IGNEOUS AQUIFER SYSTEM OF BREWSTER, JEFF DAVIS AND PRESIDIO COUNTIES, TEXAS

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INTRODUCTION

The Igneous aquifer system is the primary source of groundwater in a region that encompasses major parts of Jeff Davis and Presidio Counties and the western portion of Brewster County. The communities of Alpine, Fort Davis and Marfa rely on the aquifer system as their sole source of drinking water. In the development of the Far West Texas Regional Water Plan, it was recognized that insufficient data existed to fully assess the water supply potential from this important aquifer. The Regional Planning Group thus sought to develop a more complete picture of the area's groundwater resource by expanding the database of well locations and water-level measurements. The primary goal of the project was to gather sufficient data to better illustrate the areal extent of the aquifer system and its water supply potential. The Texas Water Development Board (TWDB) then funded the resulting proposed project. In pursuing the project, LBG-Guyton Associates, with assistance from Water Prospecting and Resource Consulting, and Sul Ross State University, gathered the necessary field data and produced the resulting report.

The results of the study suggest a marked change from the commonly held viewpoint that there is a single Igneous aquifer in this region. Rather, groundwater is stored in a complex system of aquifers that are in varying degrees of hydrogeologic communication. For this reason, this report refers to the aquifer as the "Igneous aquifer system". Also, this study recognizes a significantly larger extent of the aquifer system than is currently designated by the TWDB. The objective of this report is to present a basic description of the geology and hydrogeology of the Igneous aquifer system.

GEOGRAPHIC SETTING

Location

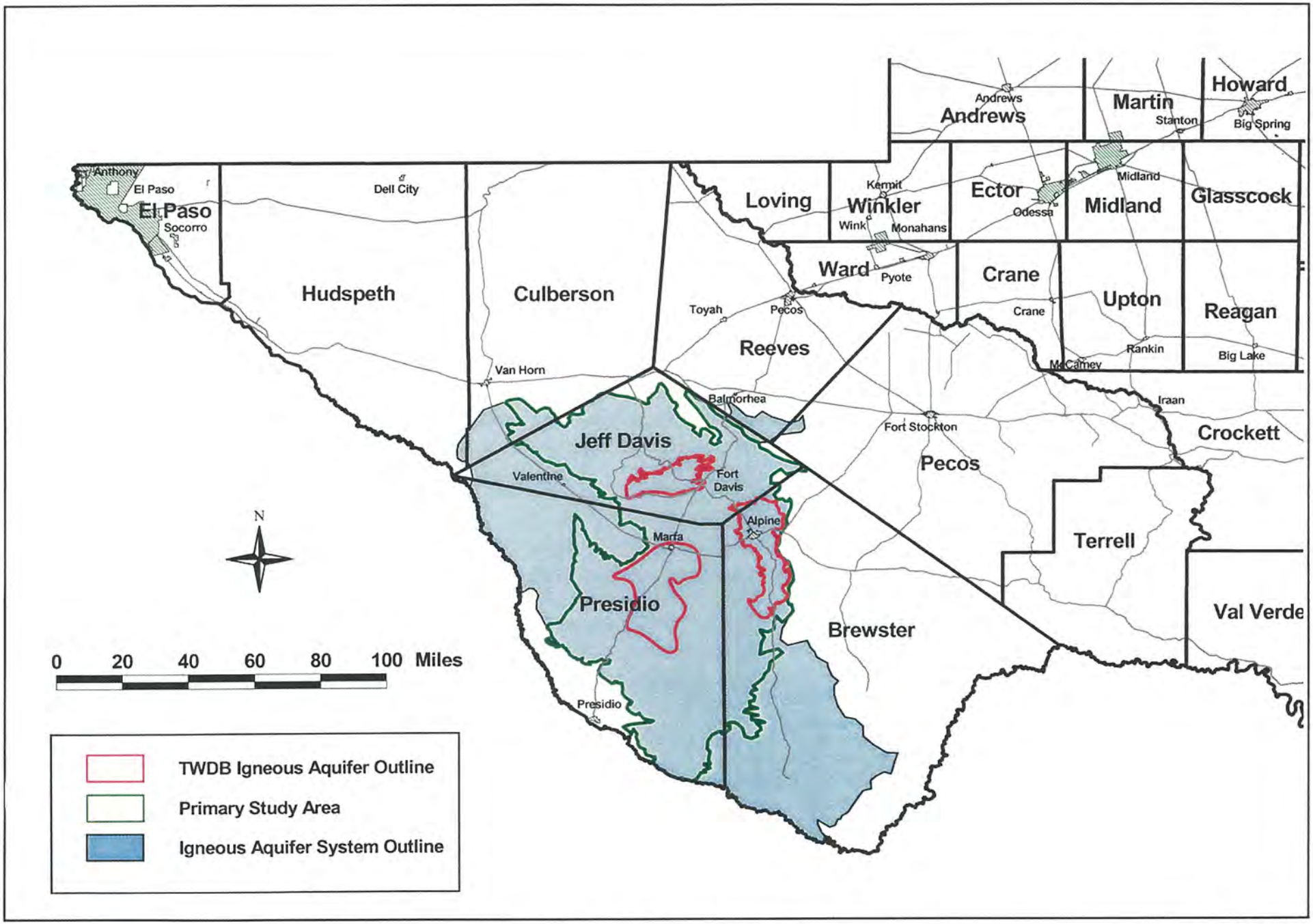
The study area lies principally within the boundaries of Brewster, Jeff Davis and Presidio Counties and only slightly into southern Culberson and Reeves Counties in the Trans-Pecos region of Texas (Figure 1). "Trans-Pecos" is a widely used term that refers to the area of Texas that lies west of the Pecos River. Points of interest within the study area include Davis Mountains State Park, Fort Davis National Historic Site, McDonald Observatory, Sul Ross State University, and the Chihuahuan Desert Research Institute.

For purposes of this study, the Igneous aquifer system is delineated based on its extent underlying the Davis Mountains in the north and the Marfa Basin to the south, and encompasses approximately 8,200 square miles. The boundary of the aquifer system is shown on Figure 1 along with the outline of the "Igneous aquifer" as delineated by the TWDB (Ashworth and Hopkins, 1995). The principal data collection area for this study represents a slightly smaller area (Figure 1).

The TWDB currently recognizes the Igneous aquifer as three separate areas that represent the population centers, thus the water demand centers, surrounding the communities of Alpine, Fort Davis and Marfa. However, for the purpose of this study, the delineation of the Igneous aquifer system is based on the contiguous extent of Igneous rocks that are exposed on the land surface. It is recognized that additional Igneous formations exist on the surface and in the subsurface outside of the delineated boundary, primarily to the northwest and southeast. However, the hydrologic connection of these units to the delineated area is uncertain and will require further study.

The topography of the Davis Mountains is some of the most rugged in Texas. Elevations range from 1,355 to 7,825 ft above mean sea level (msl) in Brewster County; from 3,871 to 8,382 ft above msl in Jeff Davis County; and from 2,400 to 7,730 ft above msl in Presidio County. Mount Livermore (Jeff Davis County) is one of the highest peaks in Texas (8,382 ft above msl).

Brewster, Jeff Davis and Presidio Counties are also among the least populated counties of the Texas. The U.S. Census Bureau lists the year 2000 populations as follows: Brewster, 8,866; Jeff Davis, 2,207; and Presidio, 7,304. The populations of the three cities that lie within the boundaries of the study area are: Alpine, 5,786; Fort Davis, 1,050; and Marfa, 2,121.



STUDY AREA LOCATION

FIGURE 1

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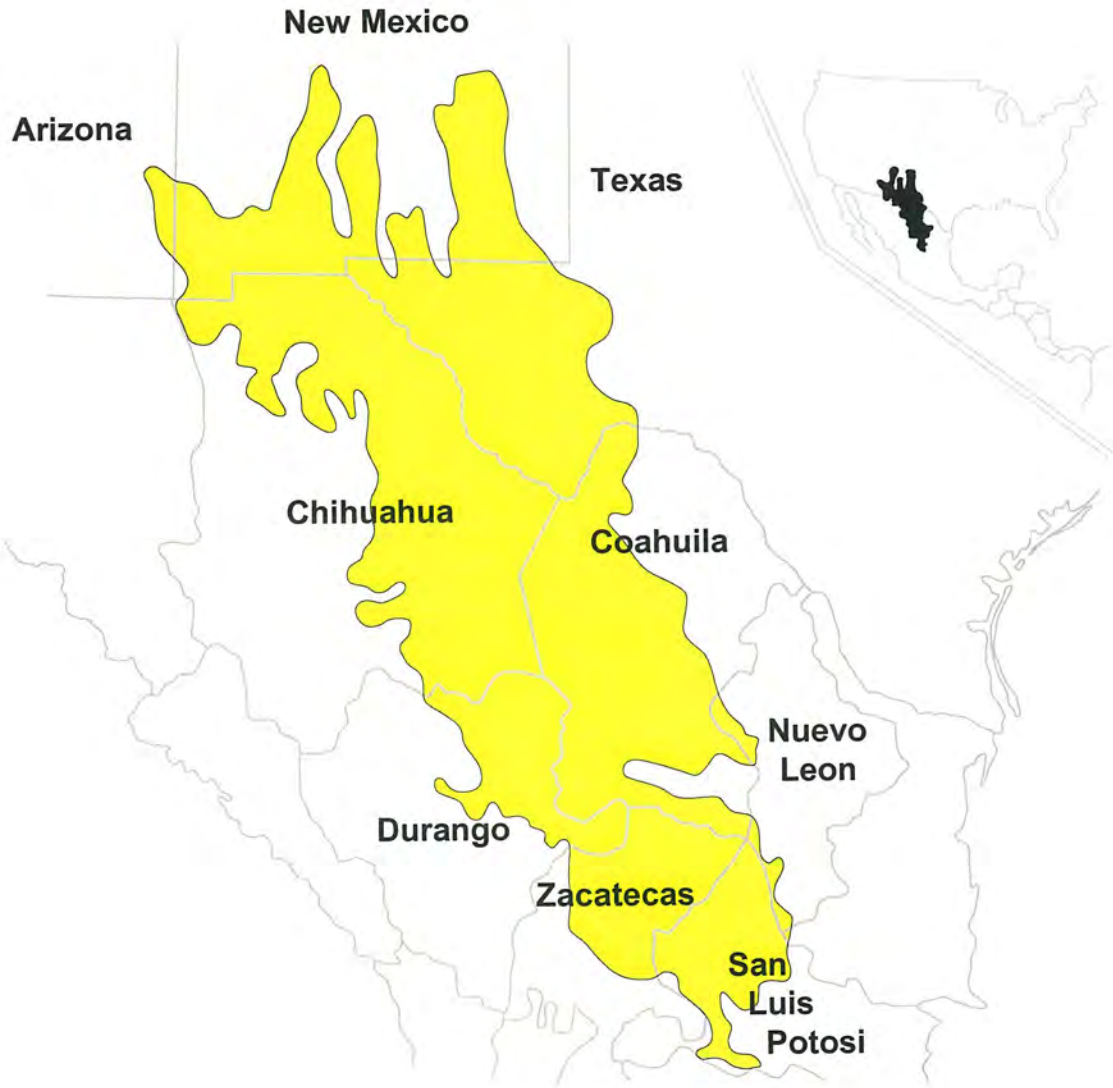
Physiographic Province and Climate

The Trans-Pecos region of Texas lies within the northern portion of the Chihuahuan Desert (Figure 2), a 1,200-mile long and 800-mile wide arid zone that extends southward into Mexico. Included in the Chihuahuan Desert region are parts of the states of Arizona, New Mexico and Texas in the United States, as well as parts of the states of Chihuahua, Coahuila, Nuevo Leon, Durango, Zacatecas, and San Luis Potosi in Mexico.

The Chihuahuan Desert is surrounded by Mexico's two great mountain ranges - the Sierra Madre Oriental and the Sierra Madre Occidental. As warm moist air rises to move across these mountains, the air cools rapidly, and the cooling generates rainfall on the windward face of the mountains. This also creates a rain-shadow effect on the lee face of the mountain ranges and over the basins of the Chihuahuan Desert. While the other North American deserts each have summer and winter rainy seasons (because of their location further to the west), rain typically comes to the Chihuahuan Desert between the months of June and October. As much as 90 percent of the annual rainfall takes place during this period.

Within the Trans-Pecos region of the Chihuahuan Desert, it is only the highest altitudes and the eastern edge of the region along the Pecos River that receive sufficient precipitation to be considered semiarid, rather than true desert (Schmidt, 1986). For example, the climate of Jeff Davis County and adjoining areas of Brewster and Presidio Counties ranges from cool-temperate-humid at elevations above 4,000 ft to arid-subtropical at lower elevations (Bomar, 1983). At elevations above 6,800 ft, summer temperatures exceed 90°F only 10 percent of the time. The mean annual temperature at Mount Locke (6,800 ft above msl) is 57°F; at Marfa (4,700 ft above msl), 61°F; at Alpine (4,500 ft above msl), 64°F; and at Balmorhea (3,256 ft above msl), 65°F. This represents an 8°F difference in temperature over a distance of less than 30 miles (Hart, 1992).



EXTENT OF THE CHIHUAHUAN DESERT IN THE UNITED STATES AND MEXICO

FIGURE 2

From highest to lowest amounts, average annual rainfall in this region is reported as follows: Mount Locke, Jeff Davis County (20.8 in); Alpine, Brewster County (16.9 in); Marfa, Presidio County (15.9 in); Sanderson, Terrell County (14.3 in); Van Horn, Culberson County (10 in); Sierra Blanca, Hudspeth County (10 in); and the City of El Paso, El Paso County (8.8 in) (Bomar, 1995). Most rainfall occurs between the months of June and October, as indicated by a graph of average monthly rainfall for selected stations (Figure 3). Rainfall during the spring and summer months is dominated by widely scattered thunderstorms (Larkin and Bomar, 1983; Nativ and Riggio, 1989 and 1990). Because of the convective nature of thunderstorms and the orographic lifting effect of mountainous areas, the amount of spring and summer precipitation increases with elevation. The influence of orographic lifting on average annual rainfall is illustrated by the higher median precipitation areas centered over the Davis Mountains in Jeff Davis County, south of Alpine in Brewster County, and in the Big Bend Chisos Mountains also in Brewster County (Figure 4).

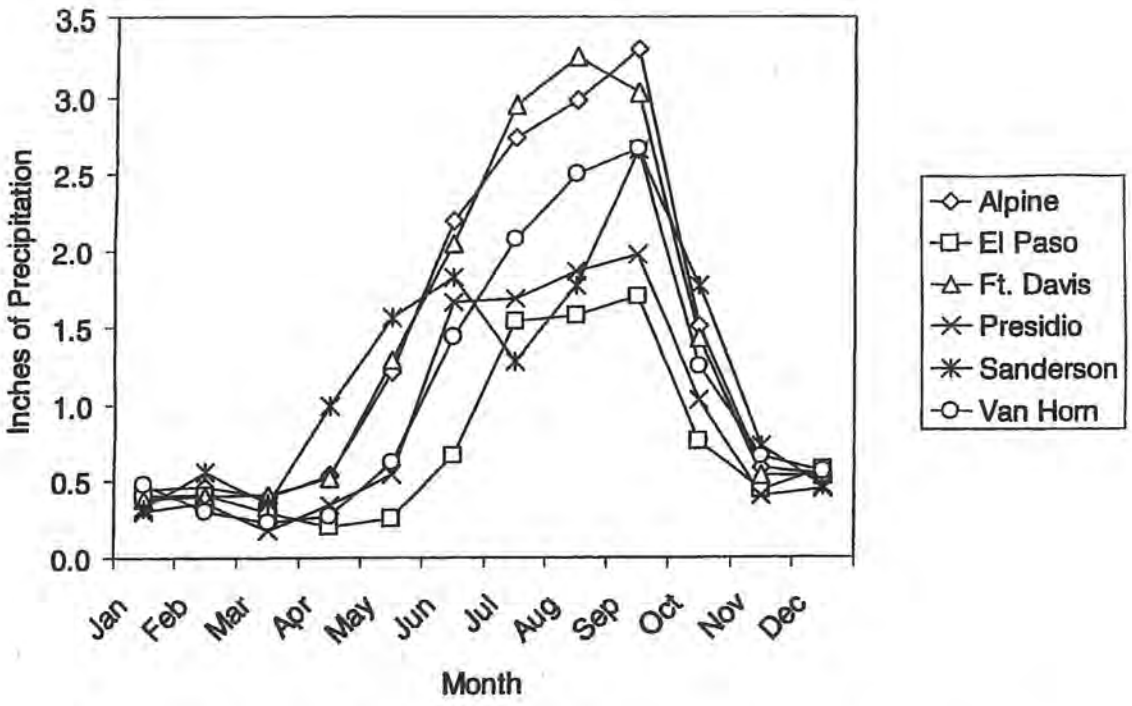
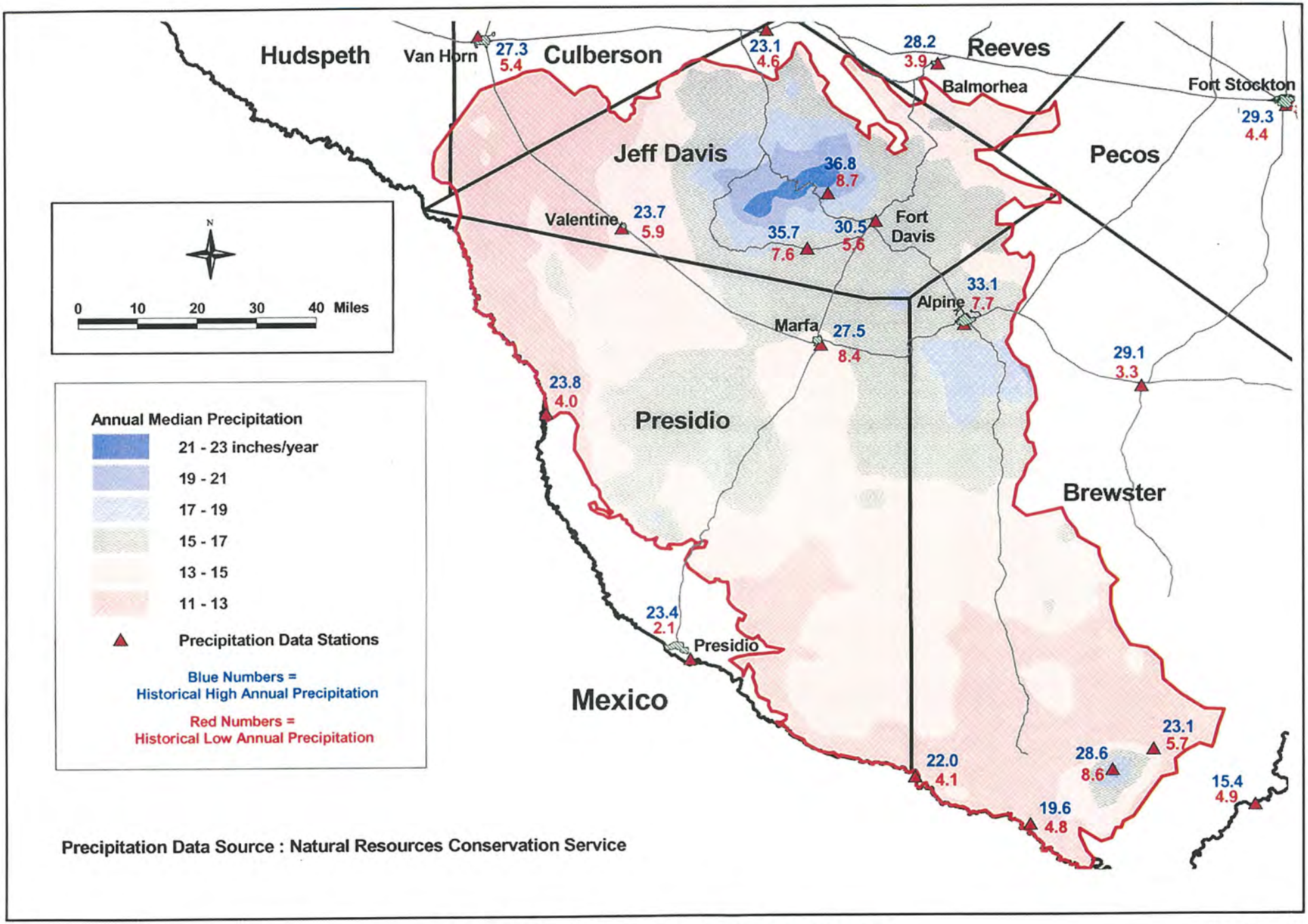


Figure 3. Average Monthly Precipitation for Selected Stations (Bomar, 1995)



REGIONAL ANNUAL PRECIPITATION DATA

FIGURE 4

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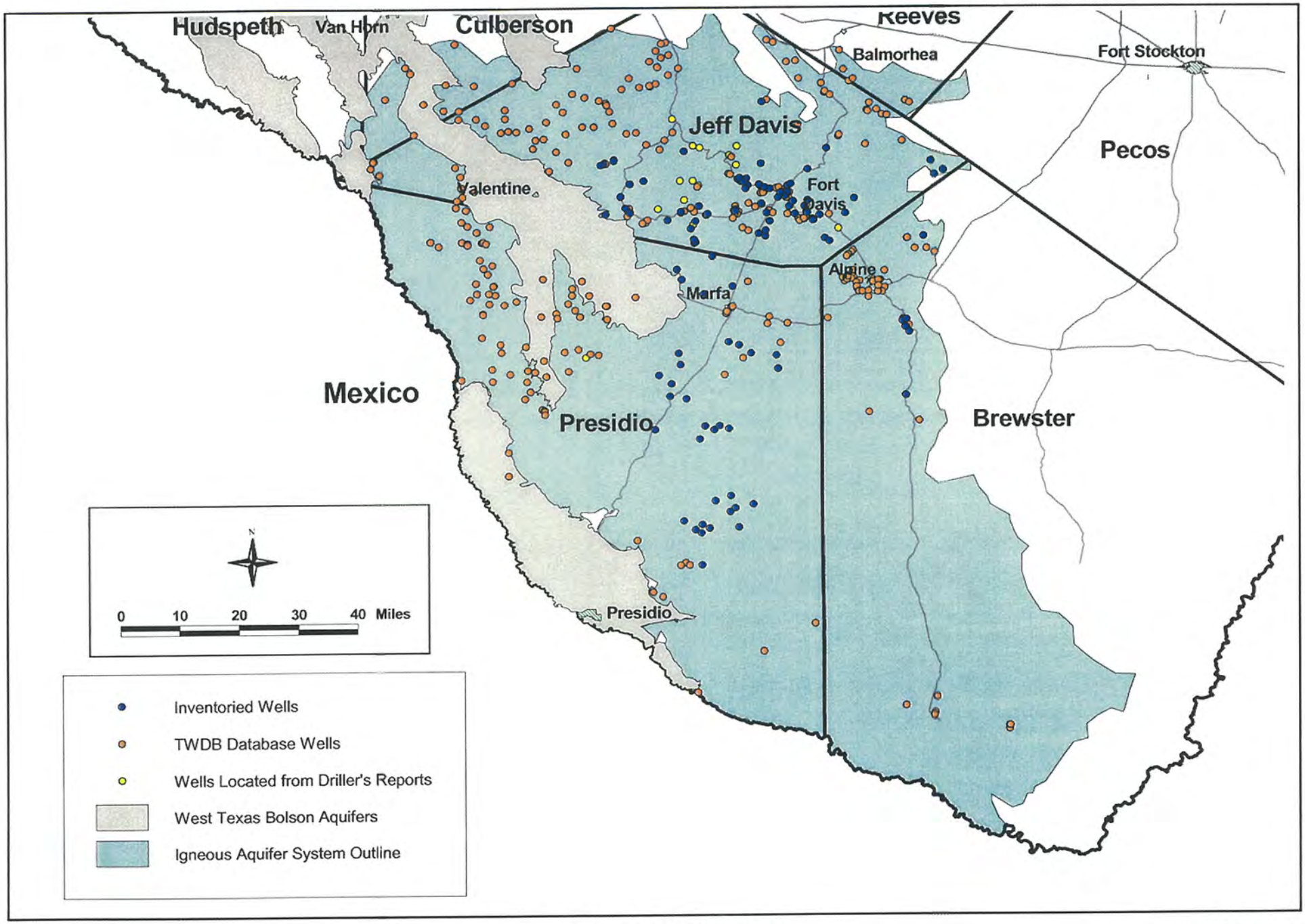
DATA GATHERING METHODOLOGY

An important step in the development of a better understanding of the Igneous aquifer system was the gathering of additional well data. Figure 5 shows the distribution of existing wells in the TWDB groundwater database, wells visited and measured during this study, and wells not field-visited but selected from water well drillers' reports. The TWDB groundwater database currently contains 374 Igneous aquifer wells with information such as depth, construction, water level, and yield. Many of these wells include a water-quality analysis. Not included and not shown on Figure 5 are wells that are likely dual completed in both Bolson and Igneous aquifers in the Ryan Flat area near Valentine.

In the performance of this study, a significant amount of new water well field data was collected. Field staff worked closely with the groundwater conservation districts in the selection of wells to be surveyed. Field measurements were taken at 118 well sites, 85 sites of which had not been previously inventoried by TWDB staff. The static water level was measured in all 85 inventoried wells as well as in 33 wells that are already in the TWDB groundwater database. Specific conductance, a measure of water quality, was measured in 21 of the inventoried wells. Table 1 contains information and measurements made at the 85 inventoried well sites. Water levels were also measured in 6 TWDB monitoring wells for the purpose of comparing summer water levels with winter water levels. And lastly, supplemental data was added to the study database in the form of information gained from drillers' reports of 16 unvisited wells that were drilled since 1996. Data collected from this task were combined with existing data to form the aquifer information base from which this report was produced. Near the completion of the field data collection task, a public meeting was held in Alpine for the purpose of enlisting local knowledge and comments on the interpretation and evaluation of the data.



LOCATED WELL DATA

FIGURE 5

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Table 1. Water Level and Water Quality Data for Inventoried Wells

State Grid No.	Latitude	Longitude	Year Drilled	Well Depth	Well Head Elev.	Water Level Date	Depth to Water	Water Level Elev.	Use	Pump Type	Casing Dia. (inch)	Est. Well Yield (gpm)	pH	Temp C °	Spec. Cond. (mmhos/cm)
Brewster County															
52-36-2	30.4854	103.5501			4116	08/16/01	61.9	4054	S	W	6				
52-44-7	30.2806	103.5992			5194	08/25/01	53.2	5141	H	S	6				
52-44-7	30.2792	103.6006	1996	300	5199	08/25/01	66.4	5133	H	S	6	1			
52-44-7	30.2828	103.5911	1984	120	5149	08/25/01	41.5	5108	H	S	6	40			510
52-44-7	30.2644	103.5919		150	5270	08/25/01	47.2	5223	H	S	6	15			410
52-44-7	30.2642	103.5919	1996	120	5275	08/25/01	59.5	5216	H	S	6	30			
52-44-7	30.2642	103.5939	1940	150	5302	08/25/01	49.0	5253	H	W	7				
52-44-7	30.2519	103.5842		165	5338	08/25/01	106.8	5231	H	S	6	14			
52-60-1	30.0976	103.5926	2001	265	4468	08/30/01	20.0	4448	I	S		60			
52-60-1	30.0969	103.5919	2001	600	4468	08/30/01	35.0	4433	I	S		150			
Jeff Davis County															
51-22-5	30.6719	104.3045		170	5275	06/08/01	32.3	5243	U	W	7				
51-22-5	30.6681	104.3051		84	5260	06/08/01	77.4	5183	U	W	7				
51-23-6	30.6921	104.1346			6038	06/21/01	202.9	5835	S	W	6				
51-24-9	30.6265	104.0007			5440	06/22/01	104.0	5336	S	W	6				
51-31-1	30.6197	104.2329		105	5780	06/18/01	58.3	5722	S	W	6				
51-31-8	30.5246	104.1747		100	5681	08/13/01	40.0	5641	S	S	6				
51-32-3	30.6234	104.0045			5305	06/22/01	307.5	4998	H	S	6	17	6.5	24.1	480
51-32-7	30.5221	104.1072		100	5501	08/13/01	86.9	5414	S	W	6				
51-32-7	30.5039	104.1180		100	5415	08/13/01	58.4	5357	H	S	6		7.8	22.6	394
51-40-1	30.4695	104.1098	1969	360	5268	08/13/01	129.7	5138	S	S	6				
51-40-1	30.4714	104.1063	1998	180	5238	08/13/01	136.7	5101	H	S	6		7.7	22.3	348
51-40-1	30.4783	104.1107	1935	100	5271	08/14/01	46.8	5224	S	S	6				
51-40-1	30.4773	104.1099	1964	125	5264	08/14/01	63.2	5201	H	S	6				
52-17-8	30.6614	103.9480			5275	06/21/01	308.3	4967	S	PJ	6				
52-18-6	30.6986	103.7878			4467	08/17/01	34.3		S	W	6				
52-18-7	30.6474	103.8338			4687	08/17/01	95.4	4592	H	S	6				
52-20-6	30.6684	103.5323			3998	08/16/01	40.9	3957	S	S	6		6.9	24	898
52-20-6	30.6683	103.5326			3998	08/16/01	47	3951	S	S	6				
52-20-6	30.6679	103.5323			3998	08/16/01	50.4	3948	S	S	6				
52-20-9	30.6339	103.5242			4097	08/16/01	71.4	4026	S	W	6				
52-20-9	30.6455	103.5020			4195	08/16/01	355.5	3840	S	S	6				356
52-25-1	30.6086	103.9802	1997	400	5180	06/07/01	183.2	4997	H	S	6	25	7.3	26	553
52-25-1	30.6253	103.9834		340	5235	06/07/01	234.2	5001	H	S	6	25	6.9	25	367
52-25-1	30.6174	103.9969	1988	440	5395	02/06/01	293.0	5102	H	S	5	11	7.6	26.1	315
52-25-1	30.6163	103.9897	2000	450	5200	06/09/01	197.0	5003	H	S	6	50	6.6	22.9	358
52-25-1	30.6008	103.9853			5320	06/21/01	281.7	5038	S	S	6				
52-25-3	30.5922	103.8992	1992	130	4955	06/05/01	75.5	4880	H	S	10	50			
52-25-3	30.5913	103.8834	2000	180	4950	06/05/01	94.3	4856	H	S		20			
52-25-3	30.6085	103.8820	1999	105	4815	06/06/01	33.0	4782	H	S	6	45			
52-25-3	30.6118	103.8750			4687	08/18/01	15.6	4671	H	S	120				
52-25-6	30.5826	103.8894			4945	06/21/01	51.5	4894	H	S	6				
52-26-3	30.5698	103.8693	1986	243	4954	06/21/01	154.8		S	S	6				
52-26-4	30.5579	103.8415			4840	06/21/01	34.0	4806	S	W		3			
52-26-7	30.5393	103.7195			4936	08/16/01	140.4		S	S	6				
52-27-4	30.5764	103.7195			4795	08/17/01	110.7	4684	S	W	6				
52-27-7	30.5411	103.7415			4618	08/16/01	178.8	4439	H	S	6		7.5	21.7	281
52-33-2	30.4917	103.9537	1994	330	5050	06/19/01	254.6	4795	H	S	6	25	6.9	24.6	528
52-33-2	30.4995	103.9365			5093	08/17/01	232.2	4861	S	S	6		7.6	22.6	232
52-34-2	30.4805	103.7918		140	4599	08/15/01	22.8	4576	P	S	6	25	7.5	22	259
52-34-3	30.4739	103.7802			4595	08/14/01	98.1	4497	S	W	6				

Presidio County

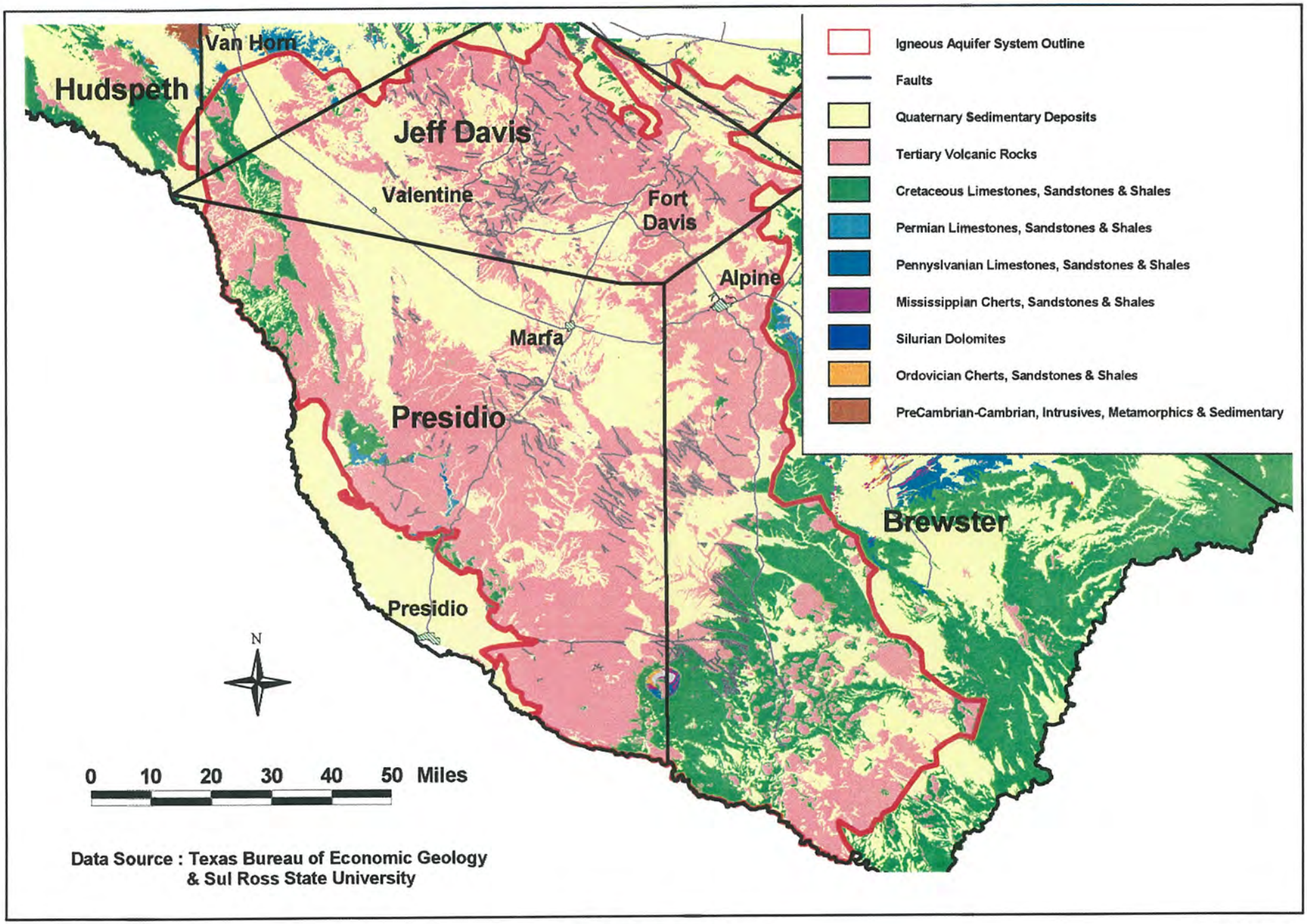
51-39-9	30.3810	104.1407			5053	06/20/01	388.0	4665	S	W	6				
51-39-9	30.4061	104.1523			5260	06/20/01	500.0	4760	U	W	6				
51-40-5	30.4379	104.0664	1969	525	5041	08/13/01	255.0	4786	S	W	6				
51-48-1	30.3451	104.0879			4843	06/20/01	302.0	4541	S	W	6				
51-48-3	30.3643	104.0177			4822	08/13/01	275.5	4547	I	S	10	350	7.6	22.5	389
51-55-6	30.2008	104.1481			4602	07/19/01	119.0	4483		W					
51-55-6	30.1733	104.1439			4759	07/19/01	286.5	4473		W					
51-55-8	30.1472	104.1958			4889	07/19/01	129.8	4759		W					
51-55-8	30.1261	104.1656			4278	07/19/01	456.0	3822		S					
51-56-3	30.2286	104.0269		540	4621	06/09/01	171.0	4451		S					760
51-56-3	30.2208	104.0017		189	4580	06/09/01	121.0	4462		S					360
51-56-3	30.2214	104.0019			4581	06/09/01	130.0	4451		S					
51-63-2	30.0958	104.1694			4839	07/19/01	125.2	4714		S					
51-63-3	30.0897	104.1292			4633	05/22/01	355.5	4278		W					
51-63-8	30.0144	104.2058			5057	07/19/01	325.0	4732		PJ					
51-64-7	30.0231	104.0839		162	4519	06/08/01	87.0	4432		S					
51-64-8	30.0136	104.0617		157	4274	06/08/01	10.0	4264		S					
51-64-8	30.0233	104.0492			4298	06/08/01	111.0	4187		W					
51-64-9	30.0164	104.0264			4164	06/08/01	64.0	4099		W					
52-49-4	30.2011	103.9725		200	4591	06/09/01	132.0	4459		W					380
52-49-6	30.1956	103.9106		300	4664	06/09/01	10.0	4654		S					
52-49-6	30.1958	103.9103			4664	06/09/01	10.0	4654	H	W					490
73-09-4	29.8308	103.9670		250	3825	06/07/01	170.0	3655	H	S					
74-08-1	29.9908	104.0967		102	4541	06/08/01	64.0	4477		S					
74-15-9	29.7903	104.1356		190	3908	06/26/01	170.0	3739		S					
74-16-2	29.8394	104.0592		50	3759	06/08/01	33.0	3727		S		15			
74-16-3	29.8519	104.0219		500	3762	06/08/01	60.0	3702	H	S		20			
74-16-6	29.8222	104.0105			3710	06/07/01	43.0	3668		S					
74-16-6	29.8130	104.0231			3690	06/07/01	79.0	3612		W					
74-16-7	29.7606	104.0931		220	3641	06/26/01	160.0	3482		S					280
74-16-7	29.7817	104.0911		150	3688	06/26/01	6.0	3684		W					
74-16-7	29.7686	104.1075		150	3734	06/26/01	130.0	3604	H	S					
74-16-8	29.7722	104.0736		150	3583	06/26/01	37.0	3546		W					
74-16-9	29.7748	104.0018			3577	06/07/01	17.0	3561		W					
74-24-4	29.6817	104.0914		225	3566	06/26/01	215.0	3352		W					

Latitude and Longitude in decimal degrees
gpm = gallons per minute
Use = Primary use of well: S = Stock, H = House, I = Irrigation, and U = Unused
Pump Type: W = Windmill, S = Submersible pump, and PJ = Pumpjack
C^{o} = temperature in degrees Centigrade
mmhos = micromhos, a measurement of conductivity

GEOLOGY

The geology of the Trans-Pecos is probably the most complex in the State of Texas. Over more than a billion years, the region has been inundated by sea water; tectonic activity has caused buckling, folding, and faulting of strata; volcanoes have spewed lava and ash over thousands of square miles; and a system of bolsons (valleys or basins between mountain ranges) formed as tensional forces caused sections of the Earth's crust to spread and sink. This section of the report offers a brief overview of the geology and geologic evolution of the Trans-Pecos. References to geologic time in the following text can be correlated with a discussion of the geologic time scale included as Supplemental Information at the end of this report. Figure 6 is a geologic map of parts of Brewster, Jeff Davis and Presidio Counties. A geologic map shows where rocks were laid down during specific periods of geologic time, along with other major features, such as faults.

The oldest strata in the Trans-Pecos are the Precambrian rocks of the Carrizo Mountains and vicinity west of Van Horn (Culberson County). These rocks, which formed from sediments that were deposited more than 1 billion years ago, were subjected to intense heat and pressure deep within the Earth's crust. Various minerals, such as talc, formed as a result of the "metamorphic" reactions caused by the heat and pressure. In other areas, rocks of several periods belonging to the Paleozoic Era [Ordovician, Silurian, and Carboniferous periods (530 – 290 million years ago (Ma))] are exposed in the Marathon Basin of northeastern Brewster County. These rocks, deposited in deep marine environments, were highly folded and faulted by compressive forces from the collision of crustal plates during the late Paleozoic Era. Rocks of Permian age are exposed in the Glass Mountains northeast of Alpine. These rocks formed from the buildup of reefs and other shallow marine limestones during the latter half of the Permian Period (~270 to 260 Ma).



REGIONAL GEOLOGY

FIGURE 6

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During the Cretaceous Period (~150 to 65 Ma), much of the Trans-Pecos was covered by shallow seas. Marine limestone, sandstone, and shale were deposited across most of the area. The broadest exposures of Cretaceous rocks are now in Brewster County. These rocks are also found underlying Igneous rocks in Jeff Davis and Presidio Counties.

Rocks belonging to the Tertiary Period (~65 to 1.8 Ma) cover much of the surface of Jeff Davis and Presidio Counties, along with western and southernmost Brewster County. Most of these rocks originated 48 to 32 Ma either as igneous intrusions or volcanic eruptions that penetrated and then buried the thick sequence of rocks that had been deposited during the Cretaceous Period. Intrusive igneous rocks form from the cooling of molten material deep within the crust. Volcanic (or extrusive igneous) rocks originate when lava is spilled onto the Earth's surface by volcanic eruptions. Extrusive volcanic rocks that comprise most of the Igneous aquifer system can generally be subdivided into ash-flow tuffs that are commonly thin and widespread, lava flows that generally are thicker and areally restricted, and volcaniclastics that include reworked or eroded volcanic rocks that take on the appearance and texture of mudstone, sandstone or conglomerate.

Centers of eruptive igneous activity within the large West Texas volcanic field shifted over time and covered all of Presidio County, most of Jeff Davis County, and more than 25 percent of the surface area of Brewster County. Over the last 30 million years, erosion has reduced the areal extent and the thickness of the flows. Today the Tertiary Igneous rocks form most of the impressive highlands in the Davis Mountains (Figure 7). There are more than 40 identified Igneous formations in the study area. A single formation, however, might consist of several lava flows. The Cottonwood Spring basalt, for example, is composed of up to seven flows in some areas, each varying in extent and thickness.