition in Triassic and Jurassic times, to alternating marine/nonmarine shorezone deposition in Cretaceous time, then back to strictly, non-shorezone, continental deposition in Tertiary time.

More specifically, the Entrada, Todilto, Sumerville, and Zuni-Bluff-Cow Springs interval probably represents deposition in various desert environments (eolian dune field, inland

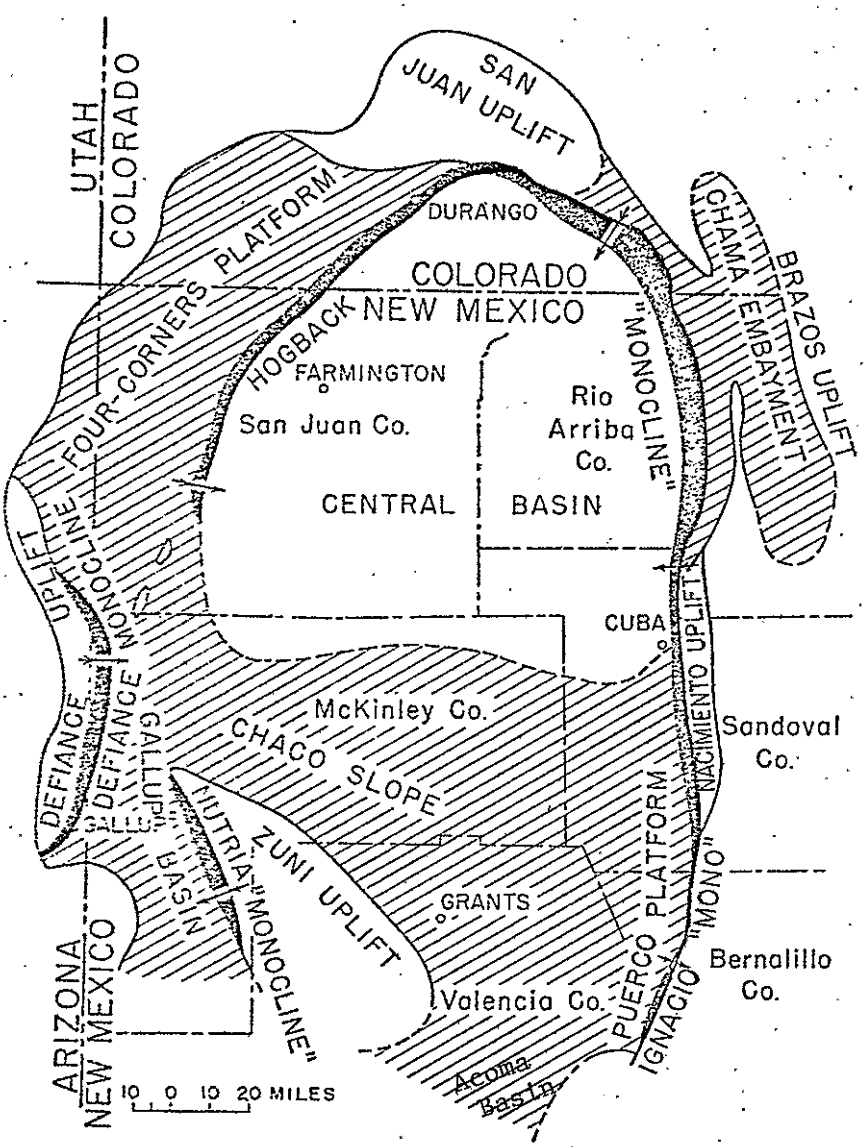

Figure 1. Location and structural elements of the San Juan Basin (as modified from Kelley, 1951, by Beaumont and others, 1976).

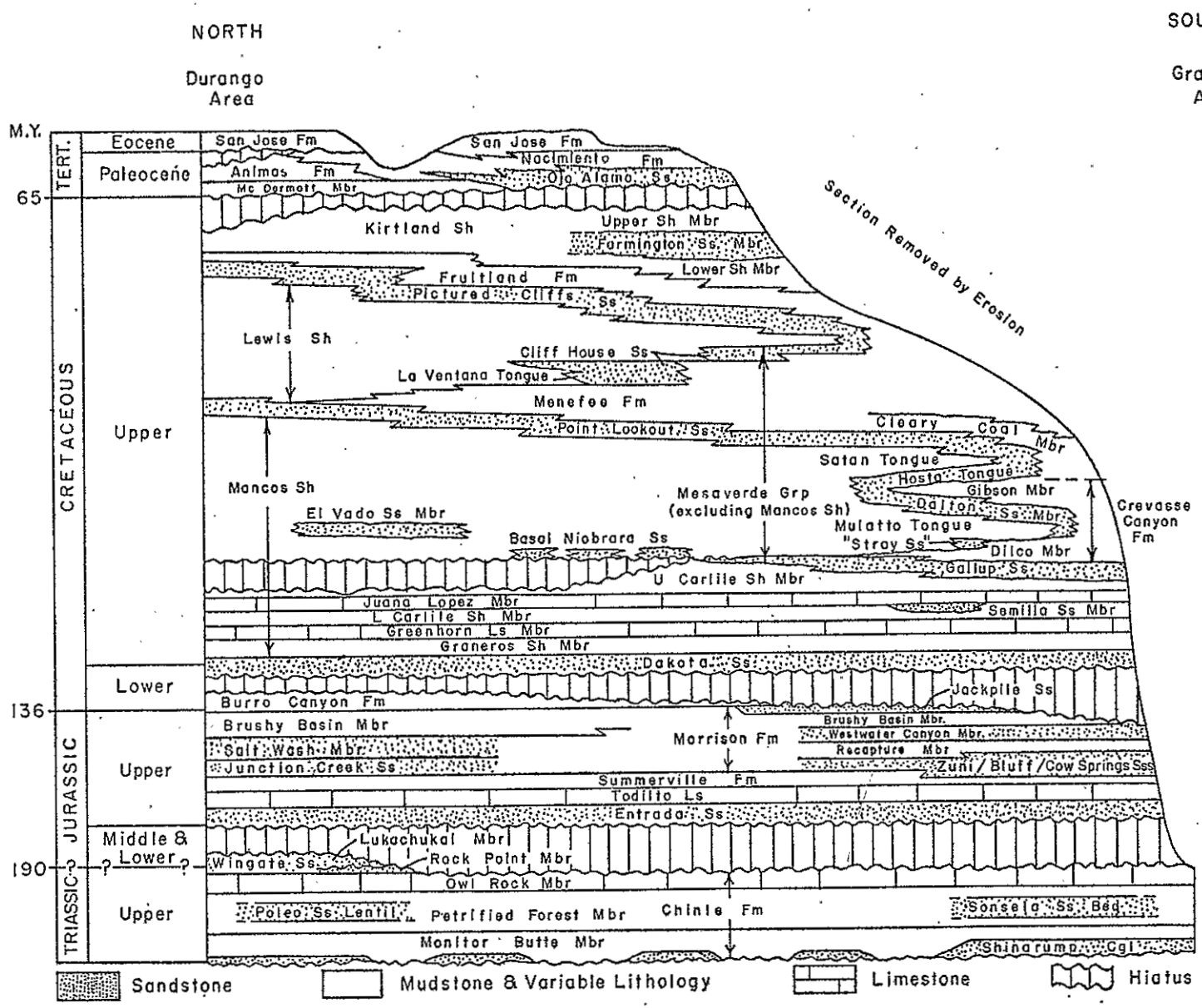

Figure 2. Time-stratigraphic framework and nomenclature, Triassic through Tertiary, San Juan Basin (modified from Molenaar, 1977).

sebkha, lake; mainly). The Morrison Formation represents deposition under wetter conditions, perhaps alternating meandering/braided fluvial stream systems. The Dakota Sandstone records the initial invasion of this portion of North America by the vast Cretaceous seaway which extended from the Arctic Ocean to the Gulf of Mexico some 135 million years ago. The Mesaverde Group of the San Juan Basin is an excellent record of the alternating transgressive and regressive deposition that characterized this arm of the Cretaceous sea. Transgressions are represented by the Dakota Sandstone, "Stray Sandstone", Hosta Tongue of the Point Lookout Sandstone, and the Cliff House Sandstone. Regressions of the shorezone are documented by the Gallup Sandstone, Dalton Sandstone Member of the Crevasse Canyon Formation, the main body of the Point Lookout Sandstone, and the Pictured Cliffs Sandstone. With the final retreat of the sea, marked by the deposition of the Pictured Cliffs Sandstone, nonmarine conditions returned and prevailed throughout Paleocene and Eocene time. To date no Oligocene deposits have been found,suggesting they have been subsequently eroded or that the modern erosional cycle was initiated as early as Oligocene time.

Previous Stratigraphic Work

Much work has been done over the years on the stratigraphy of the San Juan Basin, and with renewed interest in its energy resources such work is continuing. Although it is beyond the scope of a basic data report such as this to review previous

work in any detail, it is useful to identify for the reader the general references on the Basin stratigraphy, some of the more recent works on the subject, as well as the specific sources consulted in the preparation of the maps and cross sections presented here. Most of the publications cited below contain excellent bibliographies, giving still further references on the subject.

The stratigraphy of uppermost Triassic and Jurassic deposits of New Mexico and Arizona were compared by Harshbarger and others (1957). The stratigraphy of the Morrison Formation in various parts of the Basin was described by Freeman and Hilpert (1956), Santos (1970; 1972), and Woodward and Schumacher (1973). Various problems with the Dakota Sandstone have been addressed by Owen (1973), Owen and Siemers (1977), and Landis and others (1973). Selected units in the Mancos Shale were described by Dane and others (1966 and 1968). The classical studies of the Mesaverde Group include those by Sears and others (1941), Pike (1947), and Hollenshead and Pritchard (1961). An important revision of the nomenclature of the Mesaverde Group was implemented by Beaumont and others (1950). The existence of a pre-Niobrara unconformity was discussed by Penttila (1964) and McPeek (1965). Stratigraphy and interpretations of the Gallup and related sandstones were given by Campbell (1971 and 1973), Molenaar (1973, 1974, and 1977), and Sabins (1963). Transgressive and regressive relationships between the Dalton Sandstone Member of the Crevasse Canyon Formation and the Mancos Shale were

described by Kirk and Zech (1977). Stratigraphy of the Point Lookout Sandstone has been given by Shetiwy (1978). Various aspects of the Cliff House Sandstone have been discussed by Siemers and King (1974) and Mannhard (1976). Fassett (1977) summarized the geology of the Point Lookout, Cliff House, and Pictured Cliffs Sandstones. Fassett and Hinds (1971) gave the geology of the Fruitland Formation and Kirtland Shale. The Farmington Sandstone Member of the Kirtland Formation was described by Dilworth (1960). The subsurface recognition of the Cretaceous deposits in the Basin was illustrated and discussed by Bozanic (1955). The nature of the Cretaceous-Tertiary boundary and the stratigraphy of the Tertiary deposits were discussed by Reeside (1924), Dane (1946), Baltz and others (1966), Baltz (1967), and Brimhall (1973). Classical early works on the Tertiary deposits include those by Sinclair and Granger (1914) and Simpson (1948).

Source of Data

The relationship of wells used in this study to major roads, selected towns, the land grid, political boundaries, and principal streams of the area is shown on Plate 1. Each well has been assigned a unique number as shown on Plate 1. The specific location (legal description), name, and type of information used for any well of interest may be found in Table 1 by means of this well number. Scout cards and/or logs for all wells used are in the files of the Bureau's subsurface-data library.

Table 1. Source of subsurface data used for maps and cross sections

Well Number Assigned in This Report	Well Location	Well Name	Remarks*
1	36-32N-20W	Tenneco 1 Navajo-590	C
2	13-32N-20W	Conoco 1 Navajo-13	
3	33-32N-19W	Compass Exploration Indian 1	C
4	21-32N-19W	Conoco 1 Navajo-21	
5	36-32N-18W	Southern Union Gas 1A-Navajo	
6	17-32N-18W	Texas Company 1-N-Navajo	
7	35-32N-17W	Skelly Oil 14 Navajo P	
8	20-32N-17W	Murphy Oil 13 Navajo AA	
9	13-32N-17W	Miami Oil 1 Navajo	
10	35-32N-16W	Aztec Exploration 1 Ute	C
11	15-32N-15W	Aztec Oil & Gas 1 Ute Mtn.	C
12	14-32N-15W	Aztec Oil & Gas 3 Mid-Canyon	C
13	25-32N-14W	Amoco 1 Mtn. Ute G.C-F	C
14	26-32N-13W	Consolidated Oil & Gas 1 Ripley	
15	21-32N-13W	F.A. Schultz 1 Holloway	C
16	31-32N-12W	Johnston & Johnston 1-Culpepper-Martin	
17	24-32N-12W	EPNG 8 Moore	C
18	10-32N-12W	Aztec Oil & Gas 4 Decker	
19	31-32N-11W	Aztec Oil & Gas 1-Y Vasaly Federal	C
20	26-32N-11W	Delhi-Taylor 1 Barnes	C
21	21-32N-11W	Pacific NW Pipeline Cox Canyon 4-21	
22	32-32N-10W	Stanolind 1 Martinez	
23	32-32N-10W	Amoco 1 Martinez H	
24	24-32N-10W	Delhi-Taylor 1 Wickens	C
25	21-32N-9W	EPNG 9-21 SJU 70-X	
26	24-32N-8W	Aztec Oil & Gas 1 Wilmer Canyon	
27	15-32N-8W	Phillips Petroleum 4-15 SJU	C
28	29-32N-7W	EPNG 22-29 SJU 32-7	
29	13-32N-7W	EPNG 9 Allison Unit	
30	7-32N-6W	EPNG 24 Allison Unit	
31	35-32N-5W	Pan Am. Petroleum 2 SJU 32-5	

* Data from geophysical logs unless "C" appears indicating scout card used; A-A', B-B',C-C' refer to cross sections where log appears (Plates 26-28)

Table 1. Source of subsurface data used for maps and cross sections (continued)

Well Number Assigned in This Report	Well Location	Well Name	Remarks*
32	29-32N-4W	Phillips Petroleum 1-29 Mesa U 32-4	
33	23-32N-3W	Pan Am. Petroleum 1 Pagosa Jicarilla	B-B',C-C'
34	22-32N-3W	Stanolind Southern Ute 1	
35	12-31N-19W	D.O. Thomas 1 Navajo	C
36	10-31N-19W	Pan Am. Petroleum 1-Navajo B	
37	22-31N-18W	Standard Oil 1 Navajo-24-22	
38	21-31N-18W	Humble Oil 5 Core Hole	C
39	23-31N-17W	EPNG 1 Chimney Rock	C
40	21-31N-17W	H. Brown 1-Navajo-21	C
41	33-31N-16W	Atlantic Richfield 5-W H-Gallup	C
42	17-31N-16W	Atlantic Richfield Many Rocks 11	C
43	24-31N-15W	Aztec Oil & Gas 1-D Ute	C
44	20-31N-15W	Gulf Oil 1-SW Barker	C
45	15-31N-15W	Southern Union Gas H5 Ute Indian	C
46	9-30N-7W	Black & Nichols 18-9 NE Blanco	C
47	29-31N-14W	Standard Oil 13-Ute Mtn.-2	
48	15-31N-14W	Riddle-Gotllies 1-Ute Mtn.	C
49	13-31N-14W	Standard Oil 1 Ute Mtn.	C
50	20-31N-13W	Adobe Oil 1 Elliott	C
51	5-31N-13W	Aspen 1-5 Federal	C
52	31-31N-12W	Southern Union Gas 2 Tallafero	C
53	15-31N-12W	Aztec 9 Richardson	
54	13-31N-11W	Amoco 1 Caneple B	
55	8-31N-11W	Delhi-Taylor 5-Mudge	
56	4-31N-11W	Delhi-Taylor 7-Del-Mudge	
57	27-31N-10W	Delhi-Taylor 4X-ATL-A	
58	27-31N-10W	Delhi Oil 4A-Atlantic	
59	15-31N-10W	Aztec Exploration 7 Richardson	C
60	7-31N-10W	EPNG 1 Hutchinson Pool	
61	35-31N-9W	Anderson-Pritchard 5 Johnston	
62	34-31N-9W	Tenneco 5 Pritchard	C
63	20-31N-9W	Delhi-Taylor 1 Barrett	

Table 1. Source of subsurface data used for maps and cross sections (continued)

Well Number Assigned in This Report	Well Location	Well Name	Remarks*
64	6-31N-9W	EPNG 33 SJU 32-9	
65	22-31N-8W	Pacific N-W Pipeline 8-22 SJU	
66	32-31N-8W	EPNG 10-EPNG Cem 1	C
67	29-31N-7W	Blackwood & Nichols N.E. Blanco 1	
68	5-31N-6W	Pan Am. Petroleum 35-5X Rosa U	
69	32-31N-5W	EPNG Rosa Unit 24	B-B',C-C'
70	24-30N-20W	Amerada Petroleum 1 Navajo	C
71	4-30N-19W	A.J. Antwell 1 Dos Mesa	C
72	12-30N-19W	Benson-Montin-Greer 1 Navajo	C
73	4-30N-18W	Humble Oil 9 Core Hole	C
74	8-30N-18W	Texaco 1 Navajo AP	
75	21-30N-18W	Amalg Petroleum 5 Navajo	C
76	1-30N-17W	K. Blackford 1 Navajo	C
77	12-30N-16W	EPNG 2 Will? A	C
78	14-30N-16W	Pan Am. Petroleum 4 N.E. Hogback	
79	22-30N-16W	Pan Am. Petroleum 3 N.E. Hogback	
80	5-30N-15W	EPNG 6 Malco Copple	
81	29-30N-15W	Sunray Mid Continent Oil 1 Federal L	C
82	34-30N-15W	Sunray DX Oil 4 Federal K	C
83	13-30N-14W	J.P. McHugh 1 Piñon	C
84	19-30N-14W	Humble Oil 1 N. Kirtland	
85	3-30N-13W	Pan Am. Petroleum 2 J.F. Bell	C
86	15-30N-13W	Southern Union Gas 1 McCord	C
87	29-30N-13W	Texas National 1 Federal	
88	13-30N-12W	Tidewater 1 M.L. Wright	C
89	14-30N-12W	S.W. Production 1-L Wallace	
90	23-30N-12W	Monsanto 1 NWP	C
91	10-30N-11W	S.W. Production 1 Hampton D	
92	13-30N-11W	Fairplay 1 Michael	C
93	18-30N-11W	S.W. Production 1 Fannie Wall	C
94	19-30N-11W	Calvin, H. 1 Lebleu	
95	17-30N-10W	EPNG 12 Schumacher	C

Table 1. Source of subsurface data used for maps and cross sections (continued)

Well Number Assigned in This Report	Well Location	Well Name	Remarks*
96	24-30N-10W	Amoco 4 Riddle	C
97	15-30N-9W	Pan Am. Petroleum 3 Elliott A	C
98	20-30N-9W	EPNG 1-Florance B	C
99	22-30N-9W	Delhi-Taylor 49 Florance Federal	C
100	4-30N-9W	EPNG 4 Riddle	C
101	4-30N-8W	EPNG 4 Howell A	C
102	10-30N-8W	Delhi-Taylor 2-Howell	
103	14-30N-8W	Delhi-Taylor 50-Florance-Federal	C
104	21-30N-6W	EPNG Barron Kidd 7	
105	23-30N-5W	EPNG 28-23x SJU 30-5	B-B',C-C'
106	20-30N-5W	EPNG 27-20 SJU 30-5	
107	2-29N-19W	Eastern Petroleum 45 Navajo	C
108	2-29N-19W	Conoco 139 Rattlesnake	C
109	11-29N-19W	Conoco 140 Rattlesnake	C
110	17-29N-18W	Shiprock 1Y-Navajo K	C
111	17-29N-18W	Universal Oil 1 Navajo	C
112	28-29N-17W	C.C. Kennedy 2 Spook	C
113	30-29N-17W	Amerada-American Navajo 2	C
114	31-29N-16W	J.E. McCutchinson 1 Navajo 11	C
115	35-29N-16W	W. Duncan 1-15 Pure-Navajo	C
116	12-29N-15W	Greenbrier 1 Foutz	C
117	6-29N-14W	Sunray Mid-Continent Oil 1 Federal K	A-A'
118	12-29N-13W	Pioneer Oil 1 Smith	C
119	7-29N-12W	N.W. Production 1 Blanco 7-29-12	C
120	11-29N-11W	Aztec Oil & Gas 1 Federal PRI	C
121	24-29N-11W	O. Reynolds 1 Lohman	C
122	25-29N-11W	Tenneco 1 Eaton A	A-A'
123	26-29N-11W	Southern Union Gas 1 Calvin	
124	20-29N-10W	Pan Am. Petroleum 1 Haney B	
125	30-29N-10W	E. Roberts 1 Lochner	C
126	34-29N-10W	S.W. Production 1 Zachary Federal	A-A'
127	14-29N-9W	Pan Am. Petroleum 1 L.A. Shane	

Table 1. Source of subsurface data used for maps and cross sections (continued)

Well Number Assigned in This Report	Well Location	Well Name	Remarks*
128	16-29N-9W	Southern Union Gas 2 Mims	C
129	25-29N-9W	Delhi-Taylor 26 Florance	A-A'
130	12-29N-8W	Lively Exploration 8 Lively	A-A'
131	22-29N-7W	EPNG 65-SJU 29-7	A-A',B-B'
132	3-29N-6W	Phillips Petroleum 1-3 SJU 29-6	
133	4-29N-6W	EPNG 62-4 SJU 29-6	A-A',B-B'
134	8-29N-5W	EPNG (Pac. N.W.) 22-8 SJU 29-5	A-A',C-C'
135	22-29N-5W	EPNG 45-22 SJU 29-5	
136	33-29N-4W	EPNG 18-33 SJU 29-4	A-A',B-B'
137	27-28N-19W	Amerada Petroleum 1 Navajo 32	
138	14-28N-18W	Eastern Petroleum 2 Am - S.S.	C
139	29-28N-17W	Sunray Mid-Continent Oil 2 N.M. - Navajo	C
140	13-28N-16W	Pure Oil 1-Navajo-9	C
141	20-28N-16W	Scott Brothers 1 Magnolia Navajo	
142	26-28N-15W	Exploration Drilling 1 Navajo	
143	36-28N-15W	E.R. Richardson 1 Kittye	
144	22-28N-14W	Gulf Oil 2 Amarillo-Navajo	C
145	10-28N-13W	Eljohn Petroleum 1 Bay Mare	C
146	17-28N-13W	Benson-Montin-Greer 1 Jones A	C
147	34-28N-13W	Royal Development 1 Royal T. Federal	C
148	13-28N-12W	Pan Am. Petroleum Gallegos 203	
149	17-28N-12W	Sunray DX Oil 149 Gallegos	
150	21-28N-12W	Benson & Montin 50 Gallegos Canyon U	C
151	8-28N-11W	Flag Redfern 3 Gentile	C
152	15-28N-11W	Ohio Oil Ohio Government 2-15	C
153	11-28N-10W	Southern Union Gas 18 Zachary	
154	21-28N-10W	Sunset International 12 Sipco 21	C
155	14-28N-9W	Delhi-Taylor 1 McCully	
156	19-28N-8W	Delhi-Taylor 1-Delhi-Florance-B	
157	18-28N-7W	EPNG 28-7 SJU-30	
158	33-28N-6W	Delhi Corp. 1 McPherson	B-B'
159	27-28N-5W	EPNG 44 SJU 28-5	B-B',C-C'

Table 1. Source of subsurface data used for maps and cross sections (continued)

Well Number Assigned in This Report	Well Location	Well Name	Remarks*
160	26-28N-4W	EPNG 24-26 SJU 28-4	
161	36-28N-4W	EPNG 8-36 SJU 28-4	
162	21-28N-3W	EPNG Jicarilla 84-2	
163	27-28N-2W	Sunray DX Oil Jicarilla 1-A	
164	23-28N-1W	Mobil Oil Boulder 23-23	
165	15-28N-1W	P.M. Drilling Bayless 1	
166	29-27N-19W	EPNG 1 Beautiful	C
167	10-27N-18W	A.J. Antweil 1 Deadmans Wash	C
168	3-27N-17W	Eastern Petroleum 2 Table Mesa	C
169	3-27N-17W	Conoco VA-332	
170	9-27N-16W	Humble Oil 1 Navajo B	
171	14-27N-15W	W.O. Calloway 1 Navajo	C
172	6-27N-14W	Davis Oil 1 Navajo-Raven	C
173	18-27N-13W	Royal Development 2 Rex Uranium	
174	18-27N-13W	Max Coll 1 Rex	C
175	24-27N-13W	J.P. McHugh 2 Nassau	C
176	18-27N-12W	Benson-Montin-Greer Drilling 1 Riddle	C
177	23-27N-12W	A.M. Campbell 1 Federal Tonkin	C
178	3-27N-11W	R & G Drilling 10 R & G	C
179	16-27N-11W	EPNG 1 Frontier C	
180	16-27N-10W	Sunset International 1 Kutz Federal	
181	16-27N-10W	Amoco 2 Hargraues Federal	C
182	30-27N-10W	Big Mac 1 Galt	C
183	15-27N-9W	W. Duncan 2 Skelly	C
184	17-27N-9W	Aztec Oil & Gas 10 Whitley	C
185	19-27N-9W	R.A. Johnston 2 Lodewick	C
186	11-27N-8W	J.P. McHugh 1 Oknard	
187	19-27N-8W	Southern Union Gas 6 Navajo B	
188	3-27N-7W	EPNG 103 SJU 28-7	
189	36-27N-7W	R.A. Johnston 31 Rincon Unit	
190	4-27N-6W	EPNG 40 SJU 28-6	
191	30-27N-6W	EPNG 149 Rincon Unit	B-B'

Table 1. Source of subsurface data used for maps and cross sections (continued)

Well Number Assigned in This Report	Well Location	Well Name	Remarks*
192	4-27N-5W	EPNG 89 SJU 27-5	
193	7-27N-4W	EPNG 5 SJU 27-4	C-C'
194	32-27N-2W	L.H. Smith Jicarilla 32-1	
195	25-26N-20W	Gulf Oil 1 Navajo BB	C
196	21-26N-19W	Apache Oil 1-21-Navajo TT	C
197	16-26N-18W	Pan Am. Petroleum 3 Tribal Unit	C
198	11-26N-17W	Davis Oil 1 Conoco-Navajo	
199	36-26N-16W	Pure Oil 1-3 Navajo	C
200	24-26N-15W	Shell Oil 14-24 Burnham	
201	13-26N-14W	Pan Am. Petroleum 2 Navajo	C
202	32-26N-13W	Sunray Mid Continent Oil 1 NMF G	C
203	34-26N-13W	British Am. 4 Salge B	
204	11-26N-12W	Skelly Oil 1 Navajo J	
205	12-26N-12W	T. Dugan 1 Clay	
206	16-26N-11W	Monsanto 1 State J	
207	21-26N-11W	Tenneco 1 Berger A	
208	23-26N-11W	J.P. McHugh 3 Nassau	
209	17-26N-10W	EPNG 104 Huerfano	C
210	10-26N-9W	EPNG 80 Huerfano	
211	24-26N-9W	Beta Development 1 Babbitt	
212	9-26N-8W	Southern Union Gas 14 Newson B	C
213	22-26N-8W	Southern Union Gas 7 Hodges	
214	1-26N-7W	Tex. National Petroleum 57 Rincon	B-B', C-C'
215	5-26N-7W	International Oil & Gas Federal Miles D-1-5	
216	29-26N-6W	EPNG Vaughn 4	
217	21-26N-4W	Southern Union Gas 6-E Jicarilla	
218	18-26N-3W	J.P. McHugh 2-A Jicarilla	
219	21-26N-3W	J.P. McHugh Tiger 1	
220	4-25N-19W	Drilling & Coring Exploration 1 Navajo	
221	28-25N-16W	Gulf Oil 1 Navajo-Federal	
222	3-25N-14W	Gulf Oil 1 Pinebete-Navajo	
223	21-25N-14W	Amerada Petroleum 1 Navajo	C

Table 1. Source of subsurface data used for maps and cross sections (continued)

Well Number Assigned in This Report	Well Location	Well Name	Remarks*
224	17-25N-13W	K. Murchison 1 Federal	C
225	24-25N-13W	British Am. Petroleum 2 Ross	
226	3-25N-12W	K. Murchison 3 Murchison-Federal	C
227	24-25N-12W	Shell Oil 1 Carson	C
228	3-25N-11W	Tenneco 1 Pah	C
229	4-25N-10W	El Paso Production 1 A Lundean	C
230	14-25N-10W	S.D. Johnson 1 Federal	C
231	8-25N-9W	EPNG 155 Huerfano	C
232	27-25N-9W	A.N. Campbell 1 Rudman	C
233	15-25N-8W	Pan Am. Petroleum 9-Jicarilla 148	C
234	19-25N-8W	Zoller & Danneberg 1 Federal Pesidio	C
235	7-25N-6W	Superior Oil 1-7 Sealy Government	B-B'
236	20-25N-5W	Kay Kimball Jicarilla 1-20	
237	25-25N-5W	Amerada Petroleum 5 Jicarilla A	
238	28-25N-5W	Skelly Oil 2 Jicarilla C	
239	30-25N-4W	Conoco 30-1 Jicarilla	C-C'
240	4-25N-2W	EPNG Highsmith 4-D	
241	15-24N-19W	J.A. McCutchinson 1-Navajo 57	C
242	5-24N-17W	J.H. Laurence 1 Law-Navajo	C
243	21-24N-17W	R.L. Bayless 1 Navajo	
244	26-24N-16W	T.J. Hynes 1 Ann	C
245	32-24N-15W	Sinclair 1 Navajo A	C
246	6-24N-14W	Davis Oil 1 Magnolia Navajo	C
247	10-24N-13W	Davis Oil 1 Riddle	
248	21-24N-12W	Humble 1 Tanner	
249	14-24N-11W	Phillips Petroleum 1 Gallegos	
250	29-24N-11W	Magnolia Oil 1 Beamen	C
251	12-24N-10W	Standard Oil 12-1 Huerfano	C
252	1-24N-9W	Magnolia Petroleum 1 Wood	C
253	15-24N-9W	F.R. Jackson 2 Federal	
254	3-24N-8W	Royal Development 2 Paquenche	B-B'
255	12-24N-8W	H.L. Bigbee 5 Loco	C

Table 1. Source of subsurface data used for maps and cross sections (continued)

Well Number Assigned in This Report	Well Location	Well Name	Remarks*
256	25-24N-7W	Val Reese & Associates 1-25 Mesa	
257	2-24N-6W	Skelly Oil 3 Farming E	
258	18-24N-6W	Redfern & Herd 1 Largo Spur	
259	15-24N-5W	Conoco Northeast Hagnes 8	
260	9-24N-4W	Johnston Shear 3-9 Jicarilla	C-C'
261	22-23N-14W	Wood Petroleum 1-22 Navajo Tribal	C
262	9-23N-13W	Apache Corp. 1 Foshay	
263	23-23N-12W	Humble Oil 2 Tanner	C
264	14-23N-11W	Shell Oil 1 Meyer	C
265	25-23N-10W	Great Western Drilling 1 English	B-B'
266	27-23N-10W	E.B. Larue 3 Kinebeto	B-B'
267	12-23N-9W	Sun Oil 1 Adfl. Navajo	C
268	30-23N-8W	Davis Oil 7 Chaco	
269	7-23N-6W	Conoco 1 Federal-McBee B	
270	5-23N-4W	Skelly Oil Jicarilla D2	
271	21-23N-4W	San Juan Drilling 1 Vanderslice	
272	29-23N-3W	Reynold Mining 1 Jicarilla	C-C'
273	18-23N-2W	Magnolia Oil 1-A Jicarilla	C-C'
274	31-23N-2W	N. Am. Exploration & Tesoro Petroleum 1 Crosswise	
275	36-22N-17W	Pure Oil 1 Navajo	
276	10-22N-14W	H.A. Chapman 1 Navajo	C
277	23-22N-7W	N.W. Production 1-23 Sandoval	
278	31-22N-13W	Southern Union Gas · Santa Fe-Pacific 1	C
279	32-22N-13W	Fairway Oil & Gas 1 State	C
280	9-22N-10W	E.B. LaRue 4 Kinbeto	B-B'
281	26-22N-10W	N.W. Production 1 Kinebeto	
282	25-22N-9W	Sun Oil 1 Navajo Lands	C
283	10-22N-8W	Humble Oil 4S-Chaco	
284	16-22N-5W	Warren Drilling 1 Lanmon	
285	8-22N-4W	Skelly Oil Jicarilla 1-E	C-C'

Table 1. Source of subsurface data used for maps and cross sections (continued)

Well Number Assigned in This Report	Well Location	Well Name	Remarks*
286	32-22N-2W	L.H. Smith 32-1 Jicarilla	C-C'
287	4-21N-16W	Benson-Montin-Greer 1 Gulf Navajo A	
288	1-21N-14W	Southern Union Gas 2 Navajo	
289	1-21N-14W	Southern Union Gas 1 Navajo	
290	7-21N-13W	Southern Union Gas 1 Santa Fe	
291	18-21N-12W	Sinclair 1 Navajo	C
292	22-21N-11W	Tesoro Petroleum 1 Boundary	B-B'
293	31-21N-10W	Davis Oil 1 Boxcars	
294	12-21N-9W	Eastern Petroleum 1 Blackjack	
295	13-21N-8W	Eastern Petroleum 1 Andele-Federal	
296	10-21N-6W	Davis Oil 1-B Locke	
297	32-21N-6W	Davis Oil 1 Government Locke	
298	23-21N-2W	Sun Oil 1 McElvain	C-C'
299	27-20N-20W	Humble Oil Navajo 1	C
300	9-20N-13W	Davis Oil 1 Stoney Butte	
301	19-20N-12W	Sinclair NMA Land & Cattle	
302	19-20N-11W	Davis Oil 1 Wild Card	B-B'
303	33-20N-10W	Davis Oil 1 Monument	
304	20-20N-9W	Eastland Oil 1 Santa Fe Pacific 20	
305	1-20N-8W	Davis Oil 1 La Coy Federal	
306	28-20N-8W	Davis Oil 1 Pintado Canyon	
307	35-20N-7W	Eastern Petroleum 1 Castillo	
308	16-20N-6W	Sun Oil 1 N. Mex.-W-State	
309	36-20N-5W	Filon Exploration 2 State 36-A	C-C'
310	36-20N-5W	Filon Exploration 1 State 36-A	
311	32-19N-12W	Hughes & Hughes 1 State Tract 18	B-B'
312	14-19N-11W	Sinclair 1 Santa Fe 74 N. Ranch	B-B'
313	25-19N-10W	Sinclair 1 S.F. 82 Chaco Wash	
314	14-19N-7W	Eastern Petroleum 1 Chacra Mesa	
315	8-19N-5W	Reynolds Mining 1 Federal	
316	31-19N-5W	J. Dunigan Inc. 2 Santa Fe	
317	14-19N-3W	Magnolia Petroleum 1 Hutchinson Federal	

Table 1. Source of subsurface data used for maps and cross sections (continued)

Well Number Assigned in This Report	Well Location	Well Name	Remarks*
318	12-19N-3W	Petro-Lewis Corp. 7-22 Miller-Federal	C-C'
319	36-19N-2W	EPNG 1 Elliott State	
320	27-18N-11W	Serio Exploration 1-SFP-RR	
321	20-18N-10W	Mesa Retail 1 Navajo	
322	21-18N-9W	Eastern Petroleum 1 Whitehorse-Santa Fe	
323	31-18N-8W	Tesoro Petroleum 31 Santa Fe Railroad	
324	14-18N-7W	Young Drilling 1 Federal	
325	12-18N-5W	Gulf Oil 1 Torreon	
326	11-18N-3W	Tesoro Petroleum 1 Federal San Luis	C-C'
327	24-18N-3W	Sun Oil 1 Sandoval Federal	C-C'
328	28-18N-1W	Late Oil 1 Gulf Federal	
329	28-17N-13W	Maddox Oil 1 Longshot	
330	1-17N-9W	Great Western Drilling 1 Hospah-Santa Fe	C
331	18-17N-9W	Davis Oil 1 Hospah W.	
332	31-17N-9W	Davis Oil 1 Hospah S.W.	
333	10-17N-8W	Serio Exploration 1 Sand Springs	
334	8-17N-7W	Davis Oil 1 El Tigre	
335	26-17N-3W	Shell Oil 41-26 Wright	C-C'
336	15-16N-12W	Arkla Exploration Satan N.M.A.	
337	34-16N-11W	Gulf Oil 1 Digneo-Federal	
338	17-16N-10W	Eastern Petroleum 1 El Nariz	
339	1-16N-8W	Petro Minerals 1 Fernandez	
340	11-16N-5W	Union Oil IM 11 Chico Federal	
341	3-15N-19W	Marshal 1 Beal Miller	C
342	19-15N-7W	Shar-Alan 4 Fernandez	
343	5-15N-6W	Shar-Alan 2 Fernandez	
344	20-14N-1W	Humble Oil 1 Santa Fe B	C
345	28-10N-1E	F.H. Carpenter 1 Atrisco	C
346	8-9N-1W	Shell Oil 1 Laguna-Wilson	C
347	29-19N-17W	Pure Oil 1 Coyote Canyon	C
348	13-30N-21W	Pan Am. Petroleum 1 Navajo Tribe	

Table 1. Source of subsurface data used for maps and cross sections (continued)

Well Number Assigned in This Report	Well Location	Well Name	Remarks*
349	13-29N-19W	U.S. Bureau Mines 1-G Rattlesnake	A-A'
350	6-29N-18W	Conoco 371	
351	25-29N-17W	M.M. Garrett Navajo 1	A-A'
352	19-29N-16W	Stanolind 14 USG	
353	18-29N-15W	Humble Oil 1 Navajo Tribal-2	A-A'
354	26-29N-15W	J.R. Pickett 1 Fruitland-Amarillo	A-A'
355	11-29N-14W	Sunray Mid Continent Oil 1 N.M. Federal	A-A'
356	12-29N-13W	Redfern & Herd Smith 1	A-A'
357	6-29N-7W	J.P. McHugh 100 SJU	
358	6-28N-2W	Conoco So. Dulce	A-A',C-C'
359	34-30N-3W	Sunray DX Oil Jicarilla Tribal 1	A-A',B-B',C-C'
360	7-17N-3W	Brinkerhoff Cabezon Government 14-7-1	C
361	10-13N-3W	Texaco Howard Major 1	C
362	11-15N-8W	Northern Minerals 7 Fernandez	C
363	33-15N-8W	R.A. Crane 1 Fernandez	C
364	17-15N-9W	Largo Management 1 Pena	C
365	26-20N-11W	Sinclair 1 Santa Fe-205-SARG	
366	33-16N-8W	Shar-Alan 3 Fernandez	
367	10-16N-8W	Northern Minerals 4 Federal	C
368	12-16N-8W	Northern Minerals 3 Federal	C
369	18-16N-9W	Fairfax Exploration 2 Bullseye	C
370	6-18N-8W	Tesoro Petroleum 31 Santa Fe Railroad	C
371	32-18N-16W	Superior Oil K-1 Navajo	
372	15-24N-9W	Gulf Oil 1-X So. Huerfano-Federal	B-B'

Maps

Preparation and Use

The mapping portion of this study progressed through several steps and involved the efforts of various workers. San Juan County was mapped in 1975 by Daniel R. Brown, then a graduate research assistant with the Bureau. This early mapping involved mainly data from scout cards on file in the Bureau's subsurface-data library. It was recognized that scout-card data reflect various methods of selecting tops of units and thus are to some extent incompatible. However, it was also recognized that at the scale of mapping involved, such differences would be inconsequential. Logs were, nonetheless, consulted when major discrepancies arose or card information was incomplete. In this and subsequent phases of the mapping, an effort was made to locate one deep well per township. The portion of McKinley County lying in the study area was mapped in 1976 by Robert C. Brod, also a graduate research assistant with the Bureau at the time. In this mapping, logs were used so as to determine contacts not normally reported on the available scout cards. The mapping of the remainder of the study area, including mainly parts of Sandoval and Rio Arriba Counties, as well as the compilation of basinwide maps from those of the 3 areas, was performed by Nancy H. Mizell.

It will be noted that although all wells used in the study are plotted on each map, the well numbers shown on Plate 1 are not repeated. The numbers which do appear are the values for

the parameter of interest on that map. It is hoped that wells can be sufficiently identified by reference to Plate 1 and/or Table 1.

In order to show specific aspects of the occurrence of the potential aquifers recognized in the Basin, 24 maps were prepared utilizing subsurface data. Plates 2 through 25 include a series of 3 maps each for all but the uppermost of the potential aquifers. For each of these aquifers the following are presented:

1) a map showing the elevation of the top (structure) of the aquifer
2) a map showing the depth to the top of the aquifer (similar to structure but adjusted for topography)
3) a map showing the thickness of the aquifer (would be an isopach map but not contoured; see explanation below).

The only parameter which can be mapped for the uppermost aquifer (San Jose Formation) is thickness, as the unit lies at the surface wherever it occurs. Inasmuch as the map showing depth to top of the Nacimiento Formation also shows thickness of the overlying San Jose Formation, no separate map was prepared.

In view of local topographic irregularities, the depth to the top of the aquifers was mapped by means of zones rather than contours. The contours shown for the midpoints of the depth zones are only approximate and should be used only for general reference.

Contouring was also impractical in the case of aquifer thickness owing to the scale of the maps. The plotting of thickness values next to wells on the maps does, however, provide some guidance in estimating thickness in intervening areas.

As mentioned above, scout cards were the source of many of the data used in mapping San Juan County. Although tops of selected units are commonly reported on cards, thicknesses are not, and, unless the top of the underlying unit is given, thickness cannot be obtained from card data. Logs are not available in the Bureau for many of the wells for which there are cards. It was decided that, in the interest of time, logs would not be ordered for San Juan County and maps for that area would be based largely on the existing card data. Consequently, it may be noted that tops are reported for several units at some wells even though no thicknesses are given for those units at those wells.

The maps presented may be used not only to identify the aquifer tapped by wells for which depth alone is known, but also to generally predict the position and/or thickness of the various aquifers in a given area of interest.

Names of geologic structures referred to in the following discussions are drawn mainly from the map by Hunt and Dane (1954). Data did not always permit showing relationships between the San Juan Basin and the various side basins; contours at the mouths of the Gallup and Acoma Basins (fig. 1), for example, are deliberately not closed to indicate this.

Morrison Formation (Plates 2-4)

The Morrison (Jurassic) is the deepest unit covered by the maps presented here.

The elevation of the top of the Morrison drops rather uniformly toward the center of the Basin (plate 2). The position of the Four Corners Platform and Hogback Monocline (fig. 1) is quite apparent in the northwestern corner of Plate 2. The only other structure of note is the series of folds southwest of Star Lake. The anticlinal nose in T. 16 N., R. 9 W. coincides with Walker Dome and that in T. 18 N., R. 8 W. is the Hospah Anticline. Two other structures in this area, Ambrosia Anticline (T. 14 N., R. 10 W.) and San Mateo Dome (T. 14 N., R. 8 W.), do not show up owing to the large map scale, broad contour interval, and low data density. Major faults along the southern edge of the Basin do not appear for similar reasons.

On the Four Corners Platform (fig. 1) the depth to the top of the Morrison generally averages about 1,500 ft (plate 3). On the Chaco Slope (fig. 1) the top of the formation lies at an average depth of 2,000 ft. Near Gobernador, in the deepest part of the Basin, the depth to the top of this unit exceeds 8,500 ft. The deepest value plotted occurs in T. 29 N., R. 4 W. where the top of the Morrison is 8,822 ft below land surface.

Although the numerous Dakota Sandstone tests in the Basin permit mapping the top of the Morrison, few wells fully penetrate this unit and thickness data are sparse. On Plate 4 thicknesses are plotted only in the Shiprock and Star Lake-Cuba areas. Thicknesses in this area range from 300-790 ft.

Dakota Sandstone (Plates 5-7)

The Dakota Sandstone is the deepest of the Cretaceous aquifers in the Basin. Widespread interest in the petroleum potential of this unit has produced a considerable data base.

The map of the elevation of the top of the Dakota (Plate 5) shows many of the structures recognized on the Morrison map (Plate 2). Notable exceptions are the Stoney Buttes Anticline (R. 22 N., T. 14 W.), Tocito Dome (R. 22 N., R. 18 N.), Table Mesa Dome, (R. 28 N., T. 17 N.), Rattlesnake Dome (R. 29 N., T. 19 W.), and Hogback Dome (R. 29 N., T. 17 W.).

Depth to the top of the Dakota averages about 1,000 ft on the Four Corners Platform, about 3,000 ft on the Chaco Slope, and exceeds 8,500 ft in the center of the Basin near Governador (fig. 1, Plate 6). A depth of 8,662 ft is plotted in T. 29 N., R. 4 W.

The thickness of the Dakota Sandstone rarely exceeds 350 ft in the study area and nowhere exceeds 400 ft (plate 7). Most values lie between 200 and 300 ft. In the north, reported thicknesses may include the Burro Canyon Formation. No attempt was made to distinguish this unit from the Dakota.

Gallup Sandstone (Plates 8-10)

The main body of the Gallup, the thick regressive sandstone, occupies only the southwestern part of the Basin. It extends northeasterly to a line roughly connecting Shiprock, Chaco Canyon, and Star Lake (Plate 8) where it is cut out by the pre-Niobrara erosion surface as demonstrated by Molenaar (1973). The line shown on Plate 8 should not be taken as the southwestern extent of the unconformity as it extends a considerable distance "landward" beyond this line. Tops reported for the Gallup northeast of the boundary are either associated with offshore sand bodies in the basal Niobrara Shale Member of the Mancos Shale (as at the Bisti oil field) or with silty or limey zones in this interval (see resistive zone on Plates 26-28). The position of the upper contact for the Niobrara is uncertain.

The top of the Gallup Sandstone slopes gently northward except east of Sanostee where the steeper dips and southeasterly slope reflect the position of the Hogback Monocline. Depth to the top of the main (regressive) Gallup reaches a maximum of 4,298 ft south of Farmington (T. 24 N., R. 13 W.). Thickness of the main Gallup ranges from 93 ft northeast of Grants (T. 15 N., R. 8 W.) to 700 ft northeast of Gallup (T. 17 N., R. 16 W.).

Point Lookout Sandstone (Plates 11-13)

Although the Point Lookout Sandstone is not present on the Four Corners Platform, it is present and involved in the Hogback Monocline in western San Juan County. This is shown by the outcrop pattern and closely spaced contours between Shiprock and Farmington on Plate 11. Barker Dome (T. 31 N., R. 14 W.) is delineated for the first time on the structure map of this unit (plate 11). Other structural features are similar to those seen on maps of underlying units.

The depth to the top of the Point Lookout averages less than 3,000 ft on the Chaco Slope but exceeds 6,000 ft in the Central Basin (fig. 1, Plate 12). A maximum depth of 6,400 ft was encountered southeast of Gobernador (T. 29 N., R. 4 W.).

Thickness of the Point Lookout (Plate 13) ranges from 40 ft, southwest of Star Lake (T. 17 N., R. 7 W.), to 415 ft, about 15 mi south of these (T. 15 N., R. 7 W.).

Cliff House Sandstone (Plates 14-16)

The Cliff House occupies only the northeastern quarter of the Basin. Although it is the upper unit involved in the Hogback Monocline (San Juan County), contours on Plate 14 show it to be less deformed by the structure than is the Point Lookout Sandstone (Plate 11). In the southeast and east, several tongues of Cliff House occur (Plates 26-28). No attempt was made to apply names to these tongues. Tops mapped are those of the uppermost tongue present.

Depth to the top of the Cliff House Sandstone reaches a maximum near Gobernador as it does for other units. A maximum of 6,150 ft is plotted in T. 29 N., R. 4 W. (Plate 15). Thickness varies with the number of tongues present (Plate 16). Values range from 20 ft, northwest of Star Lake (T. 20 N., R. 7 W.), to 245 ft northwest of Farmington (T. 29 N., R. 14 W.).

Pictured Cliffs Sandstone (Plates 17-19)

The outcrop of the Pictured Cliffs Sandstone seems to be incomplete on the eastern edge of the Basin (Plate 17). Uncertainty as to outcrop position is due largely to the poorly consolidated nature of this sandstone in the east and the resulting slope-forming weathering habit of this unit there. Subsurface data suggest it extends at least as far east as R. 2 W. (plate 17).

A structure map for the Pictured Cliffs merely reflects trends seen for deeper units (Plate 17). The maximum depth to the top of this unit is 4,130 ft, plotted in T. 29 N., R. 4 W. (Plate 18). Thickness of the Pictured Cliffs Sandstone ranges from 25 ft (T. 28 N., R. 2 W.) to 245 ft (T. 29 N., R. 4 W.); both minimum and maximum values occur in the eastern part of the Basin (Plate 19).

Ojo Alamo Sandstone (Plates 20-22)

This is the deepest of the Tertiary aquifers present in the Basin. In the northeastern corner of the basin, the

Ojo Alamo has been mapped as pinching out north of Cuba (Plates 20-25). In the subsurface, however, the Ojo Alamo is seen to persist as a distinct unit across the northern part of the Basin (Plates 20-22, 26-28).

The structure of the Ojo Alamo is similar to that of underlying units and there is no evidence of tectonic activity in the Basin prior to the onset of Tertiary deposition (Plate 20). Depth to the top of the unit reaches a maximum of 3,645 ft near Gobernador in T. 29 N., R. 4 W. (Plate 21). The thickness of the sandstone (Plate 22) ranges from 72 ft (T. 21 N., R. 6 W.) to 313 ft (R. 29 N., R. 6 W.).

Nacimiento and Animas Formations (Plates 23-25)

The interval mapped on the state geologic map as Nacimiento Formation over most of the Basin is mapped as Animas Formation in the northeastern part of the Basin. The position of the nomenclature change was arbitrarily placed at Lleguas Creek, north of Cuba (T. 25 N., R. 1 E.). The Animas Formation is not mapped separately elsewhere on the state map, but the legend notes that the Animas is included with the Nacimiento in the area north of Farmington. The separation of the Animas from the Nacimiento and Ojo Alamo as shown in this area on plates 23-25 is modified from O'Sullivan and Beikman (1963). Figure 2 shows the stratigraphic relationships between the two units there based on detailed surface and subsurface studies between Farmington and Durango, Colorado.

The type locality for the Animas is Durango, Colorado. Baltz (1967) did not carry the term "Animas" into the northeastern San Juan Basin. Work planned for this area may clarify the relationship of the Animas Formation to both the Ojo Alamo and the Nacimiento. Although the state geologic map is followed in this matter, the reader should be aware that this part of the section is problematical.

The structure map for the Nacimiento and Animas Formations (Plate 23) resembles maps of deeper units. As was the case for the Ojo Alamo, there is no evidence of tectonism in the protion of the Tertiary represented by these units. Although no maps are presented for the San Jose Formation, because it lies at the surface, it should be mentioned that an angular unconformity may be observed between the Nacimiento and overlying San Jose in their outcrop area adjacent to the Nacimiento Uplift just north of Cuba. This documents activity of the Uplift at some time after deposition of the Nacimiento but prior to the deposition of the San Jose or probably latest Paleocene time. The angularity is slight and the uplift probably was minor. As might be expected, such slight uplift did not effect deposition in the bulk of the Basin area and the Nacimiento-San Jose contact is gradational at most places away from the eastern Basin edge.

The maximum depth to the top of the Nacimiento/Animas interval (Plate 24) is 2,660 ft, based on a well located between Cuba and Gobernador (T. 26 N., R. 3 W.). This interval is quite thick (Plate 25); values ranging from 418 ft (T. 22 N., R. 4 W.) to 2,232 ft (T. 29 N., R. 4 W.) were encountered in this study.

CROSS SECTIONS

Construction and Use

Many of the papers cited under "Previous Stratigraphic Work" above contain stratigraphic cross sections. Although some of these sections are basinwide and some present the logs upon which the correlations were based, none cover the entire stratigraphic interval of interest here: Jurassic and younger. The published sections were nonetheless of considerable value in providing familiarity with the kinds of stratigraphic relationships which might be anticipated. For example, the sections by Molenaar (1973, 1974, and 1977) were of great help in working with the pre-Niobrara unconformity and Gallup Sandstone. In spite of the occasional use of previously published logs, our cross sections were constructed principally from scratch.

In order to characterize the stratigraphy and structure of the San Juan Basin, three cross sections were constructed: one oriented west to east roughly along T 29 N (A-A', Plate 26), another oriented southwest to northeast passing through Chaco Canyon National Monument (B-B', Plate 27), and a third oriented south to north roughly along R 3 W (C-C', Plate 28). These three sections meet near Dulce in the northeastern part of the Basin and share common wells in that area; the resulting array of sections resembles three spokes of a wheel radiating from a central hub (see location maps on Plates 26-28).

Wells were selected for use in the cross sections according to the following criteria:

1) Location -- wells should lie near line of section

2) Depth -- wells should at least reach top of Morrison Formation

3) Log type -- wells for which electric logs available preferred

4) Log quality -- wells for which log traces clear and representative preferred

5) Log availability -- wells for which logs on file in Bureau subsurface-data library preferred.

The log curves were traced onto the cross sections from transparent prints of the reduced logs for two reasons: first, to eliminate the background grid of the logs, which not only reproduces poorly but also often obscures the log when reproduced, and second, to present the actual bases for our interpretations of the various contacts and correlations as presented.

Three additional notes are in order concerning the construction and use of the cross sections. Where strata crop out between 2 adjacent wells, an attempt was made to project contacts to their approximate positions at the surface. The apparent thinning and convergence of units that results is merely an artifact of the vastly different vertical and horizontal scales employed in the cross sections. Second, approximate time lines are provided on each cross section by 3 major unconformities and a bentonite marker bed. Unconformities include the one usually present beneath the Dakota Sandstone,

the pre-Niobrara surface, and the one at the base of the Ojo Alamo Sandstone. The marker bed is the Huerfanito Bentonite Bed of Fassett and Hinds (1971). Finally, short comments, explaining or identifying major stratigraphic features or characteristics, appear at appropriate places on the cross sections for emphasis.

Cross Section A-A' (Plate 26)

This west-to-east cross section was constructed to show 1) the nature of one of the prominent monoclines in the Basin, 2) the subsurface setting along the San Juan River -- the focus of major population and ground-water discharge in the Basin, and 3) the stratigraphy of Jurassic and younger deposits in the northern part of the Basin.

Three structural elements of the northern San Juan Basin (fig. 1) are recognizable on section A-A': the Four Corners Platform is shown by wells 349 and 351 (west half), the Hogback Monocline occurs between wells 351 and 353 (west half), and the remainder of the section covers the Central Basin (eastern part of west half, all of east half).

Major stratigraphic features include 1) the lateral facies change and eventual disappearance of the Gallup Sandstone (wells 351-355, west half), 2) the easterly convergence of the Point Lookout and Cliff House Sandstones (wells 130-358, east half), 3) the large-scale intertonguing of the Cliff House Sandstone and Lewis Shale (wells 354-130, both halves), and 4) the small-scale intertonguing of the Pictured Cliffs Sandstone and Fruitland Formation (wells 134-359, east half).

Cross Section B-B' (Plate 27)

This southwest-northeast-trending cross section was prepared to show 1) the structure in the Central Basin (Fig. 1), 2) the subsurface setting along a line crossing the Chaco River and the Fruitland coal belt near Chaco Canyon National Monument, and 3) the stratigraphy of the Cretaceous deposits along a line essentially perpendicular to the shoreline of the sea which was responsible for their accumulation.

The structure is quite uniform owing to the fact that the section lies almost entirely within the Central Basin structural element (Fig. 1).

Major stratigraphic features include 1) the lateral facies change and eventual disappearance of the Gallup Sandstone, including the development of the classical offshore-bar sand bodies which produce oil at the Bisti field (wells 311-254, southwest half), 2) the northeasterly convergence of the Point Lookout and Cliff House Sandstones (wells 131-358, northeast half), 3) the large-scale intertonguing of the Cliff House Sandstone and Lewis Shale (wells 280-191, both halves), 4) the small-scale intertonguing of the Pictured Cliffs Sandstone and Fruitland Formation (wells 136-69, northeast half), 5) the small-scale intertonguing of the Ojo Alamo Sandstone and Nacimiento Formation (wells 133-136, northeast half), 6) a fairly complete section of San Jose Formation (wells 131, 159, 136, and 359, northeast half).

Cross Section C-C' (Plate 28)

This south-to-north cross section was made to show 1) the structure of the Central Basin along a line paralleling the Nacimiento Uplift and Hogback Monocline (fig. 1), 2) the subsurface setting along this recharge area at the eastern edge of the Basin, and 3) the stratigraphy of the Jurassic and Cretaceous deposits in a section essentially along strike at the Basin's east edge.

Like section B-B', this section shows fairly uniform structure because it lies almost entirely within the Central Basin (fig. 1).

Major stratigraphic features include 1) the most complete coverage of the Jurassic sequence of any of the cross sections, 2) a zone of general nomenclature change -- Bluff Sandstone in the south and Junction Creek Sandstone in the north (between wells 239 and 358, north half), 3) development of local resistive (sandy?) intervals above the pre-Niobrara unconformity (wells 218, 159, 134, north half), 4) the northerly convergence of the Point Lookout and Cliff House Sandstones (wells 218-33, north half), 5) the large-scale intertonguing of the Cliff House Sandstone and Lewis Shale (wells 285-273, south half and wells 260-239, north half), 6) the occurrence of a Farmington-Sandstone-like interval in the Kirtland Shale (wells 239-33, north half), 7) the arbitrary but specific point of another nomenclature change -- Nacimiento Formation in the south, Animas Formation in the north (between wells 239 and 218, north half), and 8) a complete sequence for the San Jose Formation (wells 218-159, north half).

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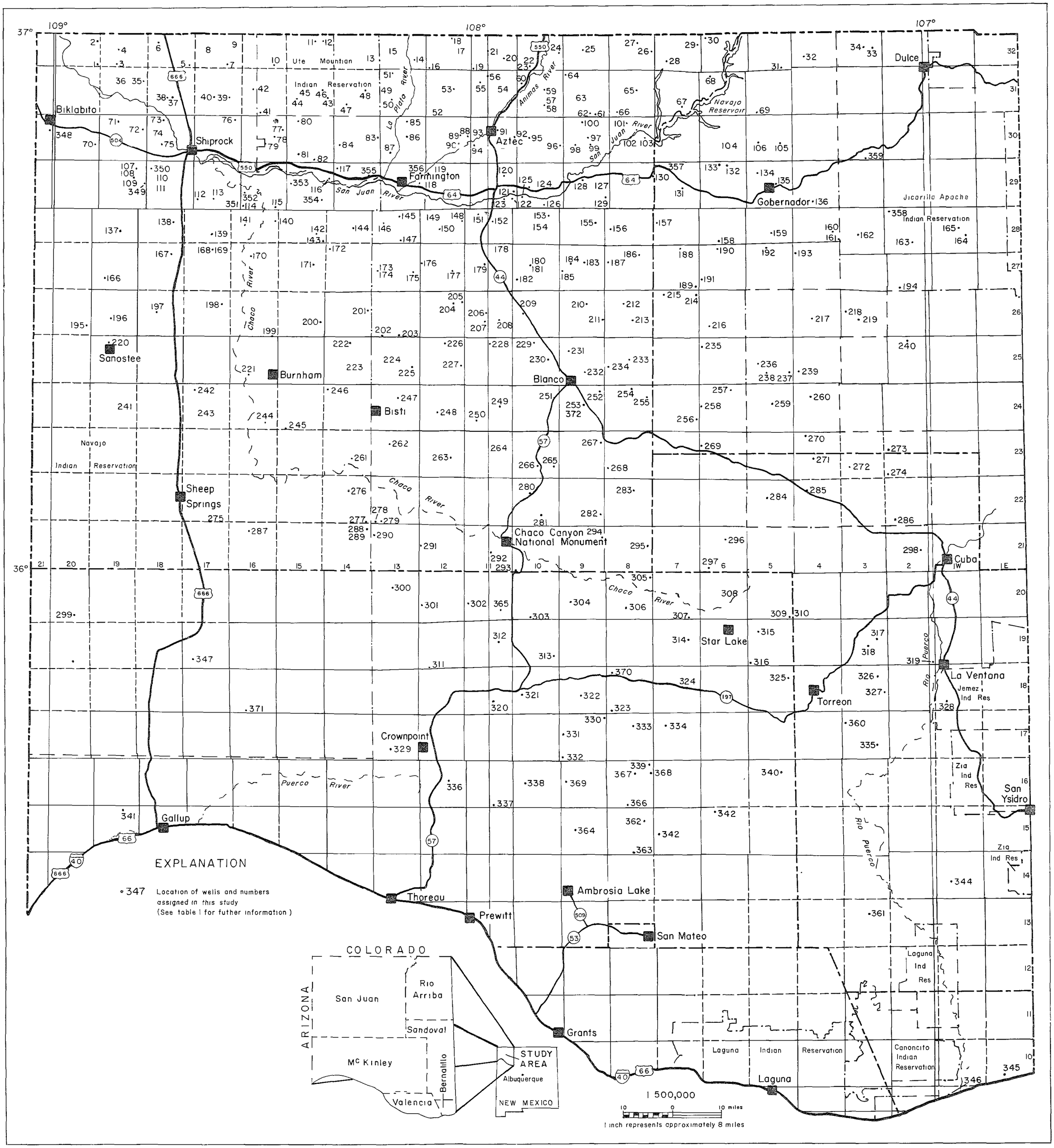


LOCATION MAP SHOWING WELLS USED IN SUBSURFACE STUDY, SAN JUAN BASIN, NEW MEXICO

OPEN FILE REPORT 89

PLATE 2

Shiprock
Aztec
Farmington
Dulce
Gobernador
Sanostee
Sheep Springs
Chaco Canyon National Monument
Cuba
Star Lake
La Ventana
Crownpoint
Gallup
Thoreau
Grants

EXPLANATION

857 Location of wells and data used in construction of this map

Location of wells and data used in other aspects of this study

Outcrop (Dane and Bachman, 1965).

1000 Contours drawn on top of unit, contour interval 500 feet

COLORADO

ARIZONA

San Juan
Rio Arriba
Sandoval
Mc Kinley
Bernalillo
Valencia

STUDY AREA

Albuquerque

NEW MEXICO

1:500,000

10 0 10 miles

1 inch represents approximately 8 miles

ELEVATION OF TOP (STRUCTURE) OF MORRISON FORMATION, SAN JUAN BASIN, NEW MEXICO

OPEN FILE REPORT 89

PLATE 3

Shiprock
Aztec
Farmington
Gobernador
Dulce
Sanostee
Sheep Springs
Chaco Canyon National Monument
Cuba
Star Lake
La Ventana
Crownpoint
Gallup
Thoreau
Grants

8500
7500
6500
5500
4500
3500
2500
1500

EXPLANATION

857 Location of wells and data used in construction of this map

Location of wells and data used in other aspects of this study

Outcrop (Dane and Bachman, 1965).

Contour showing approximate midpoint of depth zone

DEPTH RANGE

0 – 1000 feet
1000 – 2000 feet
2000 – 3000 feet
3000 – 4000 feet
4000 – 5000 feet
5000 – 6000 feet
6000 – 7000 feet
7000 – 8000 feet
8000 – 9000 feet

COLORADO
ARIZONA
San Juan
Rio Arriba
Sandoval
Mc Kinley
Bernalillo
Valencia
STUDY AREA
Albuquerque
NEW MEXICO

1:500,000
10 0 10 miles
1 inch represents approximately 8 miles

DEPTH TO TOP OF MORRISON FORMATION, SAN JUAN BASIN, NEW MEXICO

Shiprock
Aztec
Farmington
Gobernador
Dulce
Sanostee
Sheep Springs
Chaco Canyon National Monument
Cuba
Star Lake
La Ventana
Crownpoint
Gallup
Thoreau
Grants

32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1W 1E

8[illegible]
903
859
540
652
620
610
591
460
580
590
638
330
710
630
545
670
670
750
790
915
600
600

EXPLANATION

857 Location of wells and data used in construction of this map

Location of wells and data used in other aspects of this study

Outcrop (Dane and Bachman, 1965)

40 66

COLORADO

ARIZONA

San Juan
Rio Arriba
Sandoval
Mc Kinley
Bernalillo
Valencia
STUDY AREA
Albuquerque
NEW MEXICO

1:500,000

10 0 10 miles

1 inch represents approximately 8 miles

THICKNESS OF MORRISON FORMATION, SAN JUAN BASIN, NEW MEXICO

OPEN FILE REPORT 89

PLATE 5

Shiprock
Aztec
Dulce
Farmington
Gobernador
Sanostee
Sheep Springs
Chaco Canyon National Monument
Cuba
Star Lake
La Ventana
Crownpoint
Gallup
Thoreau
Grants

1000
0
1000
2000
3000
4000
5000

EXPLANATION

857 Location of wells and data used in construction of this map

Location of wells and data used in other aspects of this study

Outcrop (Dane and Bachman, 1965).

-1000 Contours drawn on top of unit, contour interval 500 feet.

COLORADO

ARIZONA

San Juan
Rio Arriba
Sandoval
Mc Kinley
Bernalillo
Valencia

STUDY AREA
Albuquerque
NEW MEXICO

1:500,000

10 0 10 miles

1 inch represents approximately 8 miles

ELEVATION OF TOP (STRUCTURE) OF DAKOTA SANDSTONE, SAN JUAN BASIN, NEW MEXICO

OPEN FILE REPORT 89

PLATE 6

Shiprock
Aztec
Farmington
Dulce
Gobernador
Sanostee
Sheep Springs
Chaco Canyon National Monument
Cuba
Star Lake
La Ventana
Crownpoint
Gallup
Thoreau
Grants

7500
6500
5500
4500
3500
2500
1500

EXPLANATION

- Location of wells and data used in construction of this map
- Location of wells and data used in other aspects of this study
- Outcrop (Dane and Bachman, 1965)
- Contour showing approximate midpoint of depth zone

DEPTH RANGE

- 0 – 1000 feet
- 1000 – 2000 feet
- 2000 – 3000 feet
- 3000 – 4000 feet
- 4000 – 5000 feet
- 5000 – 6000 feet
- 6000 – 7000 feet
- 7000 – 8000 feet
- 8000 – 9000 feet

COLORADO

ARIZONA

San Juan
Rio Arriba
Sandoval
Mc Kinley
Bernalillo
Valencia

STUDY AREA
Albuquerque
NEW MEXICO

1:500,000
10 0 10 miles
1 inch represents approximately 8 miles

DEPTH TO TOP OF DAKOTA SANDSTONE, SAN JUAN BASIN, NEW MEXICO

OPEN FILE REPORT 89

PLATE 7

Dulce
Shiprock
Aztec
Farmington
Gobernador
Sanostee
Sheep Springs
Chaco Canyon National Monument
Cuba
Star Lake
La Ventana
Crownpoint
Gallup
Thoreau
Grants

EXPLANATION

857 Location of wells and data used in construction of this map

Location of wells and data used in other aspects of this study

Outcrop (Dane and Bachman, 1965)

COLORADO

ARIZONA

San Juan
Rio Arriba
Sandoval
Mc Kinley
Bernalillo
Valencia
STUDY AREA
Albuquerque
NEW MEXICO

1:500,000

10 0 10 miles

1 inch represents approximately 8 miles

THICKNESS OF DAKOTA SANDSTONE, SAN JUAN BASIN, NEW MEXICO

OPEN FILE REPORT 89

PLATE 8

Shiprock
Aztec
Farmington
Gobernador
Dulce
Sanostee
Sheep Springs
Chaco Canyon National Monument
Star Lake
Cuba
La Ventana
Gallup
Thoreau
Crownpoint
Grants

NE extent of main body (regressive) Gallup Ss

resistive values shown NE of boundary are for top interval of Gallup/basal Niobrara zone

(Molenaar, 1963)

2000
3000
4000
5000
6000

EXPLANATION

857 Location of wells and data used in construction of this map

Location of wells and data used in other aspects of this study

Outcrop (Dane and Bachman, 1965).

1000 Contours drawn on top of unit, contour interval 500 feet.

COLORADO
ARIZONA
San Juan
Rio Arriba
Sandoval
Mc Kinley
Bernalillo
Valencia
STUDY AREA
Albuquerque
NEW MEXICO

1:500,000
10 0 10 miles
1 inch represents approximately 8 miles

ELEVATION OF TOP (STRUCTURE) OF GALLUP SANDSTONE, SAN JUAN BASIN, NEW MEXICO

OPEN FILE REPORT 89

PLATE 9

Shiprock
Farmington
Aztec
Dulce
Gobernador
Sanostee
Sheep Springs
Chaco Canyon National Monument
Cuba
Star Lake
La Ventana
Crownpoint
Gallup
Thoreau
Grants

NE extent of main body (regressive) of Gallup/basal Niobrara boundary are for top interval

Resistive Values shown NE of Gallup Ss zone (Molenaar, 1983)

3500
2500
1500
500

EXPLANATION

857 Location of wells and data used in construction of this map

Location of wells and data used in other aspects of this study

Outcrop (Dane and Bachman, 1965).

Contour showing approximate midpoint of depth zone

DEPTH RANGE

0	1000 feet
1000	2000 feet
2000	3000 feet
3000	4000 feet
4000	5000 feet

COLORADO
ARIZONA
NEW MEXICO
San Juan
Rio Arriba
Sandoval
Mc Kinley
Bernalillo
Valencia
STUDY AREA
Albuquerque

1:500,000
10 0 10 miles
1 inch represents approximately 8 miles

DEPTH TO TOP OF GALLUP SANDSTONE, SAN JUAN BASIN, NEW MEXICO

OPEN FILE REPORT 89

PLATE 10

Shiprock
Aztec
Farmington
Dulce
Gobernador
Sanostee
Sheep Springs
Chaco Canyon National Monument
Cuba
Star Lake
La Ventana
Crownpoint
Gallup
Thoreau
Grants

Of resistive values shown NE of boundary are for top interval zone, Gallup/basal Niobrara

NE extent of main body (regressive) Gallup Ss (Molenaar, 1963)

EXPLANATION

857 Location of wells and data used in construction of this map

Location of wells and data used in other aspects of this study

Outcrop (Dane and Bachman, 1965).

COLORADO

ARIZONA

San Juan
Rio Arriba
Sandoval
Mc Kinley
Bernalillo
Valencia
STUDY AREA
Albuquerque
NEW MEXICO

1:500,000

10 0 10 miles

1 inch represents approximately 8 miles

THICKNESS OF GALLUP SANDSTONE, SAN JUAN BASIN, NEW MEXICO

Shiprock
Aztec
Dulce
Farmington
Gobernador
Sanostee
Sheep Springs
Chaco Canyon National Monument
Cuba
Star Lake
La Ventana
Crownpoint
Gallup
Thoreau
Grants

1000
2000
3000
4000
5000
6000

21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1W 1E 21

32 31 30 29 28 27 26 25 24 23 22 20 19 18 17 16 15 14 13 12 11 10

EXPLANATION

857 Location of wells and data used in construction of this map

Location of wells and data used in other aspects of this study

Outcrop (Dane and Bachman, 1965) *

1000 Contours drawn on top of unit, contour interval 500 feet

* Unstippled area is Mesaverde Group undifferentiated (includes Point Lookout Sandstone)

COLORADO

ARIZONA

San Juan
Rio Arriba
Sandoval
Mc Kinley
Bernalillo
Valencia

STUDY AREA
Albuquerque
NEW MEXICO

1.500,000

10 0 10 miles

1 inch represents approximately 8 miles

ELEVATION OF TOP (STRUCTURE) OF POINT LOOKOUT SANDSTONE, SAN JUAN BASIN, NEW MEXICO

OPEN FILE REPORT 89

PLATE 12

Shiprock
Aztec
Farmington
Dulce
Gobernador
Sanostee
Sheep Springs
Chaco Canyon National Monument
Cuba
Star Lake
La Ventana
Crownpoint
Gallup
Thoreau
Grants

5500
4500
3500
2500
1500
500

EXPLANATION

857 Location of wells and data used in construction of this map

Location of wells and data used in other aspects of this study

Outcrop (Dane and Bachman, 1965).*

Contour showing approximate midpoint of depth zone

DEPTH RANGE

0 — 1000 feet
1000 — 2000 feet
2000 — 3000 feet
3000 — 4000 feet
4000 — 5000 feet
5000 — 6000 feet
6000 — 7000 feet

* Unstippled area is Mesaverde Group undifferentiated (includes Point Lookout Sandstone)

COLORADO
ARIZONA
San Juan
Rio Arriba
Sandoval
Mc Kinley
Bernalillo
Valencia
STUDY AREA
Albuquerque
NEW MEXICO

1:500,000

10 0 10 miles

1 inch represents approximately 8 miles

DEPTH TO TOP OF POINT LOOKOUT SANDSTONE, SAN JUAN BASIN, NEW MEXICO

OPEN FILE REPORT 89

PLATE 13

Shiprock
Aztec
Farmington
Dulce
Gobernador
Sanostee
Sheep Springs
Chaco Canyon National Monument
Cuba
Star Lake
La Ventana
Crownpoint
Gallup
Thoreau
Grants

21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1W 1E 21

32 31 30 29 28 27 26 25 24 23 22 20 19 18 17 16 15 14 13 12 11 10

EXPLANATION

857 Location of wells and data used in construction of this map

Location of wells and data used in other aspects of this study

Outcrop (Dane and Bachman, 1965).*

* Unstippled area is Mesaverde Group undifferentiated (includes Point Lookout Sandstone)

COLORADO

ARIZONA

San Juan
Rio Arriba
Sandoval
Mc Kinley
Bernalillo
Valencia

STUDY AREA
Albuquerque
NEW MEXICO

1:500,000

10 0 10 miles

1 inch represents approximately 8 miles

THICKNESS OF POINT LOOKOUT SANDSTONE, SAN JUAN BASIN, NEW MEXICO

OPEN FILE REPORT 89

PLATE 14

* Outcrop shown as Mesaverde Group undifferentiated (includes Cliff House Sandstone)

Shiprock
Farmington
Aztec
Dulce
Gobernador
Sanostee
Sheep Springs
Chaco Canyon National Monument
Cuba
Star Lake
La Ventana
Crownpoint
Gallup
Thoreau
Grants

1000
2000
4000
5000
6000

EXPLANATION

857 Location of wells and data used in construction of this map

Location of wells and data used in other aspects of this study

Outcrop (Dane and Bachman, 1965).

1000 Contours drawn on top of unit; contour interval 500 feet.

ARIZONA
COLORADO
San Juan
Rio Arriba
Sandoval
Mc Kinley
Bernalillo
Valencia
STUDY AREA
Albuquerque
NEW MEXICO

1:500,000

10 0 10 miles

1 inch represents approximately 8 miles

ELEVATION OF TOP (STRUCTURE) OF CLIFF HOUSE SANDSTONE, SAN JUAN BASIN, NEW MEXICO

Cliff House

* Unstippled area is Mesaverde Group undifferentiated (includes Cliff House Sandstone)

Shiprock
Aztec
Farmington
Dulce
Gobernador
Sanostee
Sheep Springs
Chaco Canyon National Monument
Cuba
Star Lake
La Ventana
Crownpoint
Gallup
Thoreau
Grants

5500
3500
2500
1500
500

EXPLANATION

857 Location of wells and data used in construction of this map

Location of wells and data used in other aspects of this study

Outcrop (Dane and Bachman, 1965).

Contour showing approximate midpoint of depth zone

DEPTH RANGE

0 – 1000 feet
1000 – 2000 feet
2000 – 3000 feet
3000 – 4000 feet
4000 – 5000 feet
5000 – 6000 feet
6000 – 7000 feet

COLORADO
ARIZONA
San Juan
Rio Arriba
Sandoval
Mc Kinley
Bernalillo
Valencia
STUDY AREA
Albuquerque
NEW MEXICO

1:500,000

10 0 10 miles

1 inch represents approximately 8 miles

DEPTH TO TOP OF CLIFF HOUSE SANDSTONE, SAN JUAN BASIN, NEW MEXICO

OPEN FILE REPORT 89

PLATE 16

* Unstippled area is Mesaverde Group undifferentiated (includes Cliff House Sandstone)

Shiprock
Aztec
Farmington
Gobernador
Dulce
Sanostee
Sheep Springs
Chaco Canyon National Monument
Cuba
Star Lake
La Ventana
Crownpoint
Gallup
Thoreau
Grants

EXPLANATION

857 Location of wells and data used in construction of this map

Location of wells and data used in other aspects of this study

Outcrop (Dane and Bachman, 1965).

COLORADO

ARIZONA

San Juan
Rio Arriba
Sandoval
Mc Kinley
Bernalillo
Valencia

STUDY AREA

Albuquerque

NEW MEXICO

1:500,000

10 0 10 miles

1 inch represents approximately 8 miles

THICKNESS OF CLIFF HOUSE SANDSTONE, SAN JUAN BASIN, NEW MEXICO

OPEN FILE REPORT 89

PLATE 17

Shiprock
Farmington
Aztec
Dulce
Gobernador
Sanostee
Sheep Springs
Chaco Canyon National Monument
Cuba
Star Lake
La Ventana
Crownpoint
Gallup
Thoreau
Grants

4000
5000
6000

EXPLANATION

857 Location of wells and data used in construction of this map

Location of wells and data used in other aspects of this study

Outcrop (Dane and Bachman, 1965)

1000 Contours drawn on top of unit, contour interval 500 feet

COLORADO

ARIZONA

San Juan
Rio Arriba
Sandoval
Mc Kinley
Bernalillo
Valencia

STUDY AREA
Albuquerque
NEW MEXICO

1:500,000

10 0 10 miles

1 inch represents approximately 8 miles

ELEVATION OF TOP (STRUCTURE) OF PICTURED CLIFFS SANDSTONE, SAN JUAN BASIN, NEW MEXICO

OPEN FILE REPORT 89

PLAT 18

Shiprock
Aztec
Farmington
Dulce
Gobernador
Sanostee
Sheep Springs
Chaco Canyon National Monument
Cuba
Star Lake
La Ventana
Crownpoint
Gallup
Thoreau
Grants

2500
3500
1500
500

EXPLANATION

857 Location of wells and data used in construction of this map

Location of wells and data used in other aspects of this study

Outcrop (Dane and Bachman, 1965).

Contour showing approximate midpoint of depth zone

DEPTH RANGE
0 — 1000 feet
1000 — 2000 feet
2000 — 3000 feet
3000 — 4000 feet
4000 — 5000 feet

COLORADO
ARIZONA
San Juan
Rio Arriba
Sandoval
Mc Kinley
Bernalillo
Valencia
STUDY AREA
Albuquerque
NEW MEXICO

1:500,000
10 0 10 miles
1 inch represents approximately 8 miles

DEPTH TO TOP OF PICTURED CLIFFS SANDSTONE, SAN JUAN BASIN, NEW MEXICO

OPEN FILE REPORT 89

PLATE 19

Shiprock
Aztec
Dulce
Farmington
Gobernador
Sanostee
Sheep Springs
Chaco Canyon National Monument
Cuba
Star Lake
La Ventana
Crownpoint
Gallup
Thoreau
Grants

EXPLANATION

857 Location of wells and data used in construction of this map

Location of wells and data used in other aspects of this study

Outcrop (Dane and Bachman, 1965)

COLORADO

ARIZONA

San Juan
Rio Arriba
Sandoval
Mc Kinley
Bernalillo
Valencia
STUDY AREA
Albuquerque
NEW MEXICO

1:500,000

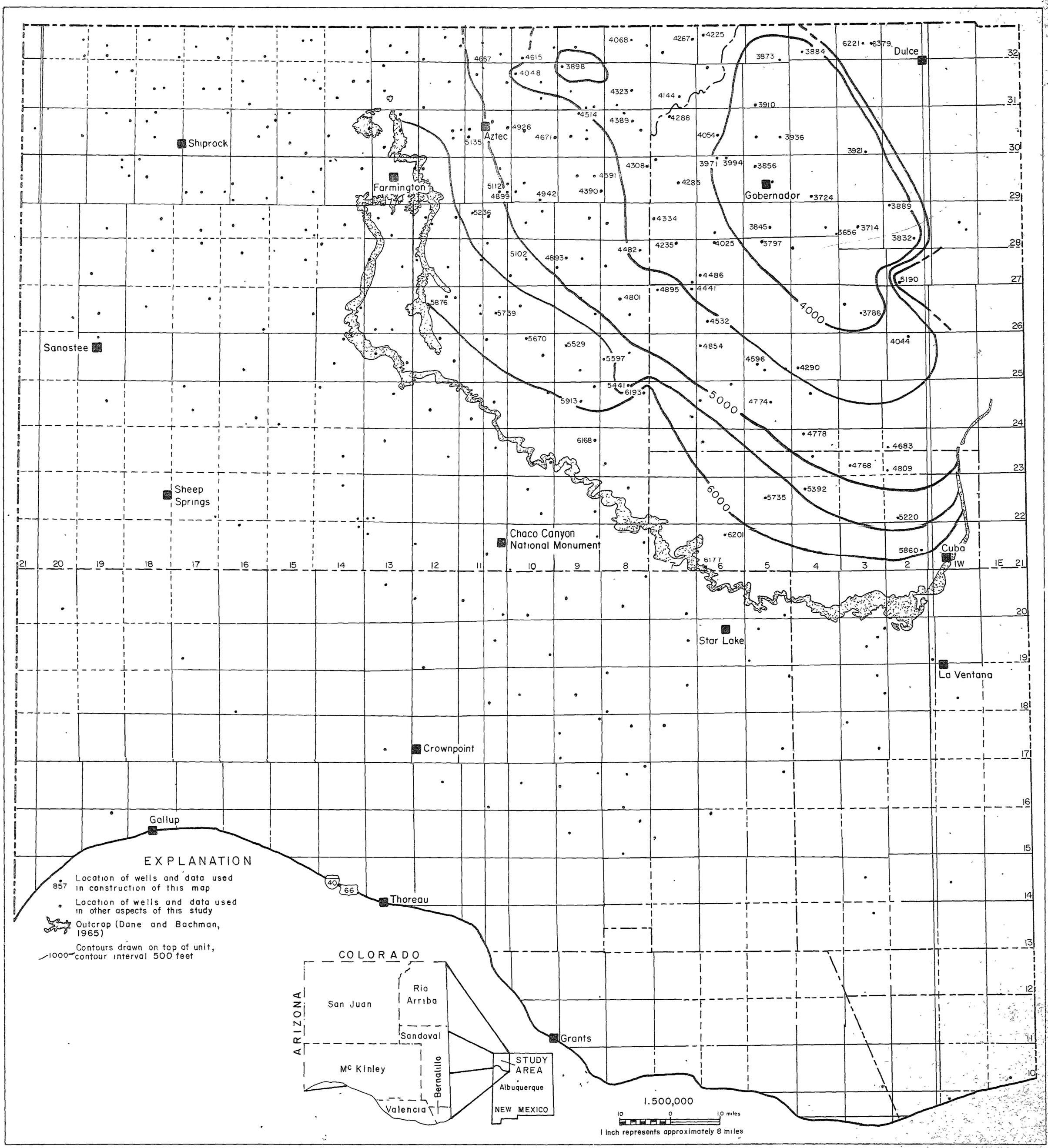
10 0 10 miles

1 inch represents approximately 8 miles

THICKNESS OF PICTURED CLIFFS SANDSTONE, SAN JUAN BASIN, NEW MEXICO

OPEN FILE REPORT 89

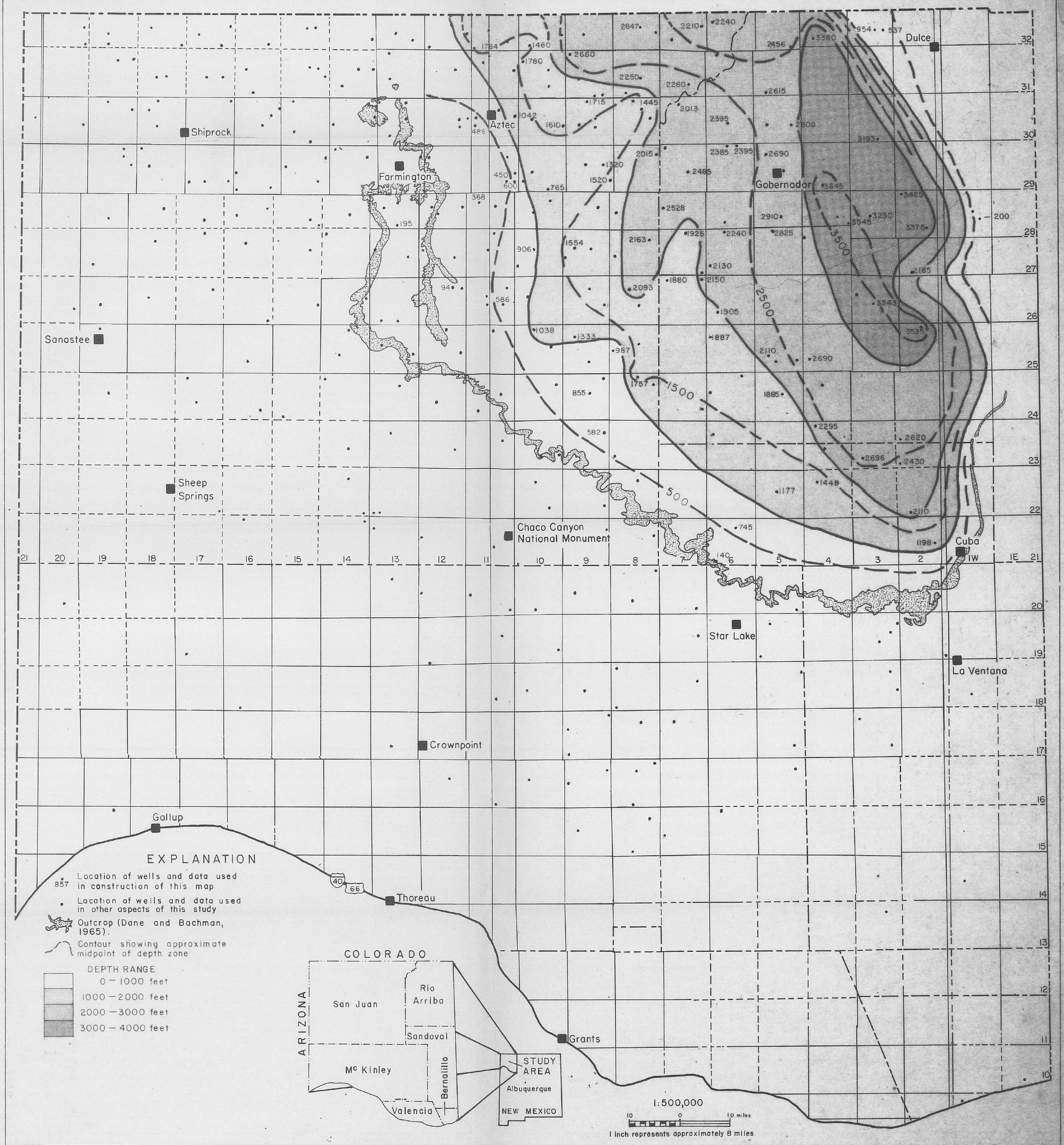
PLATE 20



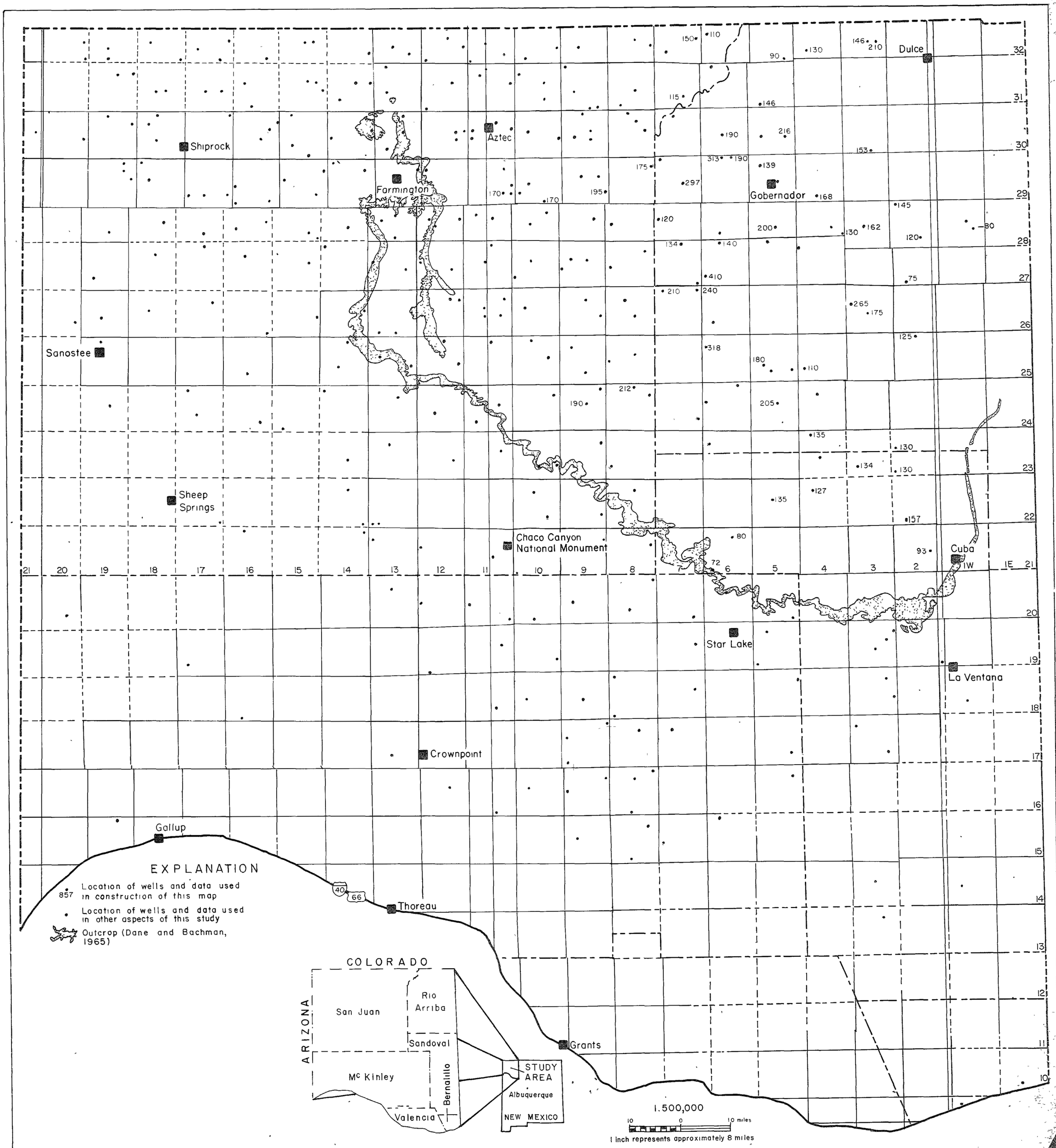
ELEVATION OF TOP (STRUCTURE) OF OJO ALAMO SANDSTONE, SAN JUAN BASIN, NEW MEXICO

OPEN FILE REPORT 89

PLATE 21



DEPTH TO TOP OF OJO ALAMO SANDSTONE, SAN JUAN BASIN, NEW MEXICO



THICKNESS OF OJO ALAMO SANDSTONE, SAN JUAN BASIN, NEW MEXICO

Shiprock
Aztec
Farmington
Dulce
Gobernador
Sanostee
Sheep Springs
Chaco Canyon National Monument
Cuba
Star Lake
La Ventana
Crownpoint
Gallup
Thoreau
Grants
ANIMAS FM.
5000
6000
5477 5665 5143 5244 5129 5092 5394 5088 5219 5652 5306 5214 4881 5545 6007 5501 5105 4755 4894 5083 5216 5234 5082 6250 5880 5621 4849 4571 5577 6086 5064 5884 5488 5684 5933 5573 5914 5809 5810 6494 6250
21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1W 1E 21
32 31 30 29 28 27 26 25 24 23 22 20 19 18 17 16 15 14 13 12 11 10

EXPLANATION

857 Location of wells and data used in construction of this map

Location of wells and data used in other aspects of this study

Outcrop (Dane and Bachman, 1965) *

1000 Contours drawn on top of unit, contour interval 500 feet.

* Animas Formation north of Farmington modified from O'Sullivan and Beikman (1963)

COLORADO
ARIZONA
San Juan
Rio Arriba
Sandoval
Mc Kinley
Bernalillo
Valencia
STUDY AREA
Albuquerque
NEW MEXICO

1:500,000
10 0 10 miles
1 inch represents approximately 8 miles

ELEVATION OF TOP (STRUCTURE) OF NACIMIENTO AND ANIMAS FORMATIONS, SAN JUAN BASIN, NEW MEXICO

OPEN FILE REPORT 89

PLATE 24

Shiprock
Aztec
Farmington
Dulce
Gobernador
Sanostee
Sheep Springs
Chaco Canyon National Monument
Cuba
Star Lake
La Ventana
Crownpoint
Gallup
Thoreau
Grants

ANIMAS FM.

1000 850 1180 2020 1275 1430 1055 1656 1895 885 1050 1170 1665 1235 1362 1355 1650 2240 2100 945 1382 1540 2230 1080 895 970 1500 2090 2660 860 2515 655 1182 1500 975 500 1140 1730 1550 1485 1030 438 1080 331

21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1W 1E 21

32 31 30 29 28 27 26 25 24 23 22 20 19 18 17 16 15 14 13 12 11 10

EXPLANATION

857 Location of wells and data used in construction of this map

Location of wells and data used in other aspects of this study

Outcrop (Dane and Bachman, 1965).*

Contour showing approximate midpoint of depth zone

DEPTH RANGE

0 — 1000 feet

1000 — 2000 feet

2000 — 3000 feet

* Animas Formation north of Farmington modified from O'Sullivan and Beikman (1963)

COLORADO

ARIZONA

San Juan
Rio Arriba
Sandoval
Mc Kinley
Bernalillo
Valencia

STUDY AREA

Albuquerque

NEW MEXICO

1:500,000

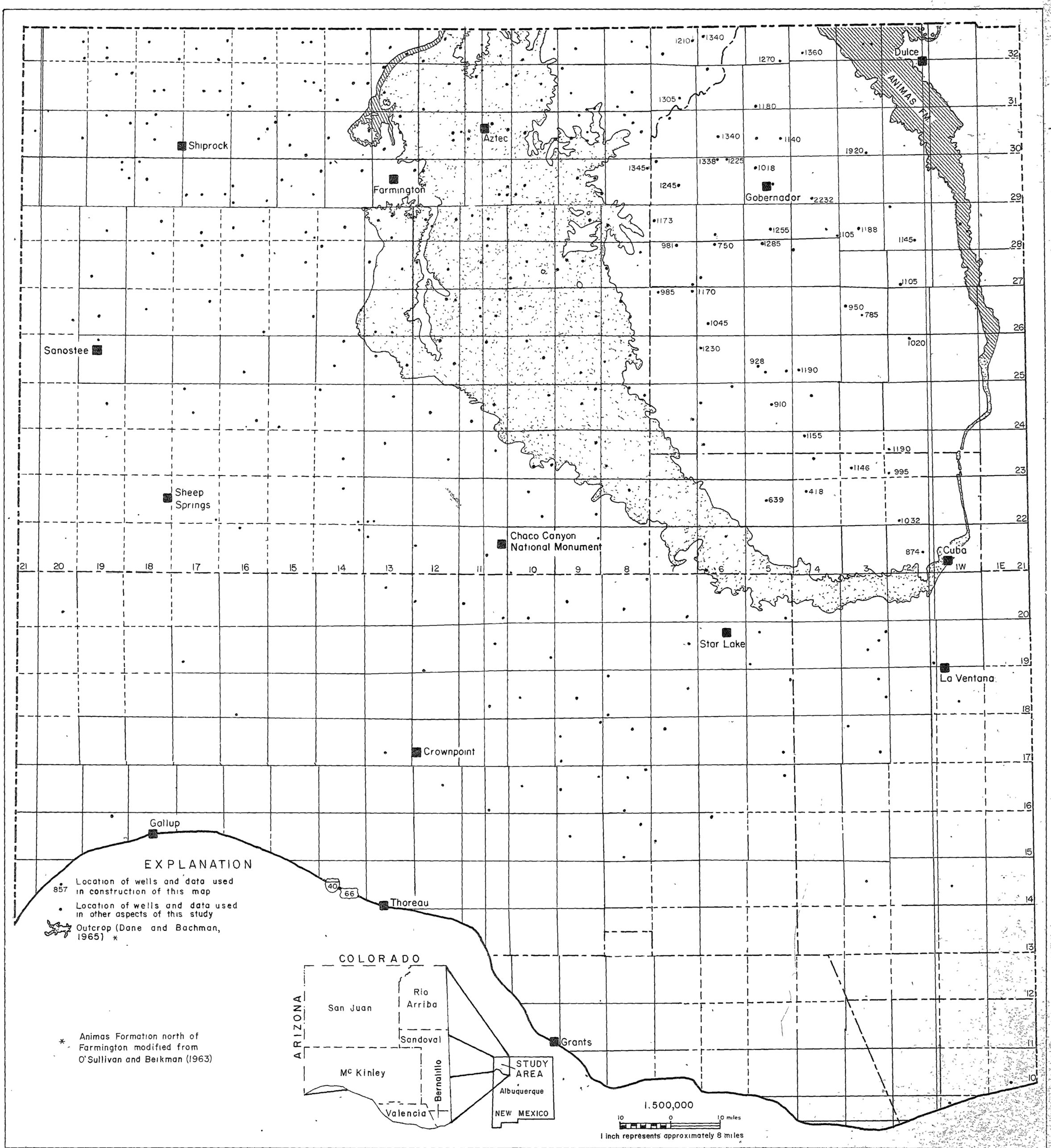
10 0 10 miles

1 inch represents approximately 8 miles

DEPTH TO TOP OF NACIMIENTO AND ANIMAS FORMATIONS, SAN JUAN BASIN, NEW MEXICO

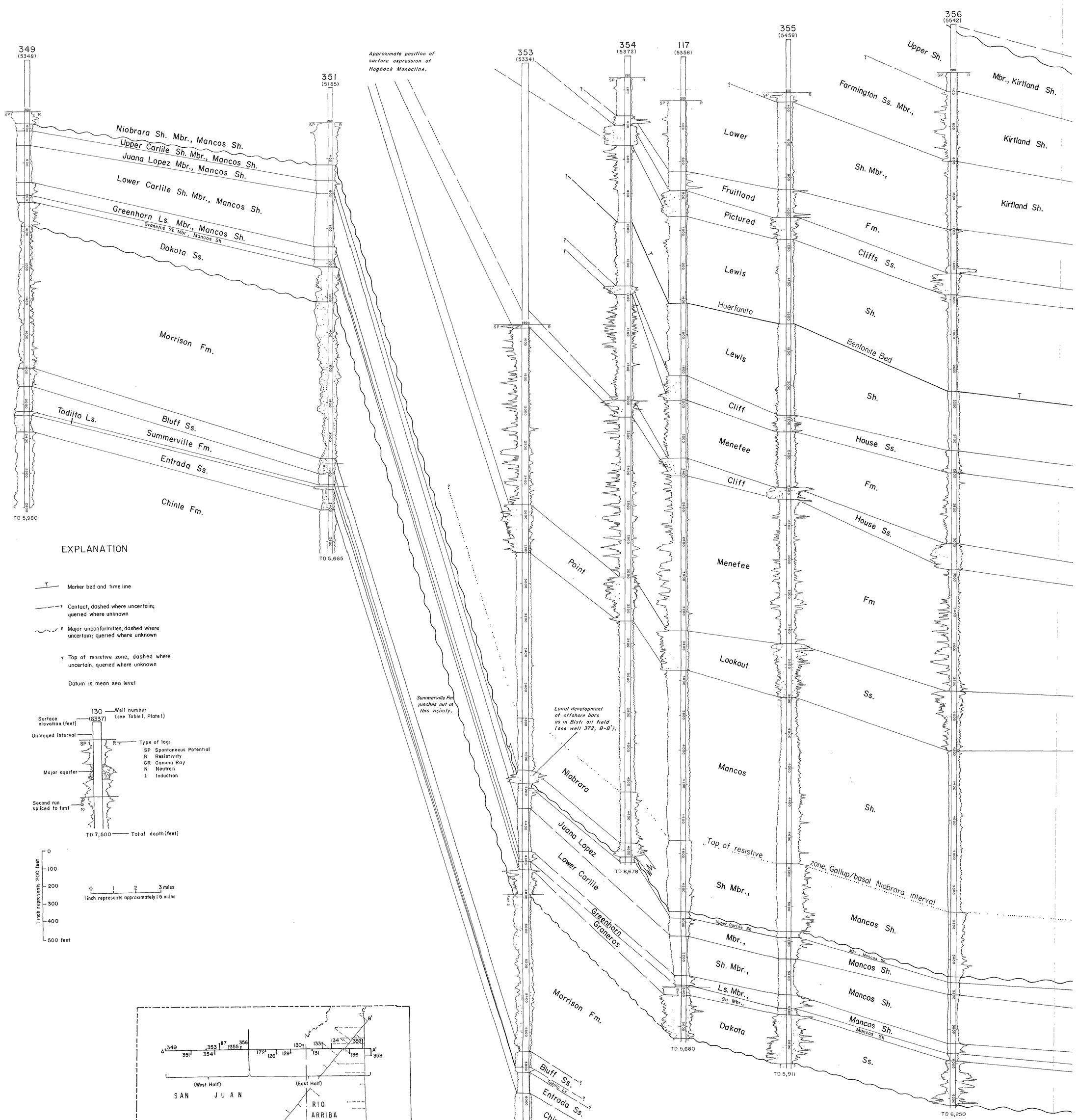
OPEN FILE REPORT 89

PLATE 25



THICKNESS OF NACIMIENTO AND ANIMAS FORMATIONS, SAN JUAN BASIN, NEW MEXICO

A



EXPLANATION

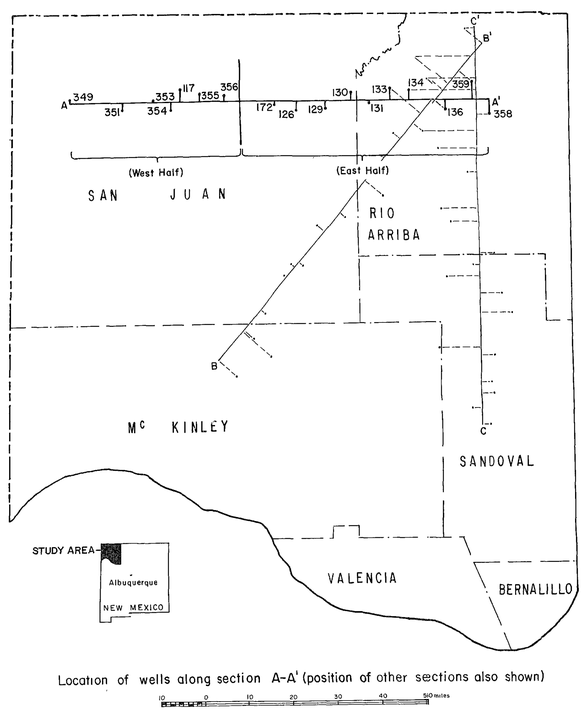
T — Marker bed and time line

—— ? Contact, dashed where uncertain; queried where unknown

~~~ ? Major unconformities, dashed where uncertain; queried where unknown

? Top of resistive zone, dashed where uncertain, queried where unknown

Datum is mean sea level



Location of wells along section A-A' (position of other sections also shown)

10 0 10 20 30 40 50 miles

WEST-EAST CROSS SECTION SHOWING STRUCTURE AND STRATIGRAPHY ALONG LINE A-A' NORTHERN SAN JUAN BASIN, NEW MEXICO
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OPEN FILE REPORT 89

PLANTE 27

B'

235 (6741)

214 (6591)

191 (6616)

158 (6597)

131 (6770)

159 (6755)

136 (7269)

133 (6356)

105 (6744)

69 (6522)

359 (7114)

33 (6916)

Cuba Mesa Mbr., San Jose Mbr., San Jose Fm.

Tapicitos Mbr., Llaves Mbr., Regina Mbr., San Jose Fm.

Llaves Mbr., San Jose Fm.

Animas Fm.

Nacimiento Fm.

Ojo Alamo

Upper Farmington Ss.

Lower Pictured Cliffs Ss.

Cliff House Ss.

Cliff House Ss.

Menefee

Point Lookout Ss.

Mancos Sh.

Niobrara Mbr., Fruitland Fm.

Upper Juana Lopez Carlile Sh.

Lower Greenhorn Carlile Ls.

Graneros Dakota Ss.

Morrison Fm.

Bluff Ss. (?)

Summerille Fm (?)

Todilto Ls.

Although the Nacimiento Fm. is a potential aquifer, it is not stippled because only local sandstone bodies produce significantly.

Ojo Alamo Ss and Nacimiento Fm. commonly have intertonguing contact.

Nomenclature changes near here; locality in subsurface uncertain.

Pictured Cliffs Ss. and Fruitland Fm intertongue locally.

Point Lookout and Cliff House Ss's. converge to northeast

Probable basis for reported Gallup tops in northeastern part of Basin Upper contact for Niobrara Mbr. is uncertain.

Top of resistive zone.

Gallup/basal Niobrara interval

Huerfanito Bentonite Bed

Dakota Ss.

Morrison Fm.

In the north, Dakota Ss. interval may locally include Burro Canyon Fm.

TD 7,704

TD 7,640

TD 7,985

TD 8,144

TD 5,960

TD 8,180

TD 7,865

TD 8,825

TD 8,332

TD 3,940

TD 8,270

TD 11,553

SOUTHWEST–NORTHEAST CROSS SECTION SHOWING STRUCTURE AND STRATIGRAPHY ALONG LINE B-B', SAN JUAN BASIN, NEW MEXICO

B

311 (6498) TD 2,713

312 (6634) TD 2,800

302 (6328) TD 3,433

292 (6265) TD 4,000

280 (6399) TD 4,968

266 (6592) TD 5,440

265 (6544) TD 4,406

372 (6768) TD 5,300

254 (7188) TD 7,239

Menefee

Point Lookout Ss.

Mancos Sh.

Crevasse Canyon Fm.

Gallup Ss.

Upper Juana Lower Greenhorn Ls.

Carlile Sh.

Lopez Sh. Mbr.

Carlile Ls. Mbr.

Sh. Mbr., Mbr., Sh. Mbr., Mbr.

Dakota Ss.

Morrison Fm.

Crevasse Canyon is cut out by pre-Niobrara erosion surface in this vicinity.

Main body of Gallup Ss. is cut out by pre-Niobrara erosion surface in this vicinity.

Top of resistive zone, Gallup/basal Niobrara interval

Lower Mbr., Pictured Cliffs Ss.

Lewis Sh.

Cliffhouse Ss. Mbr.

Menefee Fm.

Point Lookout Ss.

Mancos Sh.

Nacimiento Fm.

Ojo Alamo Ss.

Upper Mbr., Kirtland Sh.

Farmington Ss. Mbr., Kirtland Sh.

Kirtland Sh.

Fruitland Fm.

Huerfanito Bentonite Bed

Fruitland Fm.

Pictured Cliffs Ss.

Lewis Sh.

Cliff House Ss.

Menefee Fm.

Point Lookout Ss.

Mancos Sh.

Local development of offshore bar of Gallup Ss. at southeast end of Bisti Oil Field.

EXPLANATION

T ? Marker bed and time line

? Contact, dashed where uncertain; queried where unknown

? Major unconformities, dashed where uncertain; queried where unknown

? Top of resistive zone, dashed where uncertain; queried where unknown

Datum is mean sea level

130 Well number (see Table 1, Plate 1)

(6337) Surface elevation (feet)

Unlogged interval

SP R Type of log.

SP Spontaneous Potential
R Resistivity
GR Gamma Ray
N Neutron
I Induction

Major aquifer

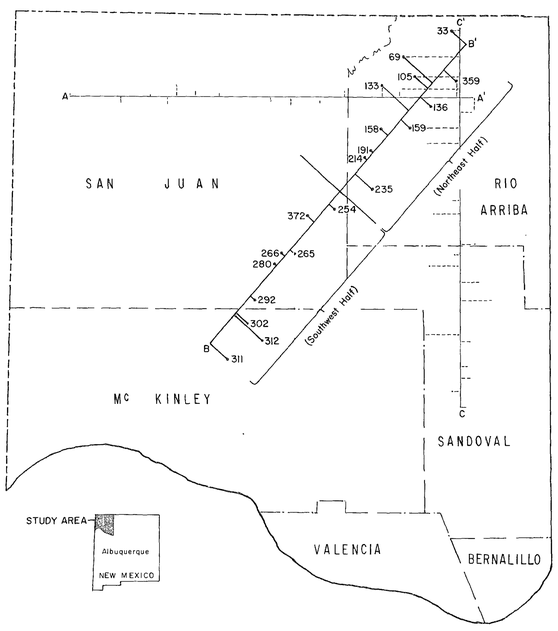
Second run spliced to first

TD 7,500 Total depth (feet)

1 inch represents 200 feet: 0, 100, 200, 300, 400, 500 feet

0 1 2 3 miles

1 inch represents approximately 1.5 miles



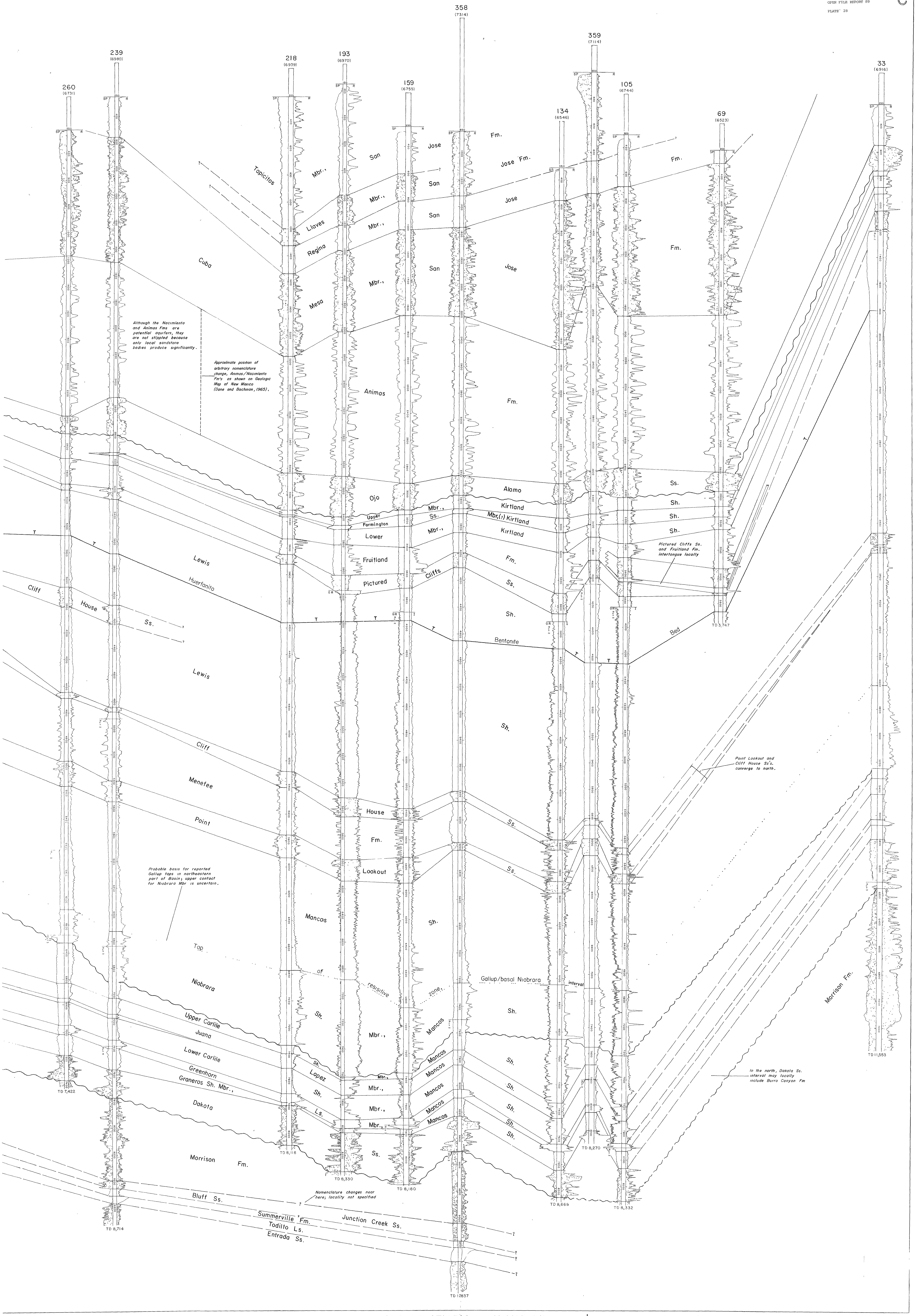
Location of wells along section B-B' (position of other sections also shown)

0 5 0 10 20 30 40 50 miles

SOUTHWEST-NORTHEAST CROSS SECTION SHOWING STRUCTURE AND STRATIGRAPHY ALONG LINE B-B' SAN JUAN BASIN, NEW MEXICO

OPEN FILE REPORT 89
PLATE 28

C'



SOUTH-NORTH CROSS SECTION SHOWING STRUCTURE AND STRATIGRAPHY ALONG LINE C-C', EASTERN SAN JUAN BASIN, NEW MEXICO

C

335 (6327)
360 (6239)
327 (6572)
326 (6685)
318 (6850)
309 (6636)
298 (7058)
286 (7330)
285 (6840)
272 (7464)
273 (7303)

Cross section begins northeast of edge of main body of Gallup Ss.

Contact between Nacimiento and San Jose Fms marked by angular unconformity in outcrop adjacent to Nacimiento Uplift near here.

Cuba Mesa Mbr., San Jose Fm.
Nacimiento Fm.
Ojo Alamo
Kirtland
Fruitland
Pictured Cliffs Ss.
Lewis Sh.
Bentonite Bed
Lewis Sh.
Huerfanito Bentonite
Cliff House Ss.
Menefee Fm.
Point Lookout Ss.
Upper Mancos Sh.
Juana Lopez Ss. Mbr.
Semilla Mancos Sh.
Lower Mancos Sh.
Greenhorn Limestone
Graneros Sh.
Dakota Ss.
Morrison Fm.
Bluff Ss.
Summerville Fm.
Todilto Ls.
Entrada Ss.
Chinle Fm.

Niobrara Sh. Mbr., Carlile Sh. Mbr., Lopez Mbr., Ss. Mbr., Carlile Sh. Mbr., Ls. Mbr., Sh. Mbr.,

Top of resistive zone

Gallup/basal Niobrara interval

TD 6,949
TD 7,973
TD 6,752
TD 4,916
TD 5,466
TD 5,596
TD 7,186
TD 6,509
TD 8,036
TD 8,436
TD 13,568

EXPLANATION

- T — Marker bed and time line
- ? — Contact, dashed where uncertain, queried where unknown
- ? — Major unconformities, dashed where uncertain, queried where unknown
- ? — Top of resistive zone, dashed where uncertain, queried where unknown

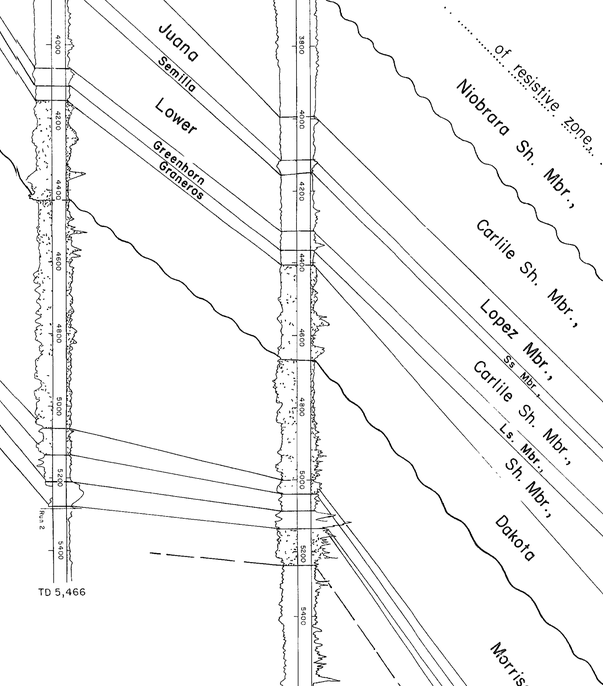
Datum is mean sea level

130 — Well number (see Table 1, Plate 1)
Surface elevation (feet) — (6337)
Untogged interval
Major aquifer
Second run spliced to first — Run 2
TD 7,500 — Total depth (feet)

SP Spontaneous Potential
R Resistivity
GR Gamma Ray
N Neutron
I Induction

1 inch represents 200 feet: 0, 100, 200, 300, 400, 500 feet

0 1 2 3 miles
1 inch represents approximately 1.5 miles



Location of wells along section C-C' (position of other sections also shown)

10 0 10 20 30 40 50 miles

SOUTH-NORTH CROSS SECTION SHOWING STRUCTURE AND STRATIGRAPHY ALONG LINE C-C', EASTERN SAN JUAN BASIN, NEW MEXICO