NUREG/CR-0597
ANL/ES-75

NUREG/CR-0597
ANL/ES-75

DESCRIPTIONS OF UNITED STATES URANIUM RESOURCE AREAS

A Supplement to the Generic Environmental Impact Statement on Uranium Milling

548 077

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ARGONNE NATIONAL LABORATORY, ARGONNE, ILLINOIS

Prepared for the U. S. NUCLEAR REGULATORY COMMISSION
under Interagency Agreement DOE 40-550-75

7907250403

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A Supplement to the Generic Environmental Impact Statement
on Uranium Milling

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Manuscript Completed: May 1979
Date Published: June 1979

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Prepared for
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Under Interagency Agreement DOE 40-550-75
NRC FIN No. A-2143

ABSTRACT

Descriptive material on six uranium-producing regions of the United States is presented in this document. The six regions include parts or all of the physiographic provinces commonly designated as the Northern Rocky Mountains, the Western Great Plains, the Wyoming Basin, the Southern Rocky Mountains, the Colorado Plateau, and the Texas Coastal Plains. The document includes chapters on climate, topography, land resources and uses, geology and seismicity, mineral resources and uses, surface water resources and uses, groundwater resources and uses, soils, terrestrial biota, aquatic biota, demographic and economic profiles, social and cultural patterns, archeology and prehistory, esthetic and recreational resources, and radiological backgrounds. Lists of threatened, endangered, and rare species and a glossary of some technical terms used are presented in appendices.

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1. INTRODUCTION

The main text of the Generic Environmental Impact Statement on Uranium Milling (NUREG-0511) is concerned with the impacts that would result from operation of a "model mill" in a "model region." The model region is designed to be a composite of the six uranium-producing regions in the United States. These regions are the Northern Rocky Mountains, the Western Great Plains, the Wyoming Basin, the Southern Rocky Mountains, the Colorado Plateau, and the Texas Coastal Plains. This supplement was prepared to present a description of many of the characteristics of these six regions. Many of the properties are quite different for the different regions, and knowledge of the variability, or the lack of it, for the different characteristics is essential if one wishes to apply the discussion of the model mill and model region to actual or potential mill sites in the individual uranium-producing regions.

The topics discussed in this supplement parallel those of the main document; this arrangement allows easy comparison of any of the regions with the model region. In addition, an attempt has been made to present enough data that this document may be used as a source of information about the uranium-milling regions of the United States.

1.1 THE SIX REGIONS

The uranium-bearing part of the United States has been divided into six regions (see Fig. 1.1). Except for one (Wyoming Basin), each region consists of part or all of a physiographic province and includes the main uranium resource areas in the province. The Northern Rocky Mountains region corresponds to the northwestern part of the Northern Rocky Mountains physiographic province and includes the uranium resource areas of eastern Washington, northern Idaho and extreme western Montana. The Western Great Plains region is a western part of the Great Plains province and includes the uranium mineralization areas of extreme eastern Wyoming and Montana, the western Dakotas, and south central Colorado. The Wyoming Basin region (the exception) includes all of the Wyoming Basin province and the Powder River Basin, which is part of the Great Plains physiographic province. It includes uranium resource areas of Wyoming, northwestern Colorado, and southern Montana. The Southern Rocky Mountains and Colorado Plateau regions coincide with the corresponding physiographic provinces. The Southern Rocky Mountains region includes uranium mineralization areas in Colorado, southern Wyoming, and northern New Mexico. The Colorado Plateau region includes uranium resource areas in Utah, Colorado, New Mexico, and Arizona. Finally, the Texas Coastal Plains region is a small part of the western edge of the Coastal Plains physiographic province and includes uranium mineralization areas in Texas.

The regions and their relation to the physiographic provinces can be seen in Figure 1.1. Further details of the uranium mineralization areas are shown in Figure 6.5.

1.2 ORGANIZATION

This document is organized so that a particular characteristic (e.g., groundwater) is discussed for each of the six regions in a single chapter. Often a chapter will have an introduction which contains some general aspects of the characteristic being discussed. In the first nine chapters, physical characteristics of the six regions and, where appropriate, their use or alteration by human activities are discussed. In the next two chapters, the terrestrial and aquatic biota of the regions are described. In the next four chapters, sociological aspects of the six regions are discussed. A chapter on the radiological background in the six regions concludes the report.

THE SIX STUDY REGIONS

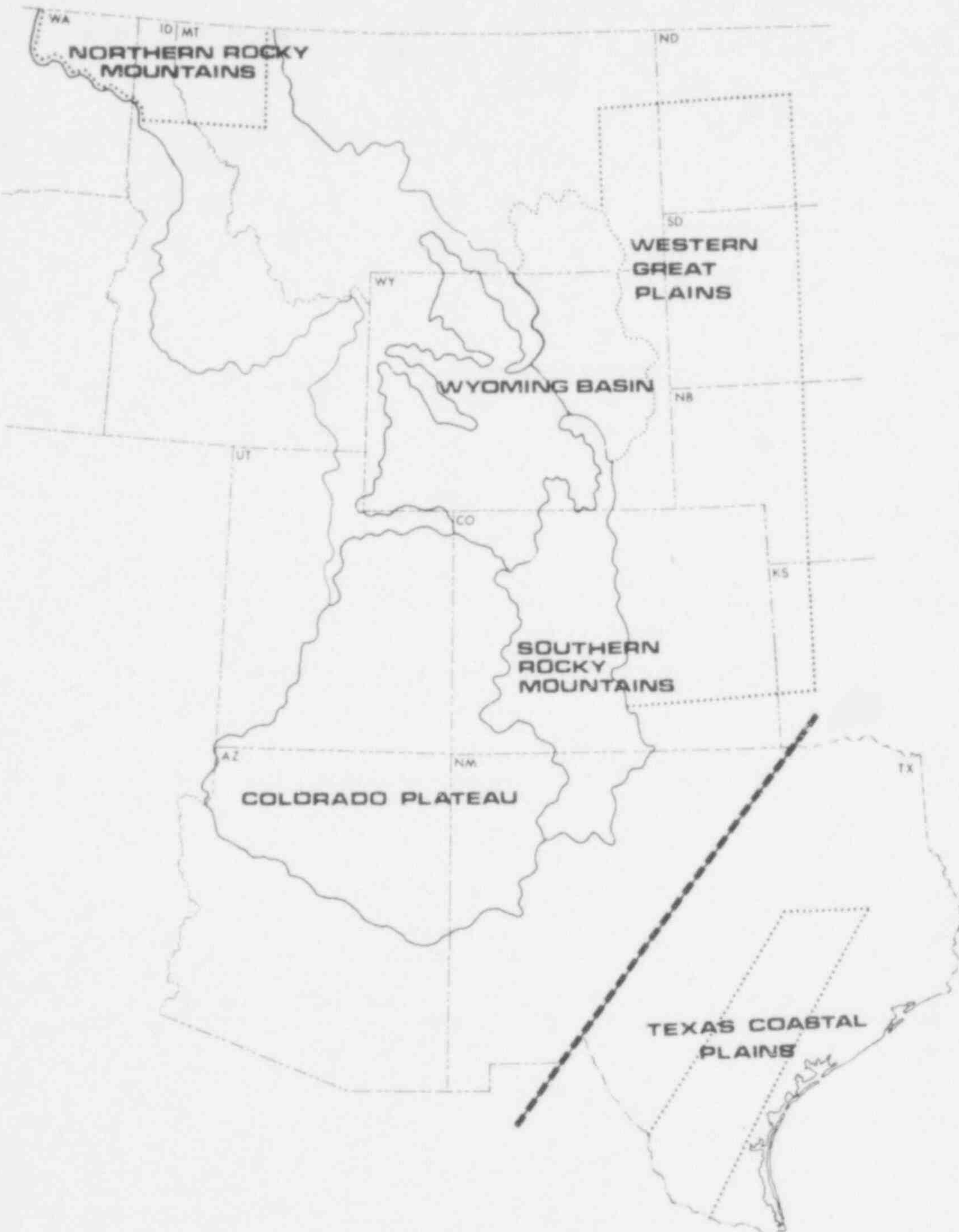

Fig. 1.1. The Six Study Regions and Corresponding Physiographic Provinces. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970. The boundaries of the study regions are shown as dotted lines if they are different from those of the physiographic provinces.)

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2. CLIMATE

In the following sections, a brief description is presented of various aspects of the climates of the six uranium-milling regions. Much of the information is contained in tables abstracted from larger collections of data listed in the references; these sources may be consulted for more extensive information. The joint frequency distributions for wind speeds and directions are included because they are needed for the calculation of dispersion of airborne contaminants. The discussions of the climates are limited to general remarks about regional characteristics, including seasonal variations in temperature, precipitation, and severe weather.

All of the regions are characterized by distinct seasons and large variations in temperature throughout the year. Total precipitation, defined as the sum of all types of precipitation expressed as an equivalent amount of liquid water, varies widely over the regions, as does that fraction which falls as snow. Nevertheless, in all cases, the annual evaporative potential exceeds the annual precipitation; thus, all six regions are classified as arid or semiarid, even those in which precipitation is substantial.

2.1 NORTHERN ROCKY MOUNTAINS

The climate of the Northern Rocky Mountains region is semiarid. Seasons are distinct, with cold, coastal-type winters and mild, dry summers. Spring and fall are transition seasons, with warm days and cool nights. Daily weather is dominated by air masses causing large variations in temperatures, cloud cover, and precipitation. Temperatures vary from summer highs near 38°C (100°F) to winter lows near -29°C (-20°F).[1] The prevailing winds are southwesterly to westerly (Table 2.1)[2] and strong winds are frequent (Table 2.2).[3]

The average annual precipitation ranges fro 30 to 50 cm (12 to 20 inches), and large variations occur in monthly and seasonal totals. Approximately 70% of the total annual precipitation falls from the first of October to the end of March, about half of this is in the form of snow. The mean and maximum monthly total precipitation and snowfall for Spokane are listed in Table 2.3. Annual evaporation potential exceeds annual precipitation, the former ranging between 100 and 160 cm (40 to 65 inches).[4] Winter storms, with snowfall, low temperatures, and high winds, occur occasionally; summer thunderstorms are infrequent and relatively mild. Tornadoes are rare. Those that do occur tend to be notably smaller, shorter-lived, and less destructive than tornadoes occurring farther east.

2.2 WESTERN GREAT PLAINS

The climate of the Western Great Plains region is continental. The seasons are distinct, with harsh winters and hot summers. Spring and fall have warm days and cool nights. The daily weather is dominated by high and low pressure centers (with attendant frontal systems) that cross the area. Temperatures vary from summer highs near 38°C (100°F) to winter lows near -34°C (-30°F).[1] Prevailing winds are northwesterly (Table 2.4).[5] Strong winds are frequent throughout the year (Table 2.5).[6]

The average annual precipitation ranges from 40 to 60 cm (16 to 24 inches). Spring and summer precipitation is often derived from thunderstorms (Table 2.6). Annual evaporation potential, which averages 100 to 150 cm (40 to 60 inches), exceeds precipitation.[4] Winter storms, with snowfall, low temperatures, and high winds, occur occasionally. Summer thunderstorms, occasionally accompanied by hail and high winds, occur frequently. Tornadoes are rare and seldom cause extensive damage.

2.3 WYOMING BASIN

The climate of the Wyoming Basin region is semiarid. Seasons are distinct, with mild summers and harsh winters. Daily weather is dominated by high- and low-pressure centers. Temperatures vary from summer highs near 38°C (100°F) to winter lows near -40°C (-40°F).[1] The prevailing winds are from the west to southwest, and the speeds are quite high (Table 2.7).[7] Strong winds are fairly frequent throughout the year (Table 2.8).[8]

Table 2.1. Joint Frequency of Annual Average Wind Speed and Direction for Spokane, Washington, 1967-1971

Direction	Speed, meters/second[a]						Total
	0-1.5[b]	1.6-3.2	3.3-5.1	5.2-8.2	8.3-10.8	>10.8	
N	0.6%	1.7%	1.1%	0.2%	0.1%	0.0	3.7%
NNE	0.5	1.7	1.3	0.3	0.0	0.0	3.8
NE	0.8	3.5	4.5	0.4	0.1	0.0	9.3
ENE	0.9	4.3	5.3	0.5	0.1	0.0	11.1
E	1.1	3.4	1.5	0.3	0.0	0.0	6.3
ESE	0.5	1.8	1.3	0.2	0.0	0.0	3.8
SE	0.3	1.6	1.8	0.4	0.0	0.0	4.1
SSE	0.4	1.9	5.3	0.7	0.1	0.0	8.4
S	0.9	3.2	5.7	2.5	0.3	0.0	12.6
SSW	0.3	1.4	3.4	4.4	1.1	0.1	10.7
SW	0.5	1.8	3.9	4.6	1.6	0.4	12.8
WSW	0.6	1.3	2.2	1.8	0.6	0.3	6.8
W	0.5	1.0	0.9	0.6	0.1	0.1	3.2
WNW	0.3	0.5	0.3	0.3	0.0	0.0	1.4
NW	0.1	0.3	0.4	0.0	0.0	0.0	0.8
NNW	0.1	0.3	0.4	0.4	0.0	0.0	1.2
Total	8.4%	29.7%	39.3%	17.6%	4.1%	0.9%	

[a]Conversion: One meter per second = 2.237 miles per hour.

[b]2.3% calm is proportionately distributed among the 16 directions in the 0-1.5 m/s column. For each direction the proportionality factor is the frequency of occurrence of the 0-3.2 m/s wind speed in the given direction divided by the frequency of occurrence of the 0-3.2 m/s wind speed for all directions.

Table 2.2. Mean and Maximum Wind Speeds and Directions for Spokane, Washington, 1967-1971

Month	Mean		Maximum	
	Speed, meters/second[a]	Direction	Speed, meters/second[a]	Direction
January	4.0	NE	26	SW
February	4.1	SSW	24	SW
March	4.3	SSW	24	SW
April	4.4	SW	22	SW
May	3.9	SSW	22	SW
June	3.9	SSW	17	SW
July	3.7	SW	19	SW
August	3.6	SW	17	SW
September	3.6	NE	17	SW
October	3.7	SSW	25	SW
November	3.7	NE	24	SW
December	3.9	NE	23	SW

[a]Conversion: One meter per second = 2.237 miles per hour.

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Table 2.3. Mean and Maximum Precipitation and Snowfall for Spokane, Washington, 1967-1971

Month	Precipitation, cm[a,b]		Snowfall, cm[b]	
	Mean	Maximum	Mean	Maximum
January	6.27	12.60	47.8	144.5
February	4.27	10.01	19.8	72.4
March	3.89	9.53	12.2	38.9
April	2.84	7.82	1.5	16.8
May	3.71	14.50	0.5	8.9
June	3.45	7.77	T	T
July	1.02	4.06	-	-
August	1.47	4.39	-	-
September	2.11	5.21	-	-
October	3.61	1.03	1.5	15.5
November	5.59	12.95	14.7	62.7
December	6.02	13.03	39.1	106.7

[a]Total precipitation of all types, in equivalent centimeters of liquid water.

[b]Conversion: 2.54 centimeters = 1 inch.

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Table 2.4. Joint Frequency of Annual Average Wind Speed and Direction for Rapid City, South Dakota, 1967-1971

Direction	Speed, meters/second[a]						Total
	0-1.5[b]	1.6-3.2	3.3-5.1	5.2-8.2	8.3-10.8	>10.8	
N	0.9%	1.8%	3.6%	3.8%	1.6%	0.5%	12.2%
NNE	0.7	1.0	1.4	0.7	0.1	0.0	3.9
NE	0.6	0.8	1.0	0.3	0.0	0.0	2.7
ENE	0.7	1.0	0.9	0.2	0.0	0.0	2.8
E	1.4	2.4	1.7	0.5	0.1	0.0	6.1
ESE	1.0	1.8	1.8	0.8	0.1	0.0	5.5
SE	1.1	2.6	3.0	1.6	0.3	0.0	8.6
SSE	0.7	1.7	2.4	2.0	0.5	0.1	7.4
S	1.0	1.6	1.4	1.3	0.7	0.1	6.1
SSW	0.4	0.8	0.5	0.2	0.1	0.0	2.0
SW	0.3	0.5	0.4	0.2	0.1	0.0	1.5
WSW	0.4	0.9	0.5	0.3	0.1	0.0	2.2
W	0.9	2.1	1.7	0.5	0.2	0.1	5.5
WNW	0.9	2.1	2.9	0.7	0.4	0.2	7.2
NW	0.6	1.5	2.2	2.2	1.5	1.8	9.8
NNW	0.7	1.4	2.9	4.8	3.9	2.8	16.5
Total	12.3%	24.0%	28.3%	20.1%	9.7%	5.6%	

[a]Conversion: One meter per second = 2.237 miles per hour.

[b]5.1% calm is proportionately distributed among the 16 directions.

Table 2.5. Mean and Maximum Wind Speeds and Directions for Rapid City, South Dakota, 1967-1971

Month	Mean		Maximum	
	Speed, meters/second[a]	Direction	Speed, meters/second[a]	Direction
January	4.7	NNW	29	SW
February	4.9	NNW	26	NW
March	5.6	NNW	29	W
April	5.9	NNW	27	NW
May	5.5	NNW	25	NW
June	4.8	NNW	25	NW
July	4.4	NNW	30	SW
August	4.6	NNW	29	NW
September	4.9	NNW	27	NW
October	5.0	NNW	26	NW
November	4.9	NNW	26	NW
December	4.6	NNW	27	W

[a]Conversion: One meter per second = 2.237 miles per hour.

Table 2.6. Mean and Maximum Precipitation and Snowfall for Rapid City, South Dakota, 1967-1971

	Precipitation, cm[a,b]		Snowfall, cm[b]	
Month	Mean	Maximum	Mean	Maximum
January	1.19	4.50	13.7	61.0
February	1.45	6.25	16.3	60.2
March	2.51	7.67	23.6	78.0
April	5.31	13.11	16.0	77.7
May	7.14	18.67	3.2	29.5
June	9.32	17.78	0.3	9.1
July	5.33	15.57	-	-
August	3.73	11.18	-	-
September	3.10	10.01	0.3	5.1
October	2.18	5.72	4.6	25.9
November	1.22	5.31	10.4	32.0
December	0.99	4.19	11.9	45.5

[a]Total precipitation of all types in equivalent centimeters of liquid water.

[b]Conversion: 2.54 centimeters = 1 inch.

Table 2.7. Joint Frequency of Annual Average Wind Speed and Direction for Casper, Wyoming, 1966-1975

	Speed, meters/second[a]						
Direction	0-1.5[b]	1.6-3.2	3.3-5.1	5.2-8.2	8.3-10.8	>10.8	Total
N	0.4%	1.5%	1.4%	0.8%	0.3%	0.1%	4.5%
NNE	0.4	1.9	2.2	2.1	0.6	0.1	7.3
NE	0.2	1.0	1.4	1.0	0.2	0.1	3.9
ENE	0.2	0.9	1.1	0.6	0.1	0.0	2.9
E	0.4	1.3	1.7	1.2	0.2	0.1	4.9
ESE	0.2	0.7	0.7	0.4	0.1	0.0	2.1
SE	0.2	0.6	0.5	0.2	0.0	0.0	1.5
SSE	0.2	0.7	0.4	0.1	0.0	0.0	1.4
S	0.2	0.7	0.4	0.1	0.0	0.0	1.7
SSW	0.2	0.9	1.8	4.5	4.3	2.4	14.1
SW	0.2	0.9	2.8	6.3	4.5	2.1	16.8
WSW	0.4	1.7	5.2	4.8	2.0	0.9	15.0
W	0.8	2.9	4.5	2.8	1.0	0.6	12.6
WNW	0.3	1.3	1.0	0.9	0.3	0.1	3.9
NW	0.2	1.1	1.0	0.5	0.2	0.0	3.0
NNW	0.4	1.8	1.3	0.6	0.2	0.1	4.5
Total	4.9%	19.9%	27.4%	27.1%	14.1%	6.6%	

[a]Conversion: One meter per second = 2.237 miles per hour.

[b]2.2% calm is proportionately distributed among the 16 directions.

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Table 2.8. Mean and Maximum Wind Speeds and Directions for Casper, Wyoming, 1966-1975

Month	Mean		Maximum	
	Speed, meters/second[a]	Direction	Speed, meters/second[a]	Direction
January	7.6	SW	26	SSW
February	6.8	SW	26	SW
March	6.4	SW	36	WSW
April	5.8	WSW	24	WSW
May	5.3	WSW	26	NW
June	5.0	WSW	23	N
July	4.5	WSW	23	WSW
August	4.7	SW	22	WSW
September	5.0	WSW	24	NW
October	5.5	SW	25	WSW
November	6.5	SW	22	WSW
December	7.2	SW	28	SSW

[a]Conversion: One meter per second = 2.237 miles per hour.

Average annual precipitation ranges from 30 to 40 cm (12 to 16 inches); much of this is received during the period May-July in the form of wet snow and rain. The mean and maximum monthly total precipitation and snowfall for Casper are listed in Table 2.9. Annual evaporation potential exceeds precipitation, averaging 100 to 180 cm (40 to 70 inches).[4] Winter storms are common. Thunderstorms, occasionally spawning tornadoes, are frequent in spring and summer. The tornadoes tend to be notably smaller, shorter-lived, and less destructive than tornadoes occuring farther east.

2.4 SOUTHERN ROCKY MOUNTAINS

The climate of the Southern Rocky Mountains region is typical of that occurring in mountainous terrain, with severe winters and showery summers. Spring and fall usually include warm days and cool nights. Daily weather is influenced by elevation, which is responsible for large daily fluctuations in temperatures. Temperature decreases and precipitation increases with increasing altitude. Summer highs are near 32°C (90°F) and winter lows near -51°C (-60°F).[1] Prevailing winds are from the south and the speeds are quite high. Representative data on wind speed and direction, for Denver, Colorado, are given in Table 2.10.[9] Strong winds are frequent throughout the year (Table 2.11).[10]

Average annual precipitation ranges from 25 to 80 cm (10 to 32 inches), and large variations occur in monthly and seasonal totals. Late spring and summer precipitation is normally derived from scattered thunderstorms. The mean and maximum monthly total precipitation and snowfall for Denver are listed in Table 2.12. Annual evaporation potential exceeds precipitation, averaging 100 to 150 cm (45 to 60 inches).[4] Winter storms, with snowfall, low temperatures, and high winds, are common. Spring and summer thunderstorms, with hail and occasional tornadoes, occur frequently. Tornadoes tend to be smaller, shorter-lived, and less destructive than tornadoes occurring farther east.

2.5 COLORADO PLATEAU

The climate of the Colorado Plateau is semiarid. Winters are harsh, and summers are generally mild and cool. Spring and fall transition seasons tend to be dry.[1] Temperatures range from summer highs near 38°C (100°F) to winter lows near -18°C (0°F), with considerable daily variations as a result of the high elevations. Prevailing winds come from the west to southwest. Representative data on wind speed and direction, for Grand Junction, Colorado, are given in Table 2.13.[11] Strong winds are frequent throughout the area (Table 2.14).[12]

Table 2.9. Mean and Maximum Precipitation and Snowfall for Casper, Wyoming, 1966-1975

Month	Precipitation, cm[a,b]		Snowfall, cm[b]	
	Mean	Maximum	Mean	Maximum
January	1.75	3.45	25.4	99.8
February	1.83	2.57	23.6	60.5
March	2.87	6.17	31.5	83.6
April	4.88	14.61	24.4	55.6
May	5.89	9.98	12.7	55.6
June	3.76	7.90	1.0	11.4
July	2.97	7.75	-	-
August	2.18	7.09	-	-
September	3.10	7.90	1.8	10.4
October	2.82	5.08	12.5	56.1
November	2.08	4.65	25.9	65.5
December	1.65	2.64	20.1	37.3

[a]Total precipitation of all types in equivalent centimeters of liquid water.

[b]Conversion: 2.54 centimeters = 1 inch.

Table 2.10. Joint Frequency of Annual Average Wind Speed and Direction for Denver, Colorado, 1970-1974

Direction	Speed, meters/second[a]						Total
	0-1.5[b]	1.6-3.2	3.3-5.1	5.2-8.2	8.3-10.8	>10.8	
N	1.1%	2.8%	3.3%	1.8%	0.4%	0.2%	9.6%
NNE	0.7	1.6	1.8	0.9	0.2	0.0	5.2
NE	0.8	1.6	1.5	0.7	0.1	0.0	4.7
ENE	0.6	1.4	1.4	0.5	0.1	0.0	4.0
E	1.3	2.6	2.0	0.5	0.0	0.0	6.4
ESE	0.8	1.8	1.4	0.4	0.0	0.0	4.4
SE	0.8	1.9	1.5	0.3	0.0	0.0	4.5
SSE	0.9	2.1	1.6	0.5	0.1	0.0	5.2
S	2.1	6.0	8.2	2.6	0.3	0.0	19.2
SSW	1.5	4.6	4.6	1.1	0.1	0.0	11.9
SW	1.1	2.5	1.7	0.4	0.1	0.0	5.8
WSW	0.7	1.2	0.7	0.3	0.1	0.0	3.0
W	0.4	0.9	1.0	1.0	0.4	0.1	3.8
WNW	0.3	0.7	0.9	1.0	0.5	0.2	3.6
NW	0.5	1.1	1.2	1.0	0.4	0.1	4.3
NNW	0.5	1.5	1.4	0.8	0.2	0.0	4.4
Total	14.1	34.3	34.2	13.8	3.0	0.6	

[a]Conversion: One meter per second = 2.237 miles per hour.

[b]6.2% calm is proportionately distributed among the 16 wind directions.

Table 2.11. Mean and Maximum Wind Speeds and Directions for Denver, Colorado, 1970-1974

Month	Mean		Maximum	
	Speed, meters/second[a]	Direction	Speed, meters/second[a]	Direction
January	4.2	S	21	SW
February	4.2	S	22	NW
March	4.5	S	24	NW
April	4.6	S	25	NW
May	4.2	S	19	SW
June	4.1	S	21	S
July	3.8	S	25	SW
August	3.7	S	19	SW
September	3.7	S	21	NW
October	3.7	S	20	NW
November	3.9	S	21	W
December	4.0	S	23	NE

[a]Conversion: One meter per second = 2.237 miles per hour.

Table 2.12. Mean and Maximum Precipitation and Snowfall for Denver, Colorado, 1970-1974

Month	Precipitation, cm[a,b]		Snowfall, cm[b]	
	Mean	Maximum	Mean	Maximum
January	1.55	3.66	20.8	60.2
February	1.70	4.22	20.1	46.5
March	3.08	7.34	32.3	74.2
April	4.90	10.59	22.9	71.9
May	6.71	18.57	4.1	34.5
June	4.90	11.91	T	0.8
July	4.52	16.28	-	-
August	3.28	11.35	-	-
September	2.87	11.86	4.6	54.1
October	2.87	10.59	9.4	79.2
November	1.93	7.54	20.1	99.3
December	1.09	7.21	16.3	78.2

[a]Total precipitation of all types in equivalent centimeters of liquid water.

[b]Conversion: 2.54 centimeters = 1 inch.

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Table 2.13. Joint Frequency of Annual Average Wind Speed and Direction for Grand Junction, Colorado, 1960-1964

Direction	Speed, meters/second[a]						Total
	0-1.5[b]	1.6-3.2	3.3-5.1	5.2-8.2	8.3-10.8	>10.8	
N	1.2%	1.5%	1.0%	0.3%	0.0%	0.0%	4.0%
NNE	0.8	0.7	0.6	0.2	0.0	0.0	2.3
NE	^.9	1.1	0.5	0.1	0.1	0.0	2.7
ENE	1.6	2.2	0.7	0.2	0.0	0.0	4.7
E	1.8	2.3	0.6	0.2	0.0	0.0	4.9
ESE	3.7	6.7	7.5	3.4	0.3	0.0	21.6
SE	2.8	5.6	6.2	1.3	0.1	0.0	16.0
SSE	1.9	2.9	2.0	0.6	0.1	0.0	7.5
S	1.6	1.9	1.1	0.5	0.1	0.1	5.3
SSW	0.9	0.6	0.2	0.2	0.0	0.1	2.0
SW	1.1	0.5	0.3	0.2	0.0	0.0	2.1
WSW	0.9	0.7	^.2	0.1	0.0	0.0	1.9
W	1.2	1.1	0.7	0.2	0.2	0.0	3.4
WNW	2.5	3.4	2.7	0.8	0.2	0.0	9.6
NW	1.8	2.3	2.5	0.7	0.1	0.0	7.4
NNW	1.0	1.4	1.5	0.6	0.1	0.0	4.6
Total	25.7%	34.9%	28.3%	9.6%	1.3%	0.2%	

[a]Conversion: One meter per second = 2.237 miles per hour.

[b]7.5% calm is proportionately distributed among the 16 directions.

Table 2.14. Mean and Maximum Wind Speeds and Directions for Grand Junction, Colorado, 1960-1964

Month	Mean		Maximum	
	Speed, meters/second[a]	Direction	Speed, meters/second[a]	Direction
January	2.5	ESE	24	S
February	3.0	ESE	25	W
March	3.8	ESE	29	S
April	4.3	ESE	26	W
May	4.3	ESE	29	NW
June	4.4	ESE	30	S
July	4.2	ESE	25	SE
August	4.0	ESE	25	W
September	4.1	ESE	27	S
October	3.6	ESE	27	NW
November	3.0	ESE	24	NW
December	2.6	ESE	21	NW

[a]Conversion: One meter per second = 2.237 miles per hour.

Average annual precipitation ranges from 20 to 40 cm (8 to 16 inches),[12] and large variations occur in monthly and seasonal totals. Much of the precipitation occurs during the late summer. Mean and maximum monthly total precipitation and snowfall for Grand Junction are listed in Table 2.15. Annual evaporation potential exceeds precipitation, averaging 150 to 200 cm (60 to 80 inches).[4] Winter storms are common, and thunderstorms are frequent in spring and summer, occasionally spawning tornadoes. These tornadoes tend to be smaller, shorter-lived, and less destructive than those occurring farther east.

2.6 TEXAS COASTAL PLAINS

The climate of the Texas Coastal Plains region varies from humid subtropical along the Gulf of Mexico to semiarid further inland. Little change occurs in the daily weather, except for occasional rainshowers or tropical storms. Seasons are distinct, with warm breezy summers and mild winters. Spring and fall are short. Temperatures vary from summer highs greater than 38°C (100°F) to winter lows near 0°C (32°F). The prevailing easterly to southeasterly winds are strongly influenced by the Gulf of Mexico. Representative data on wind speed and direction, for Beeville, Texas, are given in Table 2.16.[13] Strong winds are fairly frequent throughout the year (Table 2.17).[14]

Table 2.15. Mean and Maximum Precipitation and Snowfall for Grand Junction, Colorado, 1960-1964

	Precipitation, cm[a,b]		Snowfall, cm[b]	
Month	Mean	Maximum	Mean	Maximum
January	1.63	6.25	19.8	85.6
February	1.55	3.96	11.2	46.7
March	1.91	4.45	10.9	27.9
April	2.01	4.95	3.1	36.3
May	1.60	4.55	T	3.3
June	1.40	5.26	-	-
July	1.17	3.89	-	-
August	2.67	8.84	-	-
September	2.13	6.40	0.3	7.9
October	2.36	8.76	1.8	15.5
November	1.55	4.29	7.9	30.7
December	1.40	4.80	14.5	42.4

[a]Total precipitation of all types in equivalent centimeters of liquid water.

[b]Conversion: 2.54 centimeters = 1 inch.

Table 2.16. Joint Frequency of Annual Average Wind Speed and Direction for Beeville, Texas, 1965-1969

Direction	Speed, meters/second[a]						Total
	0-1.5[b]	1.6-3.2	3.3-5.1	5.2-8.2	8.3-10.8	>10.8	
N	2.2%	2.3%	2.4%	1.8%	0.3%	0.0%	9.0%
NNE	2.5	2.5	2.2	1.0	0.1	0.0	8.3
NE	2.5	2.2	1.5	0.4	0.0	0.0	6.6
ENE	2.9	2.0	1.1	0.3	0.0	0.0	6.3
E	4.7	3.1	1.8	0.3	0.0	0.0	9.9
ESE	3.7	3.1	2.7	0.9	0.0	0.0	10.4
SE	3.5	3.7	4.6	2.8	0.1	0.0	14.7
SSE	3.1	3.3	4.5	3.3	0.2	0.1	14.5
S	2.4	2.4	2.8	1.3	0.1	0.0	9.0
SSW	0.7	0.6	0.5	0.1	0.0	0.0	1.9
SW	0.4	0.2	0.1	0.0	0.0	0.0	0.7
WSW	0.4	0.2	0.1	0.0	0.0	0.0	0.7
W	0.7	0.5	0.2	0.1	0.0	0.0	1.5
WNW	0.6	0.4	0.2	0.1	0.0	0.0	1.3
NW	0.9	0.5	0.3	0.2	0.0	0.0	1.9
NNW	1.2	0.8	0.7	0.5	0.1	0.0	3.3
Total	32.4%	27.8%	25.7%	13.1%	0.9%	0.1%	

[a]Conversion: One meter per second = 2.237 miles per hour.

[b]11.4% calm is proportionately distributed among the 16 directions.

Table 2.17. Mean and Maximum Wind Speeds and Directions for Corpus Christi, Texas, 1965-1969

Month	Mean		Maximum	
	Speed, meters/second[a]	Direction	Speed, meters/second[a]	Direction
January	5.4	SSE	27	NE
February	5.8	SSE	23	N
March	6.3	SSE	25	S
April	6.5	SE	22	SE
May	5.9	SE	29	NE
June	5.4	SE	25	SE
July	5.2	SSE	18	S
August	4.9	SSE	54	SW
September	4.6	SE	32	E
October	4.5	SE	21	N
November	5.1	SSE	21	N
December	5.0	SSE	21	NW

[a]Conversion: One meter per second = 2.237 miles per hour.

Average annual precipitation (snowfall is rare) ranges from 35 to 115 cm (15 to 45 inches), and relatively large variations occur in monthly and seasonal totals. Tropical storms from June through November strongly affect rainfall. Mean and maximum monthly total precipitation and snowfall for Corpus Christi are listed in Table 2.18. Annual evaporation potential exceeds precipitation, averaging 165 to 215 cm (65 to 85 inches).[4] Tropical storms with rainfall and high winds are common. Tornadoes occasionally occur and can be quite severe. Severe winter storms occur only about once every three to four years.

Table 2.18. Mean and Maximum Precipitation and Snowfall for Corpus Christi, Texas, 1965-1969

Month	Precipitation, cm[a,b]		Snowfall, cm[b]	
	Mean	Maximum	Mean	Maximum
January	4.01	27.38	0.3	3.0
February	4.95	13.31	T	2.8
March	2.79	12.19	T	T
April	5.33	20.42	-	-
May	8.05	23.83	-	-
June	6.78	33.91	-	-
July	4.78	27.91	-	-
August	8.13	32.11	-	-
September	12.45	51.64	-	-
October	7.04	27.08	-	-
November	4.14	21.67	T	T
December	3.89	19.81	0.0	0.0

[a]Total precipitation of all types in equivalent centimeters of liquid water.

[b]Conversion: 2.54 centimeters = 1 inch.

References

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6. "Local Climatological Data, 1975, Rapid City, South Dakota," National Oceanic and Atmospheric Administration, 1976.

7. "Monthly & Annual Wind Distribution by Pasquill Stability Classes for Casper, Wyoming, 1966-1975," National Oceanic and Atmospheric Administration, 1976.

8. "Local Climatological Data, 1975, Casper, Wyoming," National Oceanic and Atmospheric Administration, 1976.

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10. "Local Climatological Data, 1975, Denver, Colorado," National Oceanic and Atmospheric Administration, 1976.

11. "Seasonal & Combined Wind Distribution by Pasquill Stability Classes for Grand Junction, Colorado, 1960-1964," National Oceanic and Atmospheric Administration, 1973.

12. "Local Climatological Data, 1975, Grand Junction, Colorado," National Oceanic and Atmospheric Administration, 1976.

13. "Seasonal & Annual Wind Distribution by Pasquill Stability Classes for Beeville, Texas, 1965-1969," National Oceanic and Atmospheric Administration, 1974.

14. "Local Climatological Data, 1975, Corpus Christi, Texas," National Oceanic and Atmospheric Administration, 1976.

3. TOPOGRAPHY

3.1 GENERAL ASPECTS

The topography of the six regions varies over a wide range.[1] In Colorado and Wyoming and farther north the terrain features high mountain ranges separated by intermontane valleys. In Utah and Arizona there are high tablelands and mesas and many landforms sculptured by wind and water erosion. The Dakotas, Nebraska, and eastern Montana are flatter, although there is some relief in the form of scattered mountains and hills. In southeast Texas, the terrain is quite flat, with an occasional hill and escarpment.

3.2 THE SIX REGIONS

3.2.1 Northern Rocky Mountains

The northern part of the region is characterized by mountain ranges which lie in a north-south direction and extend into Canada (Fig. 3.1). Valleys have been eroded along fault-controlled lines of weakness; several of these valleys contain elongated bodies of water, such as Flathead, Pend Oreille and Cour d'Alene lakes. The Rocky Mountain Trench is an 800-km (500-mile) long rift valley bordering the Northern Rocky Mountains on the west. This straight valley divides into three valleys in northern Montana. To the west of the trench lie the Selkirk Mountains, a range of folded and faulted Precambrian rock. The Northern Rocky Mountains extend along the eastern side of the trench and consist of overlapping blocks of sedimentary rock thrust-faulted over one another.[2] These three structures end in Montana and Idaho at a region of transverse faults oriented in a northwest-southeast direction. To the south of this region, in southern Montana and central Idaho down to the Snake River plains, there are northerly trending valleys and block-faulted mountain ranges, dome mountains, and granite batholiths (large masses of molten granite which have intruded through the surface layers).

Most of the Northern Rocky Mountains region drains towards the Pacific Ocean as the Continental Divide lies in the easternmost part of the region. Also, the streams draining to the west have in general eroded more deeply into the terrain than those draining east.

3.2.2 Western Great Plains

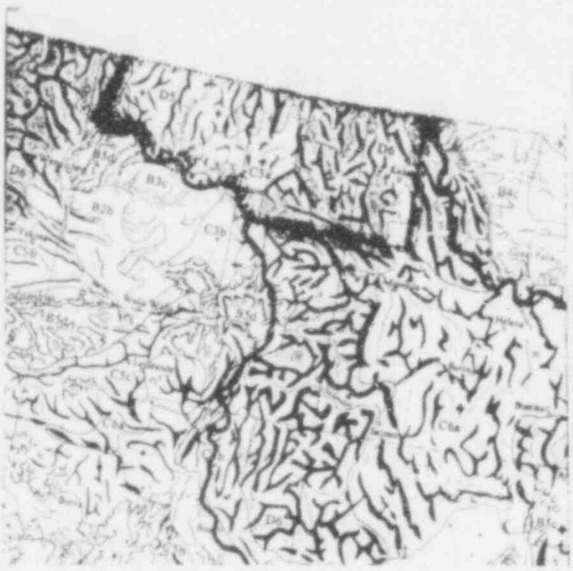
The Western Great Plains is a region of eastward-sloping plains which extend from an elevation of 1700 m (5500 ft) at the base of the Rocky Mountains to an elevation of about 600 m (2000 ft) where the plains grade into the central lowlands (Fig. 3.2). The flatness of the plains is interrupted in some places by dome mountains and areas of sand dunes.

Structurally much of the region is overlain by sediments eroded eastward from the Rocky Mountains during Cenozoic times (the last 65 million years). The volume of this eroded material is roughly equal to the present volume of the Rocky Mountains.[2] The southern end of the region, which forms the Edwards Plateau in Texas, is underlain by thick limestone deposits. The northern part of the region (the Missouri Plateau) was glaciated, and as a result it contains glacial moraines as well as rivers incised some hundreds of feet into the plateau.

The Black Hills of South Dakota, so named because they are heavily forested by dark conifers, are a large area of dome mountains in the north of the region. The dome is elliptical and is 200 km (125 miles) long from north to south and 97 km (60 miles) wide and reaches an elevation of 2200 m (7200 ft).[3] Other domal formations in the region include the Sweetgrass Hills and the Little Rocky, Highwood, Moccasin, and Judith Mountains.

Besides glacial moraines, areas of relief which are not domal include the Sand Hills of Nebraska. This region of western Nebraska, south of Pine Ridge, is covered by sand dunes over an area of about 61,000 km^2 (24,000 mi^2). Within depressions between the dunes there are many small ephemeral lakes and ponds. In the southern part of South Dakota badlands topography has developed along river bluffs where erosion is rapid and fine-grained sediments outcrop.

TOPOGRAPHY



CLASSES OF LAND-SURFACE FORM

Open Hills and Mountains

C5a	Open low mountains more than 75% of gentle slope is in lowland
C6a	Open high mountains more than 75% of gentle slope is lowland
B3c	Tablelands, moderate relief
B5d	Tablelands, high relief
D5	Low mountains
D6	High mountains

NORTHERN ROCKY MOUNTAINS

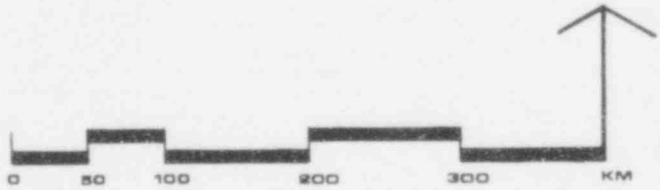


Fig. 3.1. Topography of the Northern Rocky Mountains Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

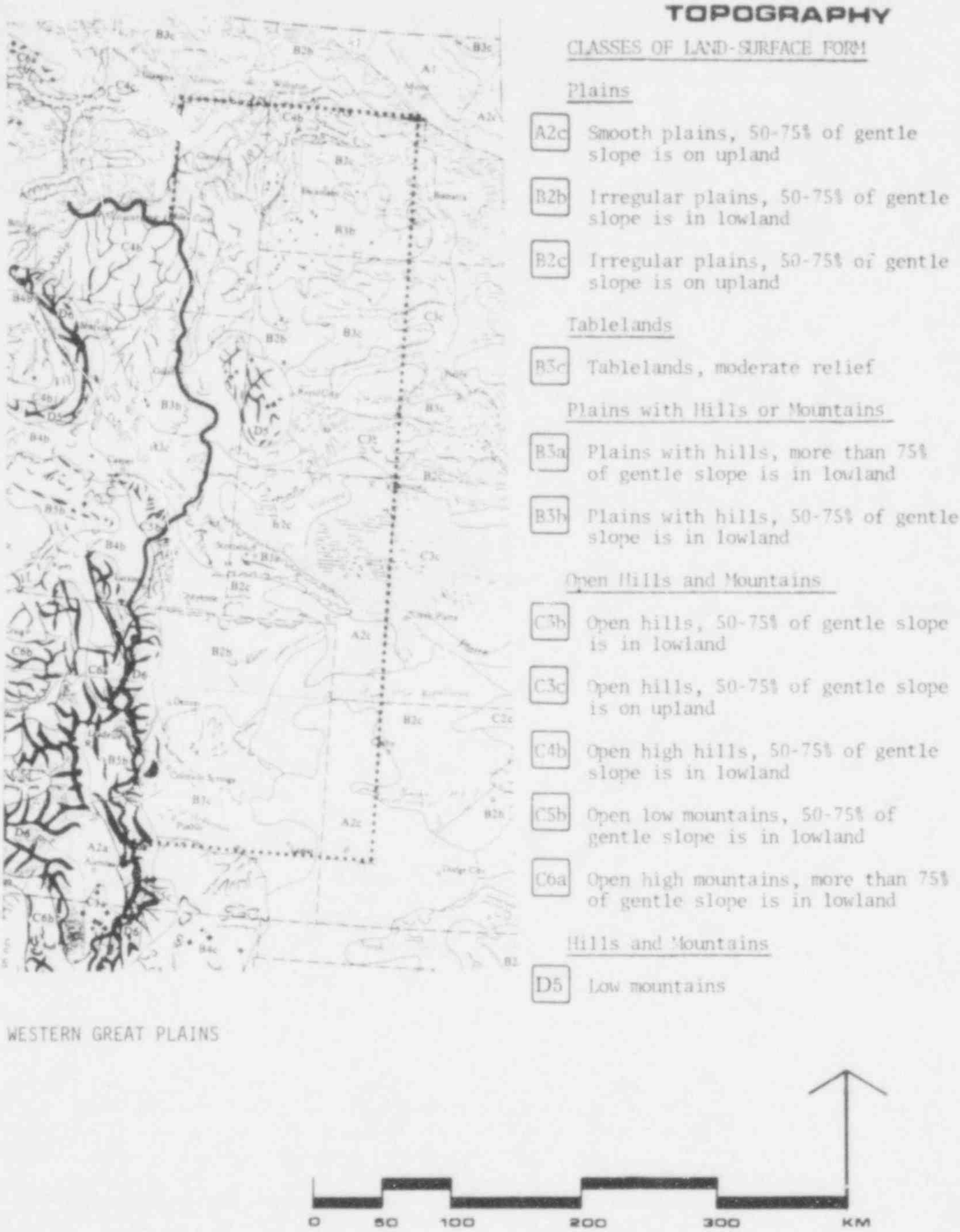


Fig. 3.2. Topography of the Western Great Plains Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

3.2.3 Wyoming Basin

The Wyoming Basin is a large, relatively flat area, mostly in Wyoming, which separates the Northern Rocky Mountains from the Southern Rocky Mountains (Fig. 3.3). For the most part, elevations range from 1800 m to 2400 m (6000 to 8000 ft), with an average elevation of 2100 m (7000 ft). The basin is almost surrounded by mountain ranges, with the Bighorn Mountains and Beartooth Mountains to the north, the Wind River and Wasatch Mountains to the west, the Uinta Mountains to the south, and the Laramie Range to the southeast. It is possible to traverse the basin from the Western Great Plains region to the Colorado Plateau region without crossing any mountains. The Continental Divide is scarcely noticeable in the Wyoming Basin region.

Geologically, the Laramie, Medicine Bow, and Park Ranges, part of the Southern Rocky Mountains, plunge in a northwesterly direction under the Wyoming Basin and divide it into small basins. These mountains have been buried under a thick covering of sediments which fill the basins and are now being partially exhumed. The Owl Creek Range separates the Bighorn Basin from the rest of the Wyoming Basin.

There are many types of landforms within these mountain ranges and basins. The most extensive tract of sand dunes is in the northern part of the Rock Spring uplift. Silt dunes occur in the Great Divide Basin (through which the Continental Divide passes) as a result of mud and silt being washed down into local playas. Playa lakes are found in several areas, and sand dunes are formed when there is an adequate supply of sand. Playas collect the small amount of rainfall runoff that flows from the western part of the Wyoming Basin. Because of the low rainfall, several areas of internal drainage have formed, particularly in the Great Divide Basin. Ephemeral lakes form in these playas. Eventually, the waters evaporate and leave alkali deposits on the basin floors.

There are many other lakes in the Wyoming Basin, including those formed by natural and man-made dams across the mouths of canyons and in the smaller basins. The numerous man-made lakes have been built for water storage for domestic and agricultural uses.

In areas where shales form the surface rock, deflation basins (basins scoured out by wind) are common. The most striking example is Big Hollow in the Laramie Basin. Badland topography is found in areas of weak Tertiary rocks (shales) which have rainfall that falls frequently as torrential thundershowers.[4] The best example is Hell's Halfacre, 69 km (40 miles) west of Casper on the headwaters of the South Fork of the Powder River. In other areas, cuestas and hogbacks (both landforms are eroded edges of sloping resistant formations which protrude from the surrounding terrain), rock benches, stream terraces, mesas, buttes, and cinder cones occur.

Because of uplifts and erosion, many of the rivers in the area have anomalous courses which pass through the mountains instead of through the lower valleys and basins. For example, the North Platte River, instead of following the valley floor between the Park Range and the Medicine Bow Mountains, flows in a deep gorge cut into hard rock on the flank of the Medicine Bow Mountains. The rim of the gorge is 200 m (700 ft) above the valley floor. Other rivers in the basin with anomalous drainage patterns include the Laramie, Sweetwater, Bighorn, and Green rivers. No river in Wyoming is free-flowing for its entire length.[2]

3.2.4 Southern Rocky Mountains

The Southern Rocky Mountains extend from north-central New Mexico to southeastern Wyoming (Fig. 3.4). With the exception of the San Juan Mountains in southwestern Colorado, the Southern Rocky Mountains consist predominantly of a group of north-south trending mountain ranges of roughly anticlinal structure. They are separated by intermontane basins. Ranges in the eastern part of the region are the Laramie Range (the northernmost), the Front Range, the Wet Mountains, and the Sangre de Cristo Range (the southernmost). The Park Range, the Gore Range, the Wasatch Range, the Elk Mountains, the San Juan Mountains, and the Jemez Mountains lie in the western portion. There are 831 peaks which reach elevations of between 3300 and 4200 m (11,000 and 14,000 ft) and 53 peaks over 4200 m (14,000 ft). Among the major peaks are Longs Peak, Pikes Peak and Mount Evans.

There are four intermontane basins separating the two major mountain belts. The North and Middle Parks form a north-south trending basin of 160 × 65 km (100 × 40 miles). A third basin, South Park, is approximately 60 × 75 km (35 × 45 miles) in dimension and is actually a granite plateau 3000 m (10,000 ft) high. Surrounding mountains tower over it.

The San Luis Valley is an intermontane basin between the Sangre de Cristo Range and the San Juan Mountains. The valley extends for 240 km (150 miles) from north to south and is about 80 km (50 miles) wide. It is an extremely flat valley with a few volcanic hills and extensive stream deposits. In the south it becomes the trough of the Rio Grande. An alluvial fan [32 km (20 miles) long] was built by the Rio Grande where the river enters the San Luis Valley near Del Norte.

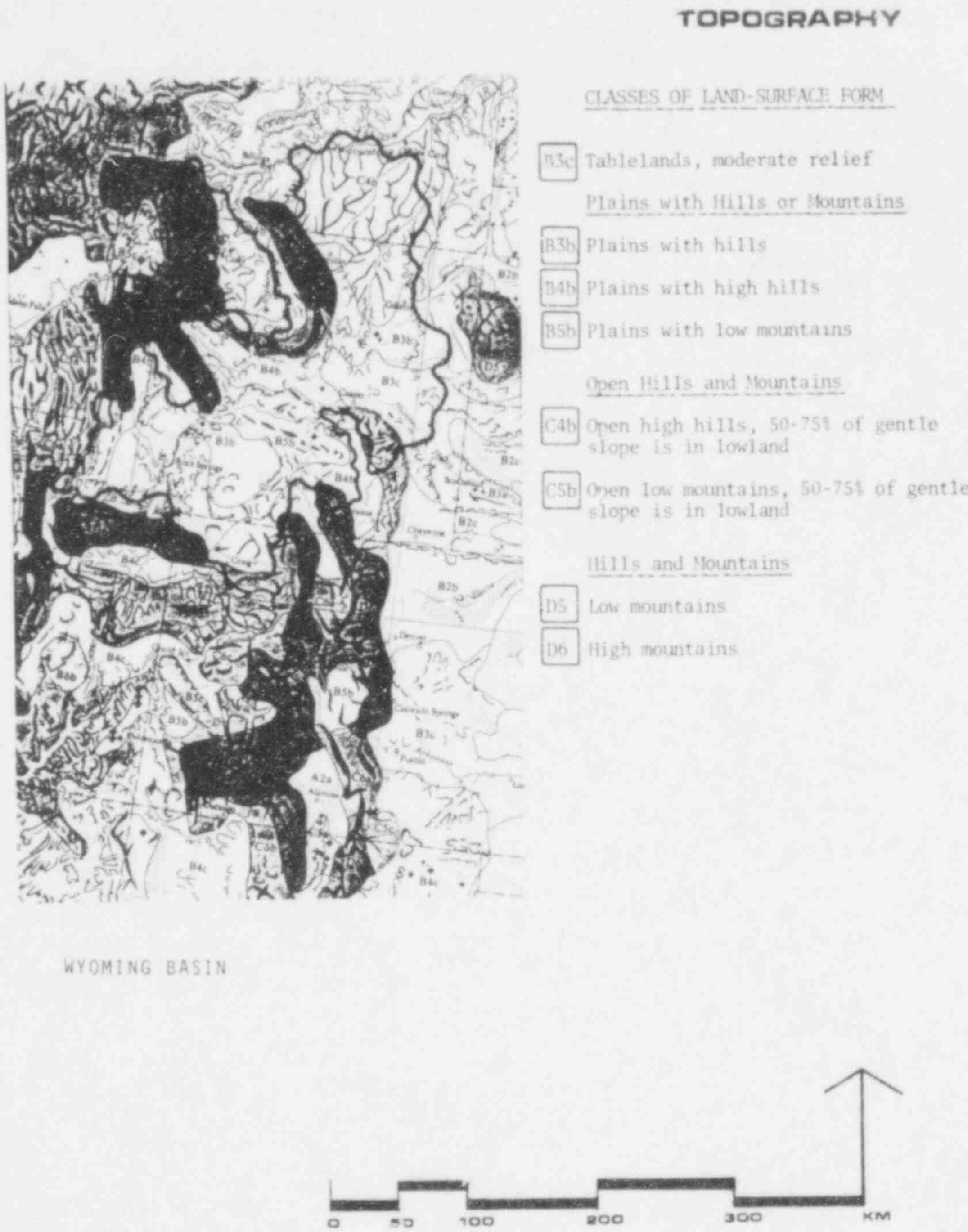


Fig. 3.3. Topography of the Wyoming Basin Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

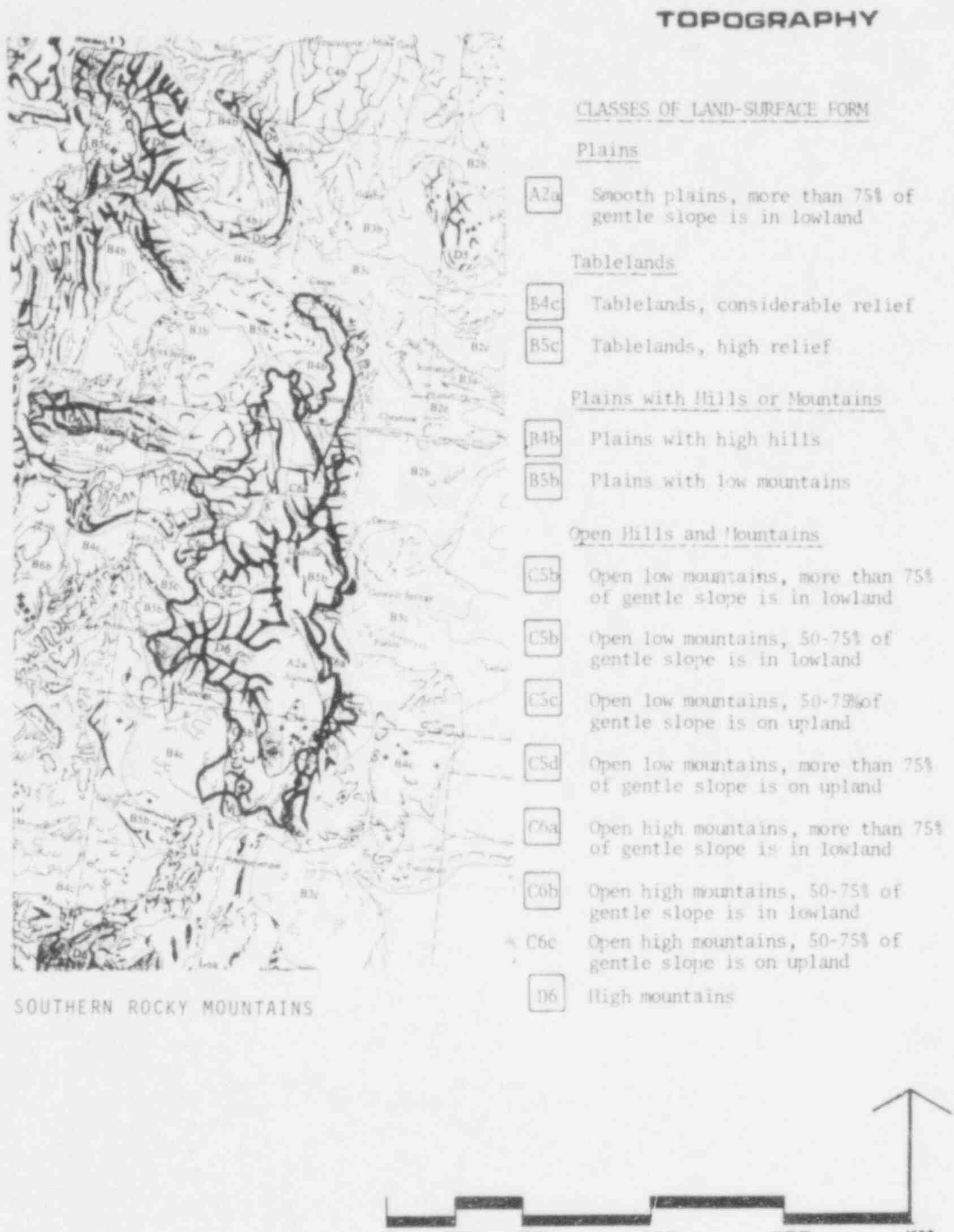


Fig. 3.4. Topography of the Southern Rocky Mountains Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

The San Juan Mountains are different from the other ranges in the region in that they are composed chiefly of volcanic materials--lavas, mudflows, and ash. One ash formation is estimated to include 4100 km^3 (1000 mi^3) of volcanic ash. Several calderas (collapsed volcanic areas, or sinks) with diameters of 15 to 20 km (10 to 12 miles) are present.

For the most part, the other mountains consist of anticlinal uplifts of Precambrian rock at the core, with younger formations exposed on the flanks. Two large granite batholiths are present, one at Pikes Peak which covers 3800 km^2 (1500 mi^2) and the other in the Laramie Range which covers 4400 km^2 (1700 mi^2).[2]

Extensive mineralization is present throughout the area. It occurs mainly in regions where irregular pipelike masses of hot rock 1.5 to 6 km (1 to 4 miles) in diameter were forcibly injected into the older formations, which formed the walls. The hot gases and liquids present altered the rock walls and resulted in the extensive mineralization.

Two-thirds of the region drains to the west and one-third drains to the east. The main eastward flowing rivers are the North and South Platte and the Arkansas. The Rio Grande drains the region to the south (and then to the east), and the Colorado, San Juan, and Gunnison drain the region to the west. The rivers draining to the west have cut their valleys more deeply than rivers of comparable drainage area and discharge flowing to the east.[2]

3.2.5 Colorado Plateau

The Colorado Plateau covers an area of about 333,000 km^2 (130,000 mi^2) in Colorado, Utah, New Mexico, and Arizona (Fig. 3.5). Topographically, the plateau can be characterized as a high saucer-shaped area tilted down towards the northeast, where at the low edge it adjoins the Rocky Mountains. The average elevation of the general surface is about 1500 m (5000 ft); however, there are small plateaus and mountains with elevations up to 3300 m (11,000 ft), particularly in the southwestern and western areas of the plateau.

Mountains, many of volcanic origin, dot the plateau region, particularly in the south and west. Several areas of upwarp and small, high plateaus consist of fault blocks separated by valleys and lower areas. The Uinta basin in the north of the Colorado Plateau is the lowest part of the plateau.

The surface of the plateau contains many outstanding landforms. These include deeply cut canyons with steep and brilliantly colored and sculptured walls, cliffs, and other areas which have been eroded by wind and water into varied landforms, including overhanging cliffs, arches and bridges, and pedestal rocks. The region contains many national parks and monuments that include examples of these varied landforms. The most dominant and spectacular feature in the Colorado Plateau is the Grand Canyon. It is over 320 km (200 miles) long. The Colorado River has cut the canyon through the high southwest region of sedimentary rock that ranges in depth from 1000 to 1800 m (3500 to 6000 ft). In the national park area the canyon is about 19 km (12 miles) wide from rim to rim.

3.2.6 Texas Coastal Plains

Climate and physiography interact to form the characteristic low relief of the Texas Coastal Plains (Fig. 3.6). In some parts of the lower coastal region, mobile sand sheets are blown across reaches of sparse vegetation. The winds lift, transport, and deposit sand and silt over a vast area. The highest altitude in the coastal region, in Bee County, is 165 m (540 ft) above mean sea level.

The West Gulf section is a belted coastal plain with a parallel series of lowlands and cuestas. Where the Great Plains topography of the north meets the coastal plain, there is an abrupt uplifting along a fault known as the Balcones Escarpment. The uranium deposits of the region are located between the lowland belt at the base of the escarpment and the Gulf Coast. Part of the region is characterized by a gently rolling landscape, dotted with areas of trees or brush. Other sections consist of dissected prairie lands and woodlands.

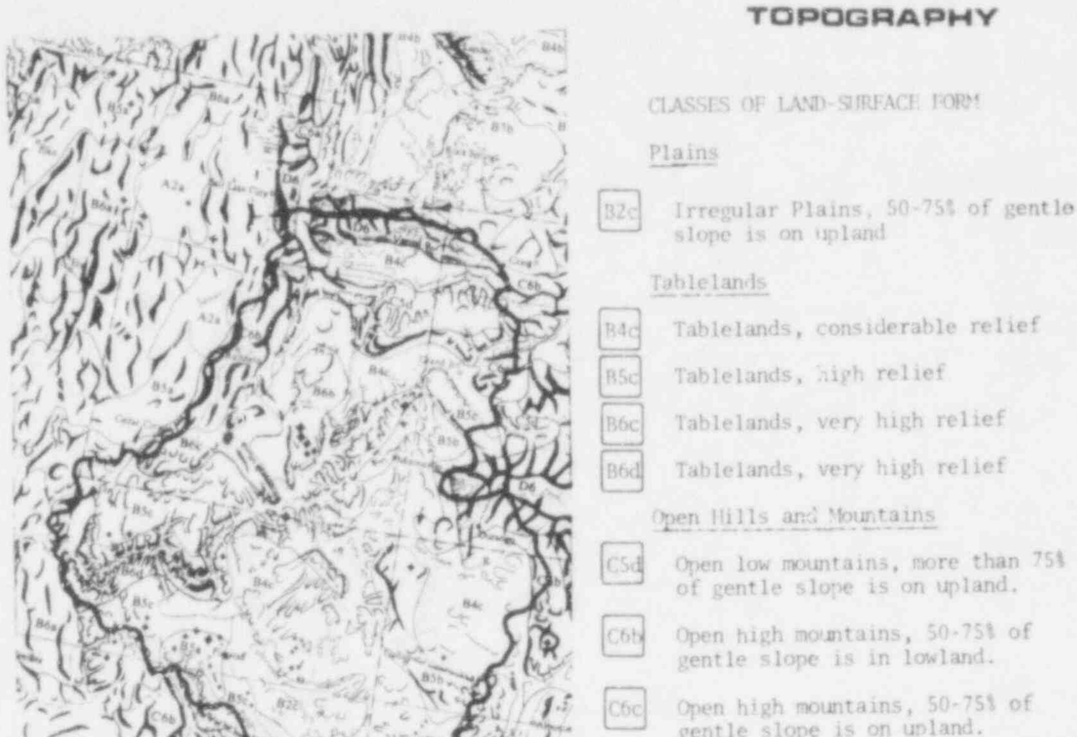


Fig. 3.5. Topography of the Colorado Plateau Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

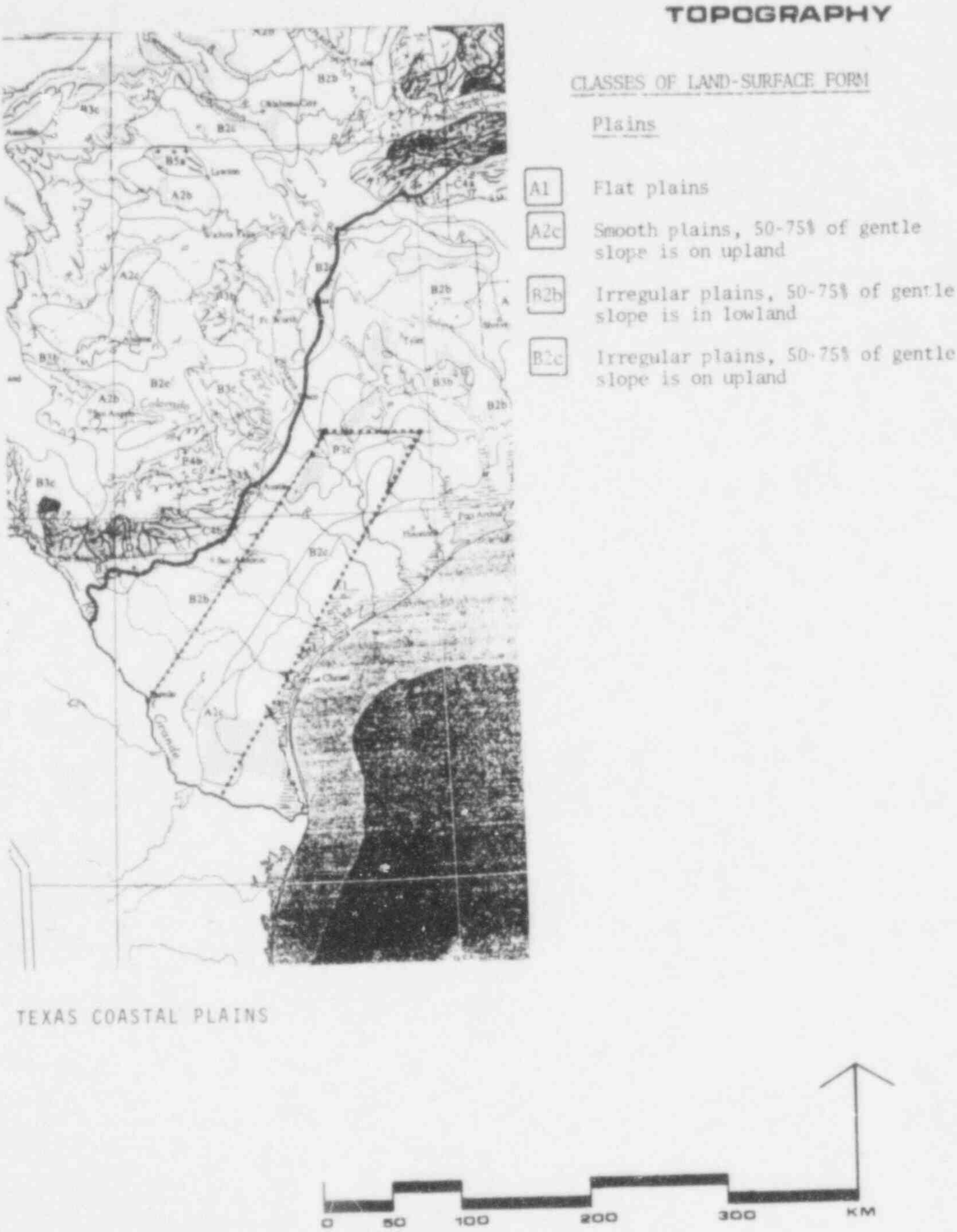


Fig. 3.6. Topography of the Texas Coastal Plains Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

References

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4. LAND RESOURCES AND USES

4.1 GENERAL ASPECTS

The term "land use" does not have a precise definition as it includes several concepts.[1] One concept commonly associated with land use is man's activities on the land. However, a given piece of land can have several activities, such as land that is used simultaneously for timber production, grazing, and recreation. In the western United States, the primary activity on the land is grazing, and the major secondary activity is timber production.[2-6]

Land use is affected by natural features. In the West, the geology and topography strongly influence climate, soils, vegetation and water availability, which in turn condition land use.[2,3] As a consequence, human population densities are low, with the most concentrated development being associated with water, mineral resources, or service centers. The scarcity of water generally restricts the amount of land and the locations that can be used for urban areas and cropland.

Institutional factors greatly influence land use. In the western states the Federal Government is the biggest land owner.[6-8] In Utah, for example, the Federal Government owns two-thirds of the land in the state (Table 4.1). Most of the Federal holdings are administered by the Forest Service (Department of Agriculture) and the Bureau of Land Management (BLM--Department of the Interior).[2] The Forest Service lands are generally at the higher altitudes and are used for summer grazing and timber production, while BLM lands are generally at lower altitudes and are used primarily for grazing.

Table 4.1. Percentages of Lands Owned by the Federal Government and Administered by Federal Agencies in Selected States[a]

State	Owned by Federal Government	Administered by Forest Service	Administered by Bureau of Land Management	Administered by Other Federal Agencies
Arizona	44%	16%	17%	11%
Colorado	36	22	13	1
Idaho	64	38	23	3
Montana	30	18	8.7	3.3
Nebraska	1.4	0.7	<0.1	0.6
New Mexico	34	12	17	5
North Dakota	5.2	2.5	0.2	2.5
South Dakota	6.7	4.1	0.6	2
Texas	1.9	0.5	-	1.4
Utah	66	15	43	8
Washington	29	21	0.7	7.3
Wyoming	48	15	28	5

[a]Based on "Public Land Statistics 1975," U.S. Dept. Interior, Bureau of Land Management, 1975.

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The Forest Service operates under several major acts: the Organic Act of 1897, the Multiple Use--Sustained Yield Act of 1960, the Forest and Rangeland Renewable Resources Planning Act of 1974, the National Forest Management Act of 1976, and the Federal Land Policy and Management Act of 1976.[9-13] This legislation basically states that the National Forests be managed on a long-term, sustained-yield, multiple-use basis. However, there has been controversy over the Forest Service's emphasis on timber cutting and the related management practices.[4,9,14-16] Because of recent litigation, legislation, and the increasing, often competing, demands for use of the National Forest lands, it is anticipated that the kinds and intensity of land uses will change in the future. In the Northern and Southern Rocky Mountains, the Forest Service controls 55 and 50% of the land, respectively (Table 4.2).

BLM lands are mixed with small parcels of private land. Through a system of leasing permits and fees, BLM controls half the land use of the Colorado Plateau, Wyoming Basin, and Southern Rocky Mountains regions. There has been much controversy over the management of the grazing lands. Until enactment of the Federal Land Policy and Management Act of 1976, there was no comprehensive act regulating BLM holdings.[7,13,17] This Act directs BLM to manage its holdings in much the same way as the Forest Service manages its lands. The land and resources are to be inventoried and managed according to a policy of multiple-use and sustained-yield. Also, BLM is to charge a fair-market value for the use of its lands and to prevent unnecessary or undue degradation of the lands. Because of this new legislation plus recent reports which characterize 83% of BLM lands as being in less than satisfactory condition,[18,19] the high demand for use of the land and its resources,[4,19-22] and recent court decisions requiring BLM to write environmental impact statements,[3] the use of BLM lands may change greatly over the next several years.

Land use is also influenced by the states. None of the states have a comprehensive permit system (Table 4.3); however, by the year 2000, such systems may be quite common.[14-23] The states can influence land use in other ways, such as by mandatory local planning, subdivision restrictions, differential tax assessment, designation of critical areas, or regulation of exploitation of natural resources.[7,9,14,16,23-28] The increased interest in the development of the energy resources in the western states is bringing to focus several issues concerning land use policy, e.g., local vs. state vs. Federal jurisdictions, and government restrictions vs. individual rights.[7,9,14,24,25,28]

Most of the states are only in an early planning stage for state land use programs.[29-39] Land data is developed piecemeal by different agencies at different levels of government for different needs. Land use categories are generally not mutually exclusive and intermix concepts of activity, natural qualities, and tenure. In order to provide land use information which could be compared from one region to another, the National Atlas of the United States[2] was used to develop the land use and land ownership maps and tables presented in this section. Also, the book "Natural Regions of the United States and Canada,"[3] was used for much of the information on the interrelations among activities on the land, natural qualities, and institutional considerations.

4.2. THE SIX REGIONS

4.2.1 Northern Rocky Mountains

Land use in the Northern Rocky Mountains region is constrained by the nature of the terrain and the natural vegetation. The region is characterized by a series of generally north-south trending mountain ranges. The elevations of the summits are generally around 3200 m (10,500 ft) and the valleys 1500 m (5000 ft). Despite the northerly latitude and high altitude, the climate is relatively mild. Coniferous forests, predominantly Douglas fir, are prevalent in the region. In the eastern half, additional forest types include cedar-hemlock-pine, western ponderosa, and western spruce-fir. These forests are used to provide commercial timber.

The two major land uses in the region (Fig. 4.1 and Table 4.4) are mostly ungrazed forest and woodland (35% of the region, mostly in the eastern half) and grazed forest and woodland (35%, scattered throughout the region). The land uses in the rest of the region are mainly subhumid grassland and semiarid grazing land (10%, especially in the southwest), woodland and forest with some cropland and pasture (10%), and cropland with pasture, woodland and forest (5% in the west).

About three-fourths of the land of the Northern Rocky Mountains region is owned by the Federal Government (Fig. 4.2 and Table 4.2). Most of the Federal holdings (55% of the region) are in National Forests, i.e., the Okanogan, Colville, Kaniksu, Kootenai, Flathead, Coeur d' Alene and Lolo National Forests. The Colville and Spokane Indian Reservations in the west and Flathead Indian Reservation in the southeast account for 15% of the region, and small scattered BLM tracts account for less than 5%. The remaining one-fourth of the region is privately owned.

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Table 4.2. Percentage[a] of Federal and Private Lands in the Six Regions[b]

Region	Bureau of Land Management (BLM)[d] Tracts, 50-100% density	Bureau of Land Management (BLM)[d]	Bureau of Land Management (BLM)[d] Tracts, 25-50% density	National Forest	Indian Reservations	National Grasslands	Private and Other[c]	Total Area of Region, Square Kilometers
Northern Rocky Mountains		5		55	15	-	25	64,000
Western Great Plains		5		5	5	5	75	390,000
Wyoming Basin		50		10	10	5	25	200,000
Southern Rocky Mountains	(20)	40	(20)	50	-	-	10	110,000
Colorado Plateau	(35)	40	(5)	15	25	-	20	320,000
Texas Coastal Plains		-		-	-	-	100	86,000

a. Rounded to the nearest 5%

b. Based on the National Atlas of the United States, U.S. Department of the Interior Geological Survey, 1975, pp. 272-273, Map entitled "Federal Lands, Principal Lands Administered or held in Trust by Federal Agencies: January 1, 1968."

c. "Private" includes only those areas entirely private. Tracts of private land which are too small to show up at the Scale of the National Atlas map are included in the BLM category. "Other" includes miscellaneous categories which constituted <5% of a region, such as National Parks and Monuments, Department of Defense Lands, and Bureau of Reclamation lands.

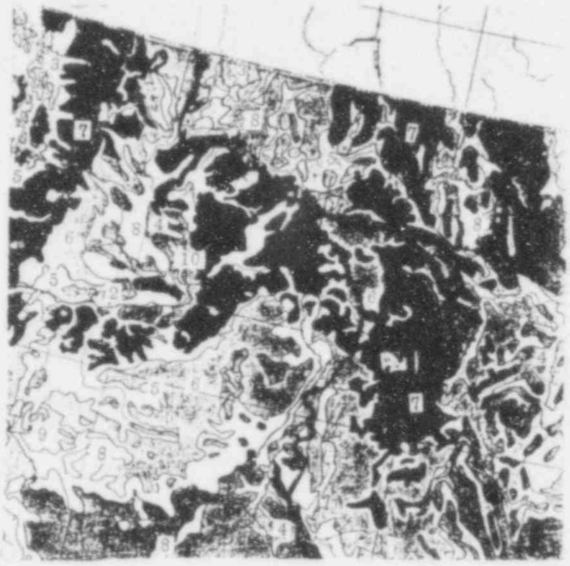
d. Since tracts of BLM land are dispersed amongst private tracts, the Atlas has two ownership categories based on the density of BLM tracts in the area.

Table 4.3. Land Use Programs for Selected States[a]

State	Type of program: Comprehensive permit system[b]	Coordinated incremental[c]	Mandatory local planning[d]	Coastal zone management[e]	Wetlands management[f]	Powerplant siting[g]	Surface mining[h]	Designation of critical areas[i]	Differential assessment laws[j]	Flood plain management[k]	Statewide shorelands Act[l]
Arizona		X				X			A	X	
Colorado						X	X	X	A	X	
Idaho			X				X		A		
Montana		X	X			X	A,B	X	B	X	X
Nebraska			X			X			B	X	
New Mexico		X				X	A		A		
North Dakota						X	A		A		
South Dakota							A	X	A		
Texas				X	X		X		B		
Utah		X					A		B		
Washington		X		X	X	X	A		B	X	X
Wyoming		X	X			X	A		A		

[a]Excerpted from "Environmental Quality--1976," The Seventh Annual Report of the Council on Environmental Quality, September 1976, Table I-25, pp. 68-69.
[b]State has authority to require permits for certain types of development.
[c]State-established mechanism to coordinate state land-use-related problems.
[d]State requires local governments to establish a mechanism for land use planning (e.g., zoning, comprehensive plan, planning commission).
[e]State is participating in the federally funded coastal zone management program authorized by the Coastal Zone Management Act of 1972.
[f]State has authority to plan or review local plans and the ability to control land use in the wetland.
[g]State has authority to determine the siting of powerplants and related facilities.
[h]State has statutory authority to regulate surface mines. (A) State has adopted rules and regulations; (B) State has issued technical guidelines.
[i]State has established rules, or is in the process of establishing rules, regulations, and guidelines for the identification and designation of areas of critical state concern (e.g., environmentally fragile areas, areas of historical significance.)
[j]State has adopted a tax measure which is designed to give property tax relief to owners of agricultural or open space lands. (A) Preferential Assessment Program: Assessment of eligible land is based upon a selected formula, which is usually use value. (B) Deferred Taxation: Assessment of eligible land is based upon a selected formula, which is usually use value and provides for a sanction, usually the payment of back taxes, if the land is converted to a non-eligible use.
[k]State has legislation authorizing the regulation of floodplains.
[l]State has legislation suthorizing the regulation of shorelands of significant bodies of water.

LAND USE



8 Subhumid grassland and semiarid grazing land

7 Forest and woodland mostly ungrazed

6 Forest and woodland grazed

5 Woodland and forest with some cropland and pasture

3 Cropland with pasture, woodland and forest

4 Irrigated land

NORTHERN ROCKY MOUNTAINS

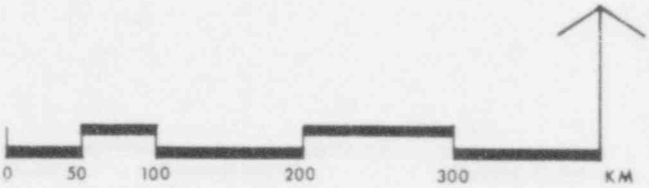


Fig. 4.1. Land Use in the Northern Rocky Mountains Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

Table 4.4. Major Land Uses in the Six Regions (percent distribution)[a,b]

Region	Irrigated Land	Mostly Cropland	Cropland with Grazing Land	Cropland with Pasture, Woodland and Forest	Alpine Meadows and Other[c]	Open Woodland, Grazed	Forest and Woodland, Grazed	Forest and Woodland Mostly Ungrazed	Woodland and Forest with Some Cropland and Pasture	Subhumid Grassland and Semiarid Grazing Land	Desert Shrubland, Grazed	Desert Shrubland, Mostly Ungrazed
Northern Rocky Mountains	-	-	-	5	-	-	35	35	10	10	-	-
Western Great Plains	5	20	25	-	-	- (5)[d]	-	-	-	45	-	-
Wyoming Basin	5	5	-	-	-	10	5	-	-	40	35	-
Southern Rocky Mountains	5	-	-	5	5	15	45	-	-	15	10	-
Colorado Plateau	-	-	-	-	-	40	10	-	-	15	30	5
Texas Coastal Plains	-	10	10	5	-	25	5	-	30	15	-	-

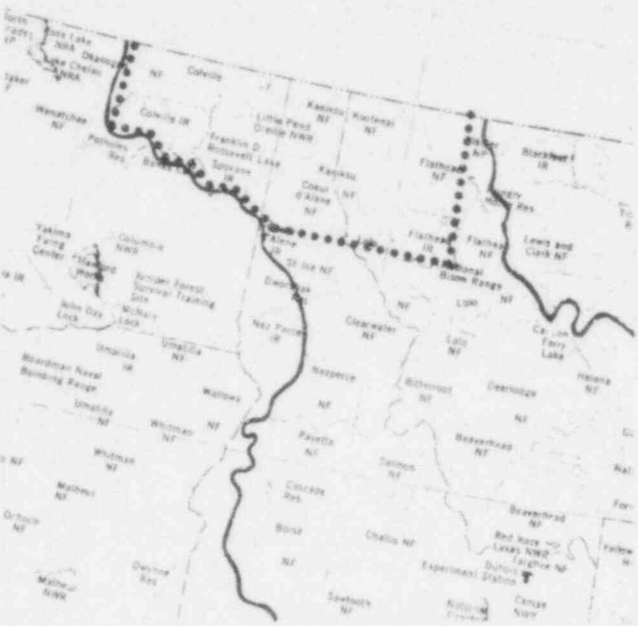
[a]Based on the "National Atlas of the United States, U.S. Dept. of the Interior, Geological Survey, pp. 158-159, map entitled "Major Land Uses," 1975.

[b]Values represent percent (rounded to nearest 5%) of total land devoted to specified use.

[c]Includes alpine meadows, moutain peaks above timberline, sparse dry tundra, lava flows, and barren land.

[d]Includes both open and forest woodland, grazed.

LAND OWNERSHIP



NORTHERN ROCKY MOUNTAINS

National Park Service

National park (NP)

National monument (NM), national seashore (NS), and national recreation area (NRA)

Bureau of Indian Affairs

Indian reservation (IR)

Bureau of Sport Fisheries and Wildlife

National wildlife refuge (NWR)

Department of Agriculture

Forest Service

National forest (NF)

Forest purchase unit (PU)

National grassland (NG)

Land utilization project (LU)

Department of Defense

Army, Navy, Air Force (AF, AFB), Civil Works Projects of Corps of Engineers, and Marine Corps Base (MCB)

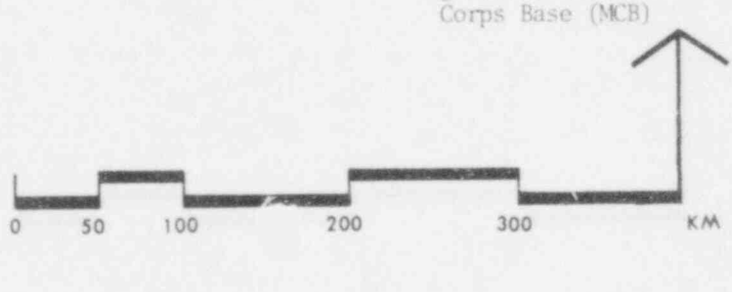


Fig. 4.2. Land Ownership in the Northern Rocky Mountains Region. (Modifed from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

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4.2.2 Western Great Plains

Land use in the Western Great Plains region reflects both environmental constraints and historical development. The region is subjected to repeated, protracted droughts. Soils are alkaline, and the predominant vegetation is shortgrass prairie. Except for the Black Hills (central) and Colorado Piedmont (southwest), trees are largely confined to valleys. Prior to the westward expansion of the United States, the region was inhabited by American Indians who subsisted primarily on bison that roamed the plains; agricultural use of the plains was minor. Today, cropland and cropland with grazing land account for almost half of the land use (Fig. 4.3 and Table 4.4). The land put to these uses coincides with the wheatgrass-needlegrass grassland in the north, the grama-wheatgrass-needlegrass grassland in the northwest, and the grama-buffalo grass grassland in the south. Irrigated land, which accounts for only 5% of the land use, is located primarily in long fingers along the Arkansas and North and South Platte Rivers in the south. Other irrigated areas occur along the Yellowstone and Belle Fourche Rivers in the north.

The other major land use in the region (45%) is subhumid grassland and semiarid grazing land. While land in this category is dispersed throughout the region, there is one large area in the east-central part which coincides with the Nebraska Sandhill prairie.

Other land uses are grazed forest and woodland and grazed open woodland. Lands put to these uses coincide with the Black Hills pine forest and the Colorado Piedmont pine-Douglas fir forest.

Development of mineral resources affects local land uses in several areas of the Western Great Plains. The Black Hills area is one of the principal gold-producing areas in the United States. Coal is becoming increasingly important in the northern part of the Western Great Plains. The western edge of the region is an important oil- and gas-producing area. Uranium deposits are located in the northwest.

The Federal Government controls less than one-fourth of the region (Fig. 4.4 and Table 4.2). The Fort Betthold, Standing Rock, Cheyenne, Pine Ridge and Rosebud Indian Reservations, located in the northeastern and east-central parts of the region, account for the largest Federal holdings (approximately 7%). The other holdings include several National Grasslands (Little Missouri, Grand River, Cedar River, Buffalo Gap, Ogala, Pawnee, and Comanche) located throughout the region, National Forests (the Black Hills in the west-central portion and several in the southwest), and BLM tracts (in the western half).

4.2.3 Wyoming Basin

The Wyoming Basin region is covered mostly with alkaline desert soils and sagebrush. Grazing is the primary activity on the land. Lower elevations are used for winter range and mountains are used for summer range. Land use for the western half of the Basin is largely grazed desert shrubland (35% of the region, Fig. 4.5 and Table 4.4). The natural vegetation is sagebrush steppe, saltbush-greasewood shrubland, and wheatgrass-needlegrass shrubsteppe. The eastern part of the region is subhumid grassland and semiarid grazing land (40% of the region). The natural vegetation is grama-needlegrass-wheatgrass grassland and sagebrush steppe.

The forested areas in the mountains at the edges of the region (Wind River Mountains in the northwest, Big Horn Mountains in the north, Laramie Mountains in the southeast) and in the northeastern corner are also used for grazing. The forest types include Douglas fir, western spruce-fir and pine-Douglas fir in the mountains and eastern ponderosa forest in the northeastern corner. The corresponding land uses are grazed forest and woodland (5% of region) and grazed open woodland (10%).

Irrigated land scattered throughout the region along river floodplains and pockets of cropland in the east make up 10% of the land use.

Mineral resources in the region are considerable and diverse. Development of the surface-mineable coal deposits is increasing. Petroleum is obtained from the Laramie and Great Divide Basins. Uranium is found in many parts of the region. Exploitation of these resources removes a small amount of land from other uses.

Over two-thirds of the Wyoming Basin is controlled by the Federal Government (see Fig. 4.6 and Table 4.2). About 50% of the land is in BLM tracts of 50% to 100% and 25% to 50% density. The other major Federal holdings include: Indian reservations (Crow, Northern Cheyenne, Yellowtail and Wind River--10% of the region), National Forests (Custer, Bighorn, Teton, Shoshone, Medicine Bow, and Bridger--10%), and the Thunder Basin National Grassland (5%). The privately owned land in the Basin (25%) is primarily located in the northeast.

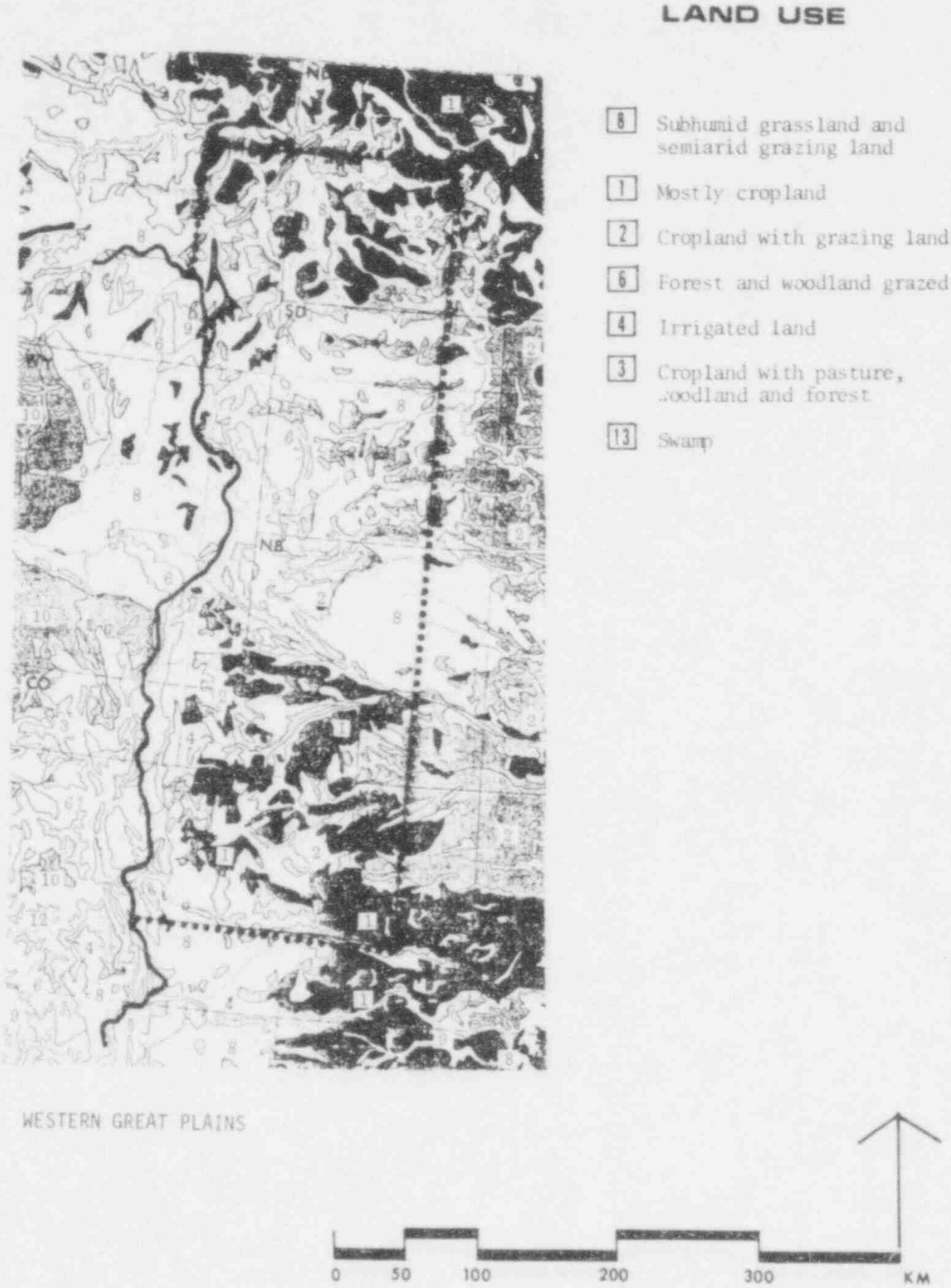

Fig. 4.3. Land Use in the Western Great Plains Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

LAND OWNERSHIP

National Park Service

National park (NP)

National monument (NM), national seashore (NS), and national recreation area (NRA)

Bureau of Indian Affairs

Indian reservation (IR)

Bureau of Sport Fisheries and Wildlife

National wildlife refuge (NWR)

Department of Agriculture Forest Service

National forest (NF)

Forest purchase unit (PU)

National grassland (NG)

Land utilization project (LU)

Department of Defense

Army, Navy, Air Force, (AF, AFB), Civil Works Projects of Corps of Engineers, and Marine Corps Base (MCB)

WESTERN GREAT PLAINS

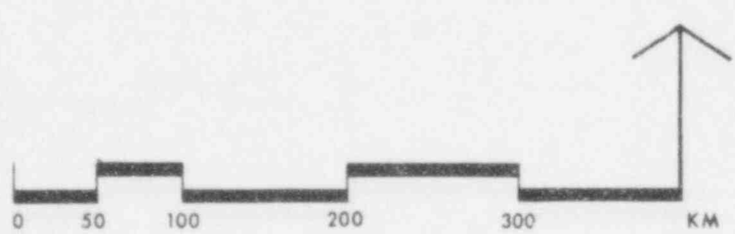

Fig. 4.4. Land Ownership in the Western Great Plains Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

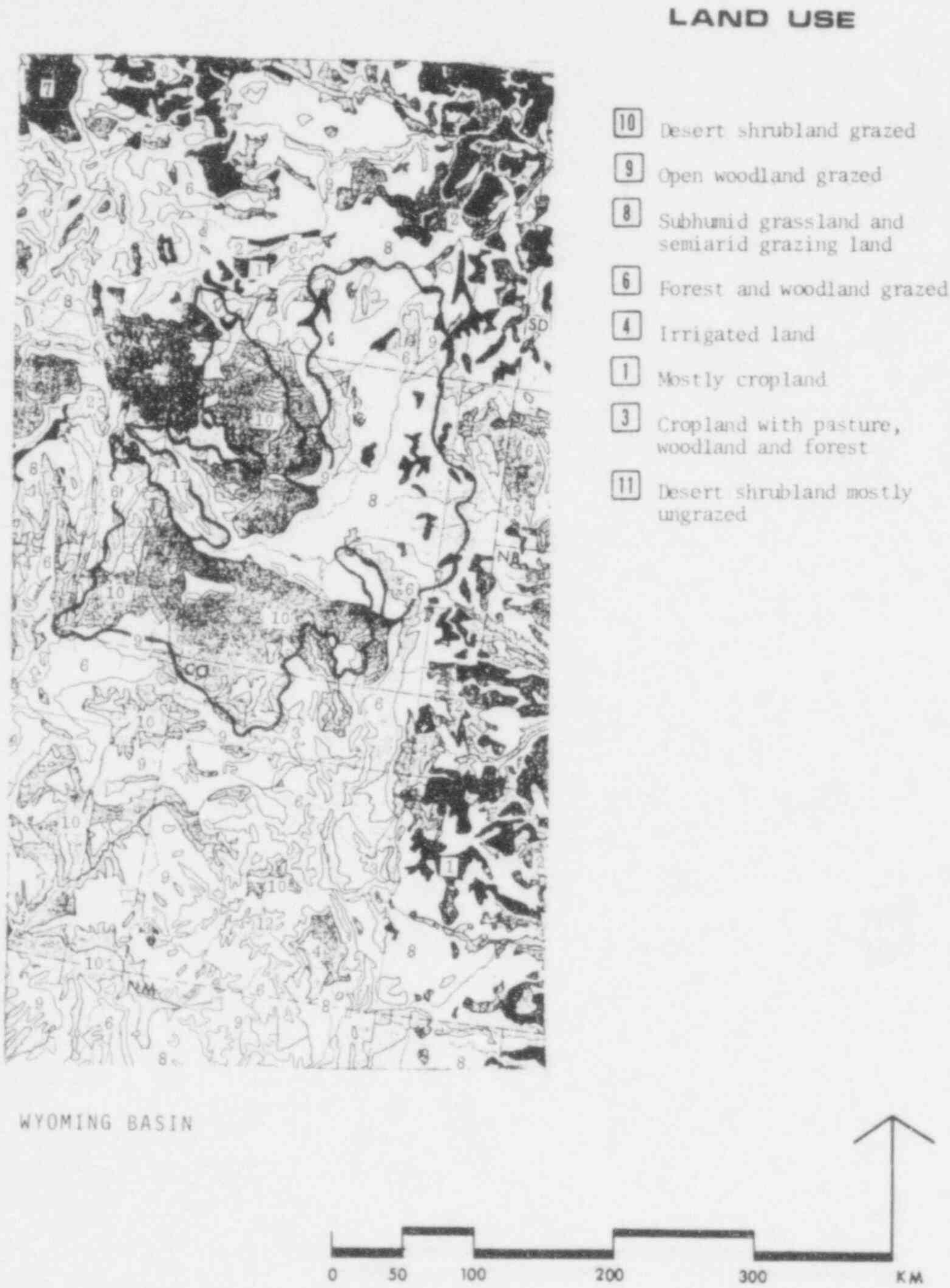

Fig. 4.5. Land Use in the Wyoming Basin Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

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LAND OWNERSHIP

WYOMING BASIN

National Park Service

National park (NP)

National monument (NM), national seashore (NS), and national recreation area (NRA)

Bureau of Indian Affairs

Indian reservation (IR)

Bureau of Sport Fisheries and Wildlife

National wildlife refuge (NWR)

Department of Agriculture

Forest Service

National forest (NF)

Forest purchase unit (PU)

National grassland (NG)

Land utilization project (LU)

Department of Defense

Army, Navy, Air Force (AF, AFB), Civil Works Projects of Corps of Engineers, and Marine Corps Base (MCB)

Fig. 4.6. Land Ownership in the Wyoming Basin Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

4.2.4 Southern Rocky Mountains

The Southern Rocky Mountains region consists of an agglomeration of several mountain ranges. These mountains form a major barrier to travel, with passes higher than 2700 m (9000 ft). Towns and urban development are concentrated in the east. The population at the eastern foot of the Southern Rocky Mountains is about 1.5 million; while there is only one-tenth as many people at the western foot.

The major land use patterns in the region (Fig. 4.7 and Table 4.4) coincide with vegetational patterns. Mountains and intermediate plateaus and basins are used primarily for grazing. The largest land uses (grazed forest and woodland and grazed open woodland) generally coincide with the pine-Douglas fir, southwestern spruce-fir, and western spruce-fir forests. The spruce-fir forests are a major timber resource.

Alpine meadows (grasses and sedges) and barrens are scattered throughout the central part of the region and account for 5% of the land.

Grazed desert shrubland (10% of the region) and irrigated land (5%) coincide with the following vegetation: grama-needlegrass-wheatgrass grassland (northwest), sagebrush steppe (north-central), Great Basin sagebrush (west-central) and saltbush-greasewood (south of mid-central). Irrigated lands occur along river valleys. The remainder of the region is in subhumid grassland and semiarid grazing land (15%, in the east) and cropland with pasture, woodland, and forest (5%).

The Colorado mineral belt stretches in a northeasterly direction across the central part of the region. Therefore some of the land is used for exploitation of mineral resources, which include gold, silver, lead, zinc, copper, molybdenum, and uranium.

Most of the region is owned by the Federal Government (Fig. 4.8 and Table 4.2). About half of the region is in National Forests, including the Medicine Bow, Routt, Roosevelt, Arapaho, White River, Gunnison, San Isabel, San Juan, Rio Grande, Carson, and Sante Fe National Forests. About 40% of the land is in BLM tracts of 50% to 100% or 25% to 50% density. Rocky Mountain National Park is located near the northeastern border and Great Sand Dunes National Monument is in the southeast. There are only a few major areas which are entirely in private ownership (approximately 10% of the region).

4.2.5 Colorado Plateau

The Colorado Plateau region is generally at an elevation greater than 1500 m (5000 ft). It is noted for its array of landforms, such as pediments, badlands, mesas, cuestas, hogbacks, alcoves, arches, bridges, tanks, pedestal rocks, and monuments, as well as the deeply incised drainage systems with brightly colored canyons. Extensive upland areas are covered by sand.

The vegetation reflects the arid, extreme climate, the high elevation, and the saucer-shape of the Plateau. The rims and isolated mountains have forests (Douglas fir, pine-Douglas fir, Arizona pine, spruce-fir-Douglas fir, and southwestern spruce and fir), while the interior has desert shrub or grassland (juniper-pinyon woodland, Great Basin sagebrush, saltbush-greasewood shrub, grama-galleta steppe, blackbrush shrub, galleta-three awn shrubsteppe, and grama-tobosa shrubsteppe).

The Plateau is used mostly for grazing--winter range at the lower elevations and summer range in the mountains and high plateaus. The major land uses are grazed open woodland (40% of the region) and grazed desert shrubland (30%). Other uses include subhumid grassland and semiarid grazing land, grazed forest and woodland, and desert shrubland, mostly ungrazed (Fig. 4.9 and Table 4.4). Small pockets of irrigated lands are located in the northwestern and east-central parts of the region.

For grazing purposes, the carrying capacity of the land is only about two cows per square kilometer (5 to 6 cows/sq. mile). There is thus controversy over the use of the land for grazing. There are claims that the severe soil erosion and present arroyo-cutting may have been triggered by settlement and consequent overgrazing.[3] There is doubt that the land could heal itself, even if grazing were reduced or stopped, without the return of wetter climatic conditions.

In some areas of the Colorado Plateau, land use is greatly influenced by development of mineral resources. The Plateau contains numerous metallic and non-metallic ore deposits and substantial reserves of energy resources such as petroleum, coal, and gas. About half of the uranium mined in the United States comes from this region, mostly from the Grants, New Mexico area. Large deposits of bituminous and subbituminous coal occur in several places, in particular the Uinta,

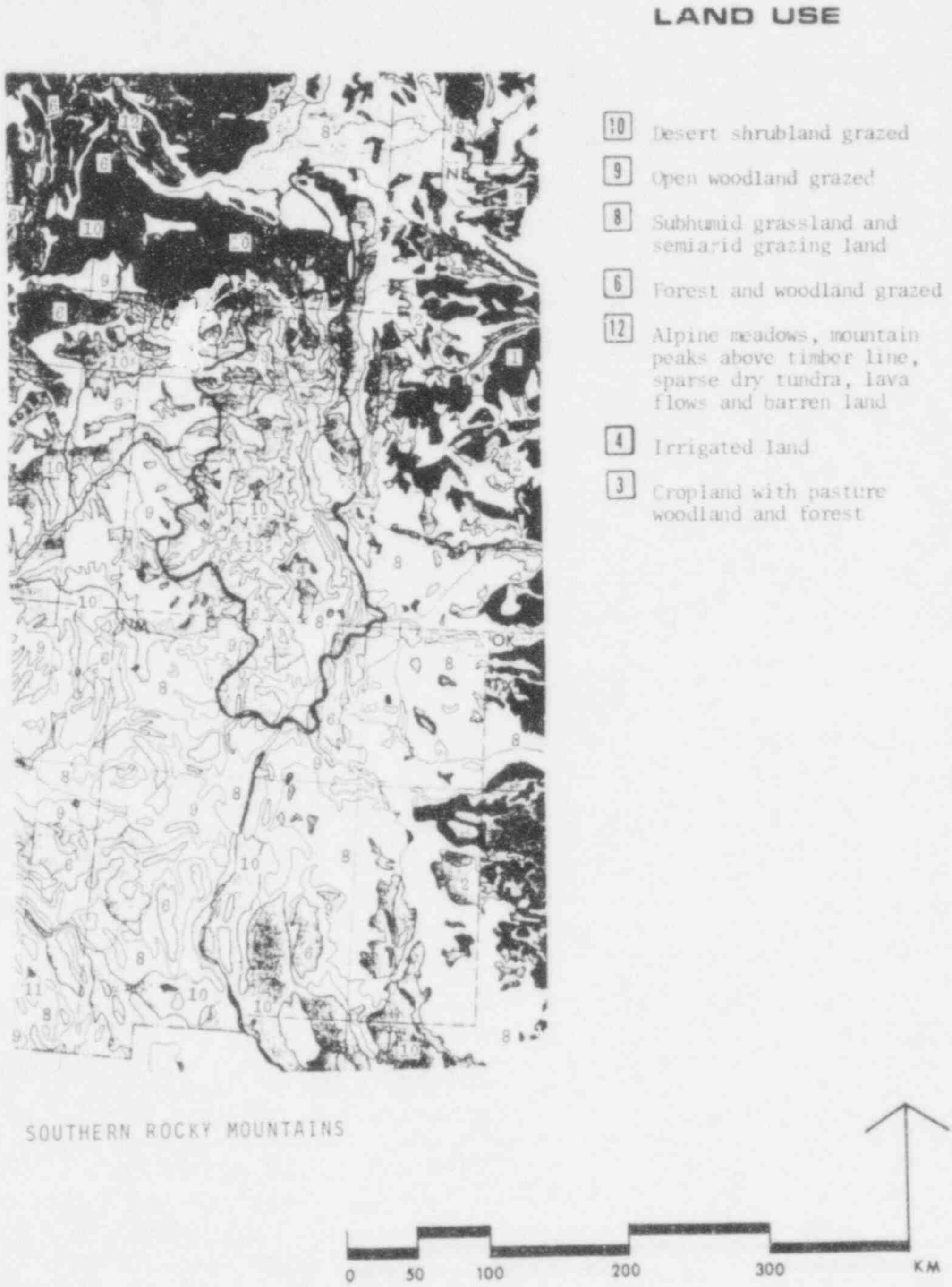

Fig. 4.7. Land Use in the Southern Rocky Mountains Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

LAND OWNERSHIP

National Park Service

National park (NP)

National monument (NM), national seashore (NS), and national recreation area (NRA)

Bureau of Indian Affairs

Indian reservation (IR)

Bureau of Sport Fisheries and Wildlife

National wildlife refuge (NWR)

Department of Agriculture

Forest Service

National forest (NF)

Forest purchase unit (PU)

National grassland (NG)

Land utilization project (LU)

Department of Defense

Army, Navy, Air Force, (AF, AFB), Civil Works Projects of Corps of Engineers, and Marine Corps Base (MCB)

SOUTHERN ROCKY MOUNTAINS

Fig. 4.8. Land Ownership in the Southern Rocky Mountains Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

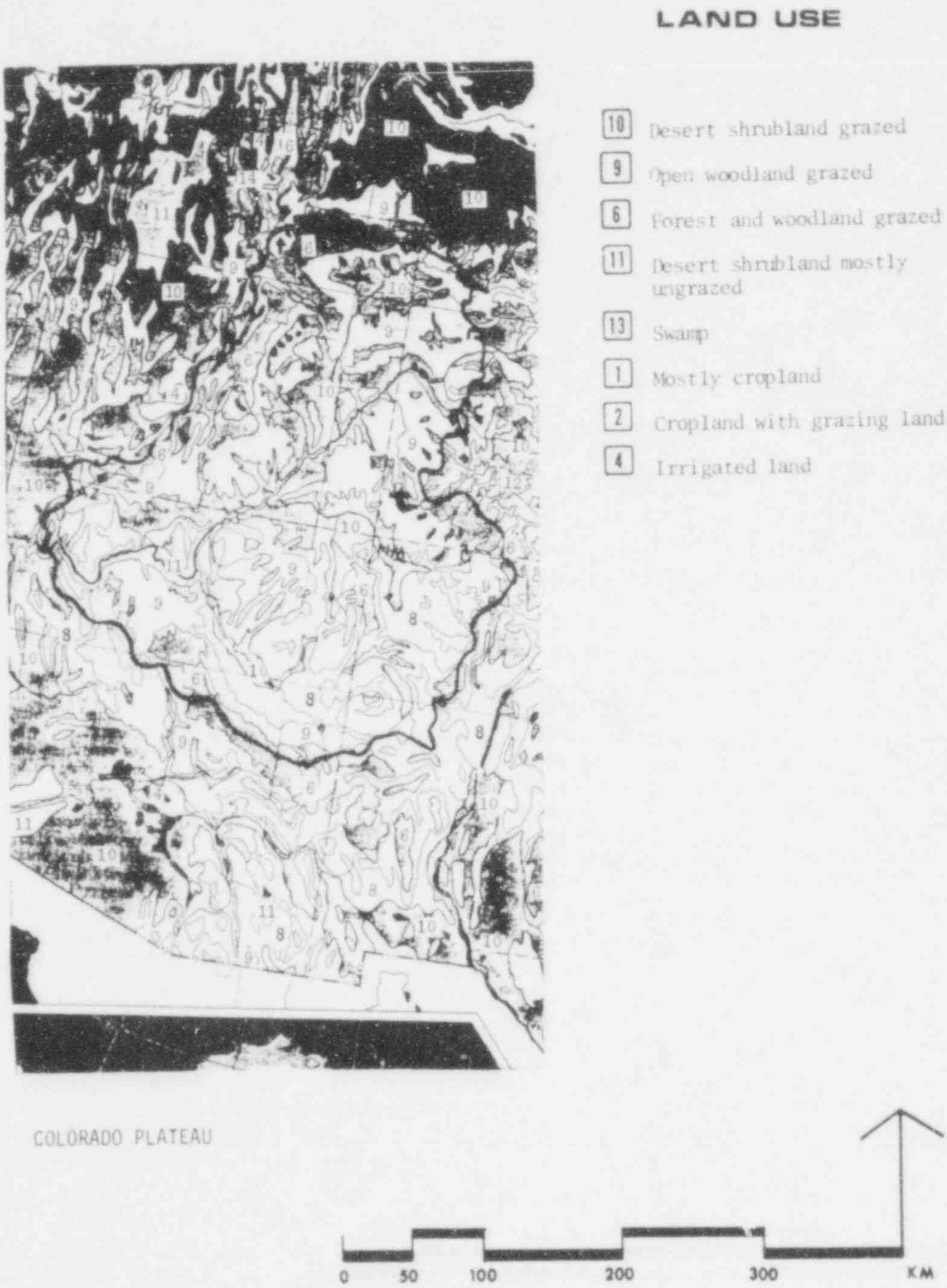

Fig. 4.9. Land Use in the Colorado Plateau Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

Piceance Creek, San Juan, Black Mesa, and eastern Paradox basins. Petroleum in conventional deposits occurs in the Uinta, Piceance Creek, and San Juan basins. In addition, deposits of oil shale in the Green River formation in the Uinta and Piceance Creek basins have a large potential for petroleum production but have not been commercially developed.

Most of the Colorado Plateau is owned or managed by the Federal Government. The large Navajo (and Hopi) Indian Reservation dominates the center of the Plateau (especially northeastern Arizona) and constitutes about 20% of the land area (Fig. 4.10 and Table 4.2). Other Indian reservations (Uinta and Ouray, Ute, Jicarilla, Pueblo, Zuni, Hualapai, Kaibab, Apache, and Ramah) account for another 5% of the Plateau.

Another large portion of the Plateau (15%) is in national forest. There are several such forests scattered throughout the region, primarily at the higher elevations. About 35% of the Plateau is in BLM tracts of 50% to 100% density and about 5% is in tracts of 25% to 50% density.

Along reservoirs, particularly along the Colorado River in the southwest and Lake Powell in the center, the land is controlled by the Bureau of Reclamation. There are numerous national parks and monuments, including Canyonlands, Mesa Verde, Bryce Canyon, Zion, Grand Canyon and Petrified Forest National Parks, and Dinosaur, Arches, Natural Bridges, and Canyon de Chelly National Monuments.

4.2.6 Texas Coastal Plains

Unlike the other regions, the Texas Coastal Plains region is almost entirely privately owned (Fig. 4.11 and Table 4.2). The only Federal land is a small piece of the Sam Houston National Forest in the northeast. The region is in the Gulf Coastal Plain, which is one of the country's major fruit-growing and cattle-raising areas. There is a marked contrast in land uses between the northern and southern portions of the region (Fig. 4.12). This difference coincides with a distinct difference in natural vegetation and climate.

In the southern half of the region, rainfall can be as high as 50 to 75 cm (20 to 30 inches) annually, but evaporation is high, creating semiarid conditions. The natural vegetation is principally mesquite-acacia savanna. Land therefore is used mostly as grazed open woodland (25% of the region) and subhumid grassland and semiarid grazing land (15%) (Table 4.4). There is a little cropland and cropland with grazing land in the southeast on the Gulf side of the region.

The northern half of the region receives more rainfall and has a much different natural vegetation. Oak-hickory forest and Fayette prairie predominate. Here the primary land use is woodland and forest with some cropland and pasture (30% of the region). The rest of the northern half of the region is used mostly for cropland; cropland with grazing land; cropland with pasture, woodland and forest; and grazed forest and woodland.

LAND OWNERSHIP

COLORADO PLATEAU

National Park Service

National park (NP)

National monument (NM), national seashore (NS), and national recreation area (NRA)

Bureau of Indian Affairs

Indian reservation (IR)

Bureau of Sport Fisheries and Wildlife

National wildlife refuge (NWR)

Department of Agriculture

Forest Service

National forest (NF)

Forest purchase unit (PU)

National grassland (NG)

Land utilization project (LU)

Department of Defense

Army, Navy, Air Force (AF, AFB), Civil Works Project of Corps of Engineers and Marine Corps Base (MCB)

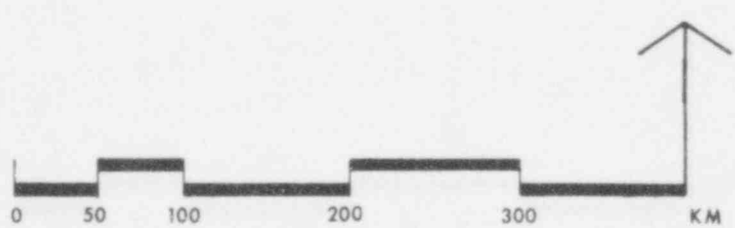

Fig. 4.10. Land Ownership in the Colorado Plateau Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

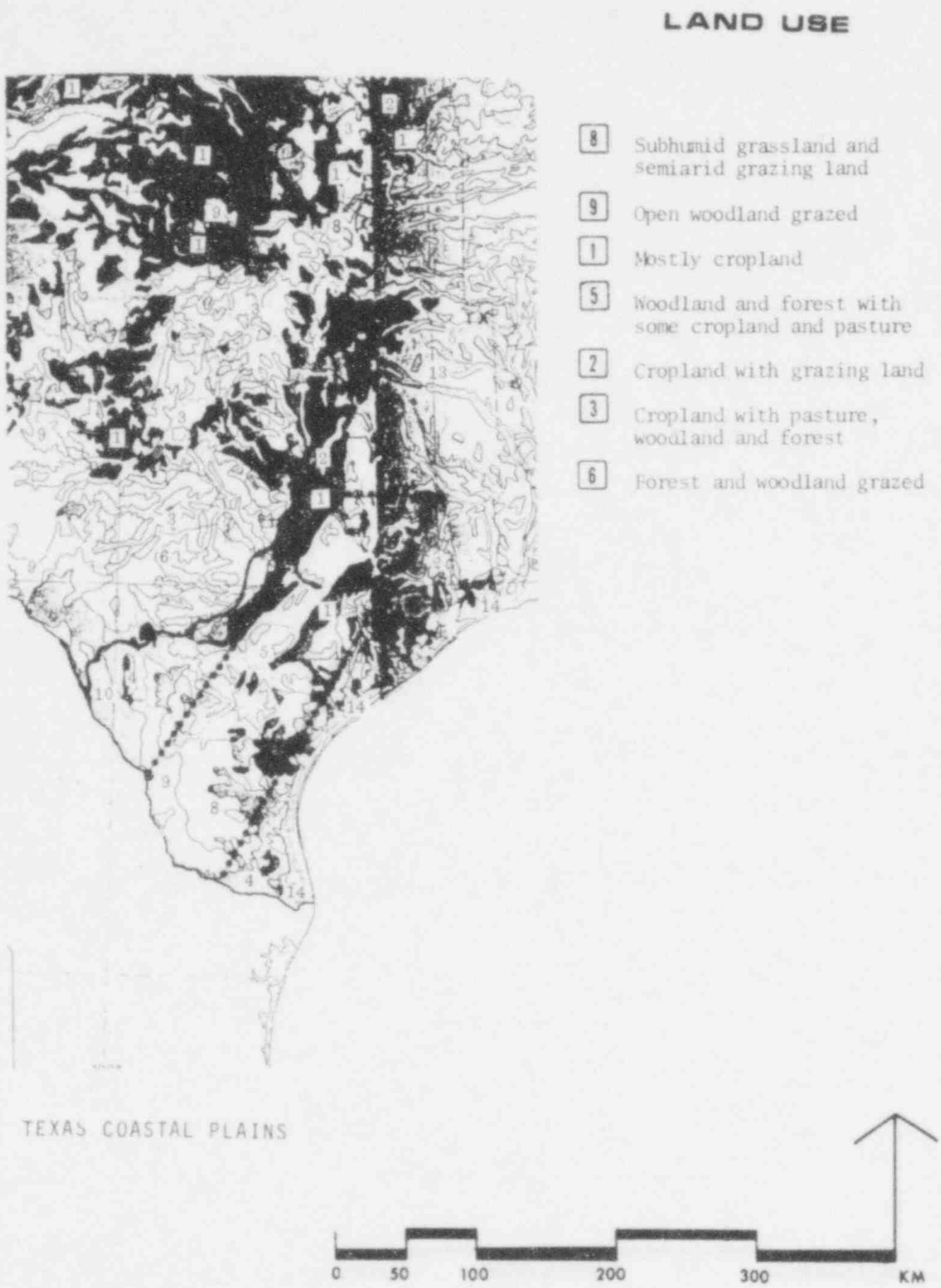

Fig. 4.11. Land Use in the Texas Coastal Plains Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

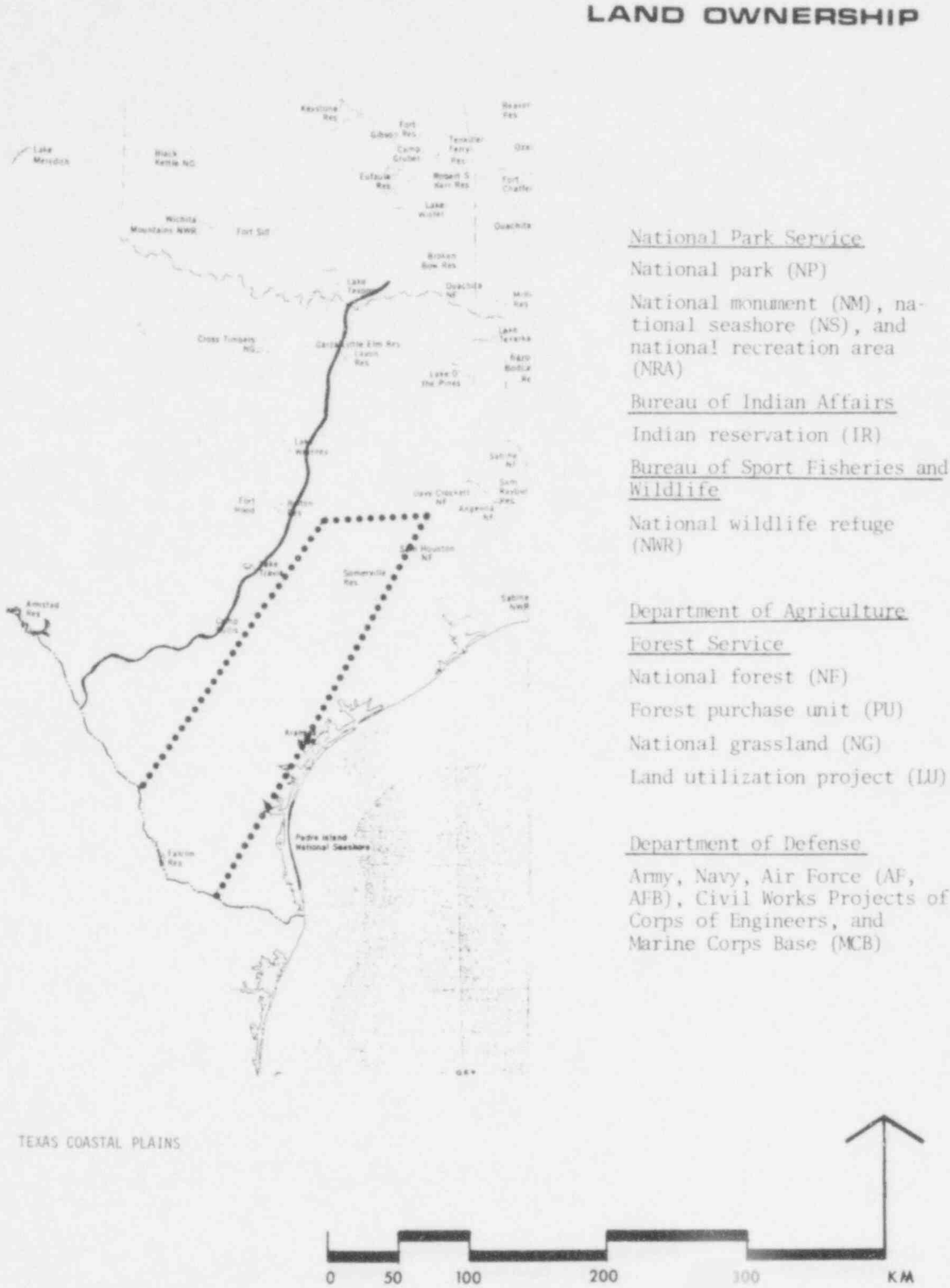

Fig. 4.12. Land Ownership in the Texas Coastal Plains Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

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31. Letter from A. William Johnson, Regional Environmental Assessment Program, Bismarck, North Dakota, to Sandra O'Connor, Argonne National Laboratory, Argonne, Illinois, 1 July 1977.

32. Letter from Tom Loveland, State Planning Bureau, Pierre, South Dakota, to Sandra O'Connor, Argonne National Laboratory, Argonne, Illinois, 28 June 1977.

33. Letter from Richard M. Weddle, Montana Dept. of Community Affairs, Division of Planning, Helena, Montana, to Sandra O'Connor, Argonne National Laboratory, Argonne, Illinois, 1 June 1977.

34. Letter from Brace Hayden, Dept. of State Lands, Helena, Montana, to Sandra O'Connor, Argonne National Laboratory, Argonne, Illinois, 11 May 1977.

35. Letter from Warren White, Office of Planning and Programming, Lincoln, Nebraska, to Sandra O'Connor, Argonne National Laboratory, Argonne, Illinois, 30 June 1977.

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37. Letter from Cecil Parker, Office of the State Planning Coordintor, Salt Lake City, Utah, to Sandra O'Connor, Argonne National Laboratory, Argonne, Illinois, 12 July 1977.

38. Letter from Ronald J. Clarke, Local Planning Assistance, Office of Community Development, Olympia, Washington, to Sandra O'Connor, Argonne National Laboratory, Argonne, Illinois, 18 July 1977.

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5. GEOLOGY AND SEISMICITY

5.1 GEOLOGY

The geology of the area encompassing the six physiographic regions is extremely varied, ranging from the igneous and complexly folded and faulted sedimentary rocks of the Rocky Mountains to the nearly flat coastal plain sediments of the Texas Gulf Coast. The regions of interest are shown in Figure 5.1.

The Rocky Mountain Range is a dominant feature of the western United States. The stratigraphic units in the northern and southern portions of the Rocky Mountains are shown in Figure 5.2. At the end of Precambrian time, the area that now encompasses the Rocky Mountains consisted of rocks, mostly granite, schist, and gneiss, eroded to an extensive surface of low relief. Marine sediments accumulated from Cambrian through Cretaceous time. The Laramide orogeny, a period of upheaval during Cretaceous-Paleocene time, caused uplifting of individual mountain ranges, such as the Beartooth, Bighorn, Uinta, and Wind River ranges. Large bodies of granite, e.g., the Idaho and Butte batholiths, were emplaced during the Laramide orogeny. Along the western part of the Northern Rocky Mountains region, for example the Wyoming-Utah border, thrusting and folding was the dominant mechanism of Laramide displacement. Erosion of uplifted mountains has continued since the Laramide orogeny, and much of the eroded debris has accumulated in intermontane basins. Cenozoic basin-and-range faulting has created fault-block mountains in parts of the region, such as the Wasatch Mountains. In the Yellowstone Park area, late Cenozoic volcanic processes have dominated. Pleistocene glaciers have modified the high mountains and northern parts of this region during the past several million years. The geological descriptions of the six physiographic regions are treated individually in subsequent subsections, with emphasis on those areas where uranium mining has occurred.

5.1.1 Northern Rocky Mountains

Older Precambrian granite and gneiss are exposed in the interior of the higher mountains, such as the Wind River, Bighorn, and Beartooth mountains. Younger Precambrian metamorphic rocks, e.g., the Belt Series of slate and quartzite, make up a large part of the mountains in northwestern Montana and northern Idaho. The mountains of central Idaho and northeastern Washington are largely Cretaceous granite. Outcrops of Paleozoic and Mesozoic sedimentary rocks are found scattered throughout the Northern Rocky Mountains region. The Paleozoic rocks are typically limestone; the Mesozoic rocks are typically shale and sandstone. Tertiary volcanic rocks, largely rhyolite lava, make up the bulk of the Absaroka Mountains and Yellowstone Park area. Cenozoic sediments underlie most lowlands.

The principal uranium-mining area of the region is at the Midnight mine (Sherwood project) east of Spokane, Washington. The ore is in uraniferous veins found in Tertiary volcanic rocks. A geologic cross section of the Midnight mine tailings pond area, where Pleistocene alluvium rests directly on top of Cretaceous granite, is shown in Figure 5.3.

5.1.2 Western Great Plains

The most common rocks cropping out in the Western Great Plains region are Cretaceous shales of marine origin and Tertiary shales and sandstones of terrestrial origin (Fig. 5.1). The Black Hills area is an isolated uplift exposing Precambrian crystalline rocks surrounded by outward-dipping Paleozoic and Mesozoic limestones, shales, and sandstones (Fig. 5.4).

The Western Great Plains region was covered by seawater through most of the Paleozoic and Mesozoic eras and thus was subject to accumulation of marine sediments. During the Laramide orogeny the Black Hills were uplifted, and vast aprons of Tertiary terrestrial rocks were deposited over most of the region. These deposits are being eroded today by streams tributary to the Missouri River. The Sand Hills of north-central Nebraska were wind-deposited during the Pleistocene.

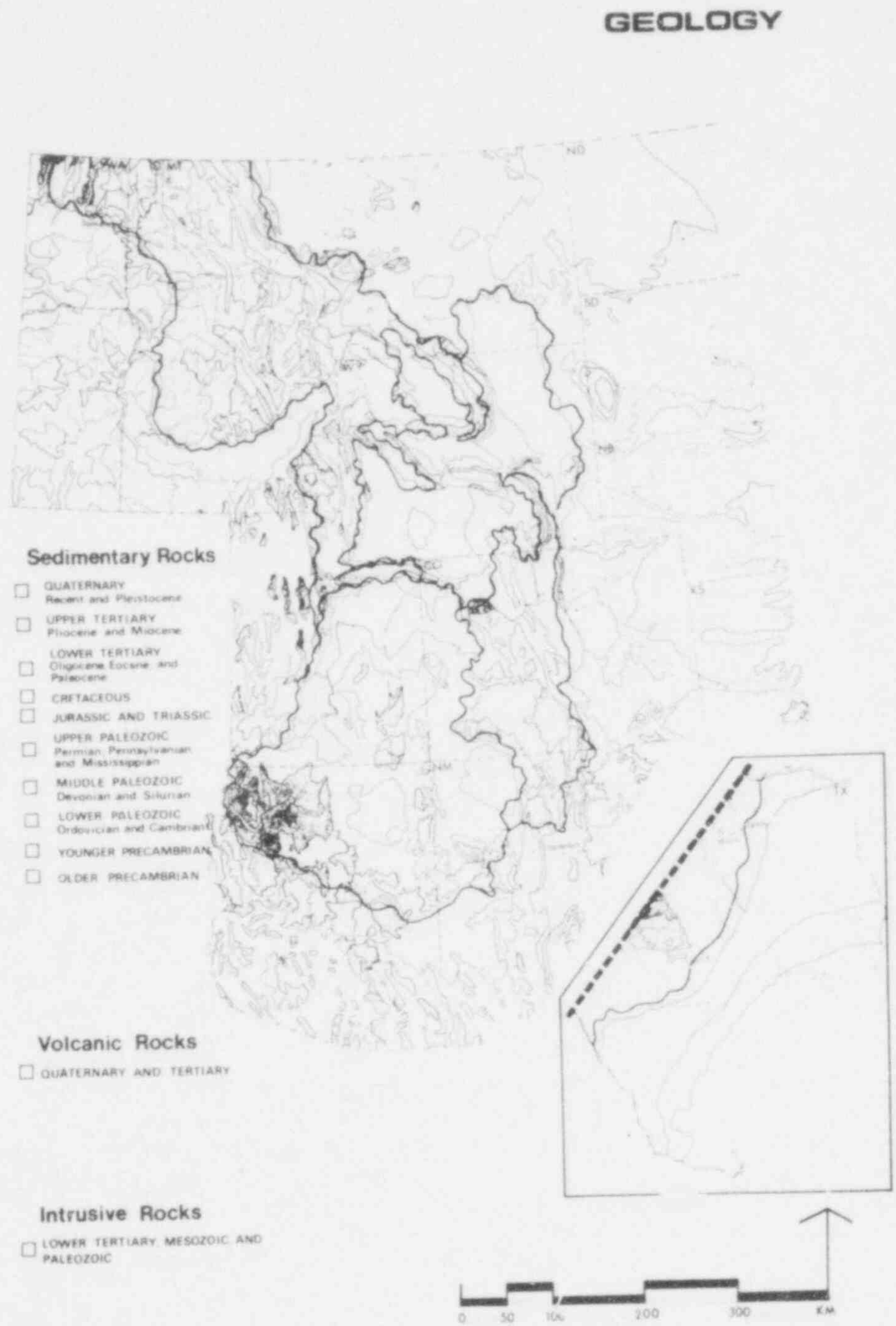
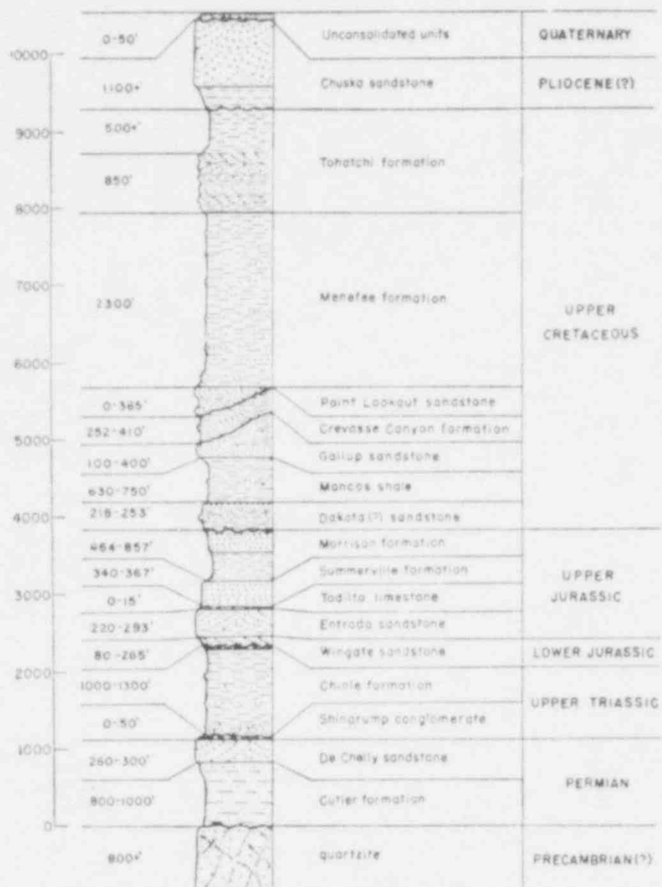


Fig. 5.1. Geologic Map of the Western United States. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)



(A) Southern Rocky Mountains (Northwestern New Mexico)

(B) Northern Rocky Mountains
(Powder River Basin, Wyoming)

Fig. 5.2. Stratigraphic Units of the Northern and Southern Rocky Mountain Regions. (Diagram (A) from Allen and Balk, "Mineral Resources of Fort Defiance and Tohatchi Quadrangles, Arizona and New Mexico," New Mexico State Bureau of Mines and Mineral Resources Bulletin 36, 1954; Diagram (B) from "Draft Environmental Impact Statement, Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming," U.S. Dept. of Interior et al., 1974.)

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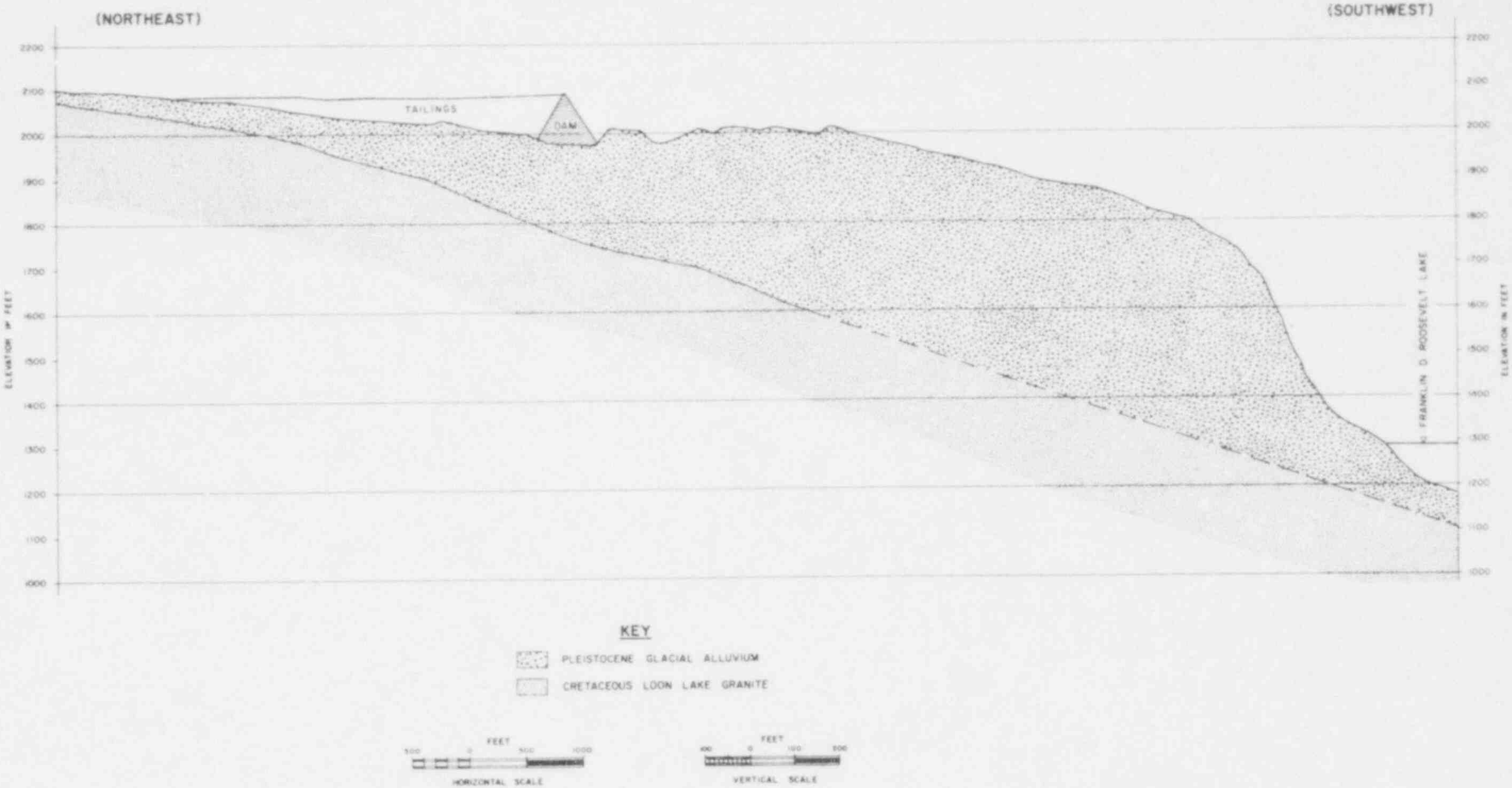
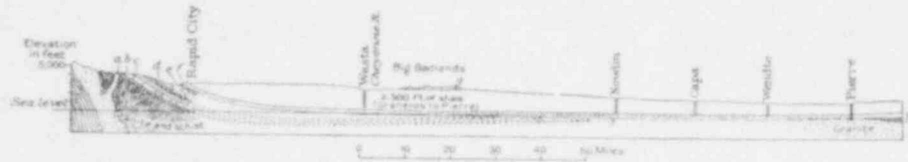
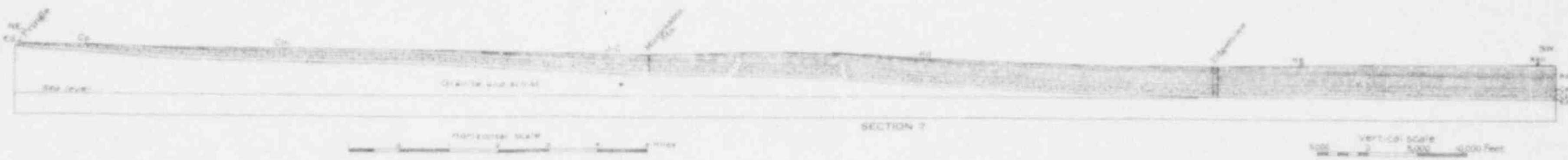


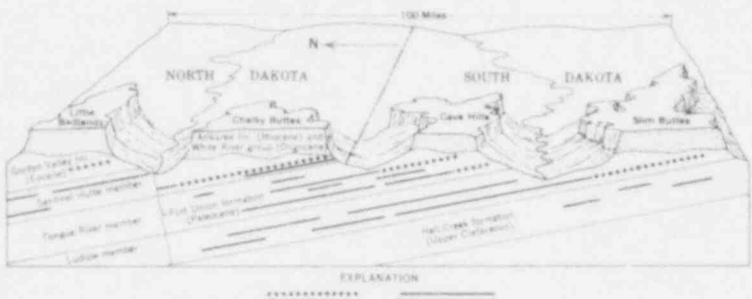
Fig ..3. Geologic Cross Section of the Sherwood Uranium Project Tailings Pond Area. (From "Final Environmental Statement, Sherwood Uranium Project, Spokane Indian Reservation," U.S. Dept. of Interior, 1976.)



(A) - Section across South Dakota from the Black Hills to Missouri River, showing the general relations of waterbearing rocks. *a*, Deadwood formation; *b*, Englewood and Pahasapa limestones; *c*, Minnelusa sandstone; *d*, red beds (Opeche, Minnekahta, and Spearfish formations); *e*, Sundance formation, Unkpapa sandstone, and Morrison shale; *f*, Lakota, Minnewaste, Fuson, and Dakota formations; *g*, White River group in Big Badlands; *h*, pre-Cambrian quartzite. (From N. H. Darton, "Artesian Waters in the Vicinity of the Black Hills, South Dakota," U. S. Geological Survey, Water Supply Paper 428, 1918.)



(B) - Section across Southern Black Hills from Pringle to Edgemont. Kp, Pierre shale; Kn, Niobrara formation; Kc, Carlile shale; Kgh, Greenhorn limestone; Kg, Graneros shale; Kd, Dakota to Lakota sandstones Upper water-bearing beds; J-C, Morrison, Unkpapa, Sundance, Spearfish, Minnekahta, and Opeche formations; Cm, Minnelusa sandstone Middle water-bearing beds; Cp, Pahasapa and underlying limestones; Cd, Deadwood formation (sandstone and shale) on granite, schist, etc. Lower water-bearing beds. (From Darton, 1918).



(C) - Diagrammatic Section across northwestern South Dakota and Southwestern North Dakota. (From "Contributions to the Geology of Uranium and Thorium by the United States Geological Survey and Atomic Energy Commission for United Nations International Conference on Peaceful Uses of Atomic Energy," 1956.

Fig. 5.4. Representative Geologic Cross Sections of the Western Great Plains Region.

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There are two principal areas of uranium deposits within this region (Fig. 5.4):

(1) Edgemont, South Dakota--Uraniferous sandstones occur within the Fall River and Lakota formations. These beds dip about ten degrees to the south off the Black Hills uplift;

(2) Harding County, South Dakota--Thin, uraniferous lignite beds are found in the flat-lying Tongue River member (a conglomeratic sandstone) of the Fort Union group of Paleocene age.

5.1.3 Wyoming Basin

The Laramide orogeny that formed the Rocky Mountains also was responsible for the formation of great basins which subsided up to 7 km (4 miles) and received terrestrial sediments throughout most of the Cenozoic era. The great structural basins make up the topographic lowland included in this region. As shown in Figure 5.1, most of the rocks exposed in the Wyoming Basin region are lower Tertiary in age, although Mesozoic and Paleozoic sediments crop out in some places.

A geologic cross section through the Powder River Basin, which contains some of the largest uranium deposits in the United States, is shown in Figure 5.5. Although upper Cretaceous rocks, such as the Pierre shale, make up much of the volume of the sediments in the Powder River Basin, the Paleocene Fort Union group and the Eocene Wasatch (Wind River) formation have the largest areal extent.

In the Wyoming Basin region, uranium ore is commonly found in the Fort Union, Wasatch, or Wind River formations. These formations are terrestrial in origin and consist of fluvial sandstone, siltstone, shale, and subbituminous coal. The sediments are generally semiconsolidated and rarely dip more than a few degrees basinward.

5.1.4 Southern Rocky Mountains

Precambrian granite, which forms the Front Range, is the most common rock which crops out in the Southern Rocky Mountains region. The San Juan Mountains are composed of Tertiary volcanic rocks. Scattered stocks and intrusives of Laramide age also occur. There are considerable thicknesses of upper Paleozoic, Jurassic, and Triassic sediments, especially in the southern part of this region northeast of Albuquerque. Numerous small basins within the region subsided during Tertiary time and collected terrestrial sediments, e.g., the San Luis Basin in Colorado (Fig. 5.6).

The dominant style of deformation in this region is that of high-angle faulting which developed during the Laramide orogeny. The Front Range, Wasatch, Sangre de Cristo, and other blocks were uplifted and eroded, exposing Precambrian rocks. Downdropped blocks collected debris eroded from adjacent uplifts. During and following the Laramide orogeny, plutons of intrusive rocks formed, and extensive volcanic fields, such as the San Juan Mountains, developed.

The uranium deposits within this region are small, typically veins or fillings in breccia zones. Most of these deposits are in Precambrian rocks, although some occur in Paleozoic or Mesozoic sediments.

5.1.5 Colorado Plateau

The most common rocks in the Colorado Plateau region are sediments of upper Paleozoic and Mesozoic ages. These sediments are typically flat-lying or very gently dipping. The upper Paleozoic sediments include such prominent formations as the Mississippian Redwall limestone, Permian Coconino sandstone, and Kaibab limestone; these rocks form the grand cliffs of the Grand Canyon and crop out over a large area in northwestern Arizona. Mesozoic sediments include the Triassic Moenkopi formation and Wingate sandstone, the Jurassic Navaho sandstone and Morrison formations, and the Cretaceous Dakota sandstone and Mancos shale. Some large areas of Tertiary sediments collected in such basins as the San Juan and Uinta. Cenozoic volcanic rocks crop out in the Flagstaff, Arizona, and Grants, New Mexico, areas and occur interbedded with sediments in the San Juan and Uinta Basins.

Structurally, the Colorado Plateau is an immense isolated block not significantly involved in the periods of mountain-building (e.g., the Laramide orogeny) that affected the rest of the Rocky Mountains. Nevertheless, Laramide orogeny did cause some large faults and monoclines and some structural basins within the Colorado Plateau region. Before the Laramide orogeny the Colorado Plateau was the site of marine sediment deposition. Erosion has predominated since the Laramide orogeny, and streams have carved the landscape into buttes, mesas, plateaus, and canyon lands.

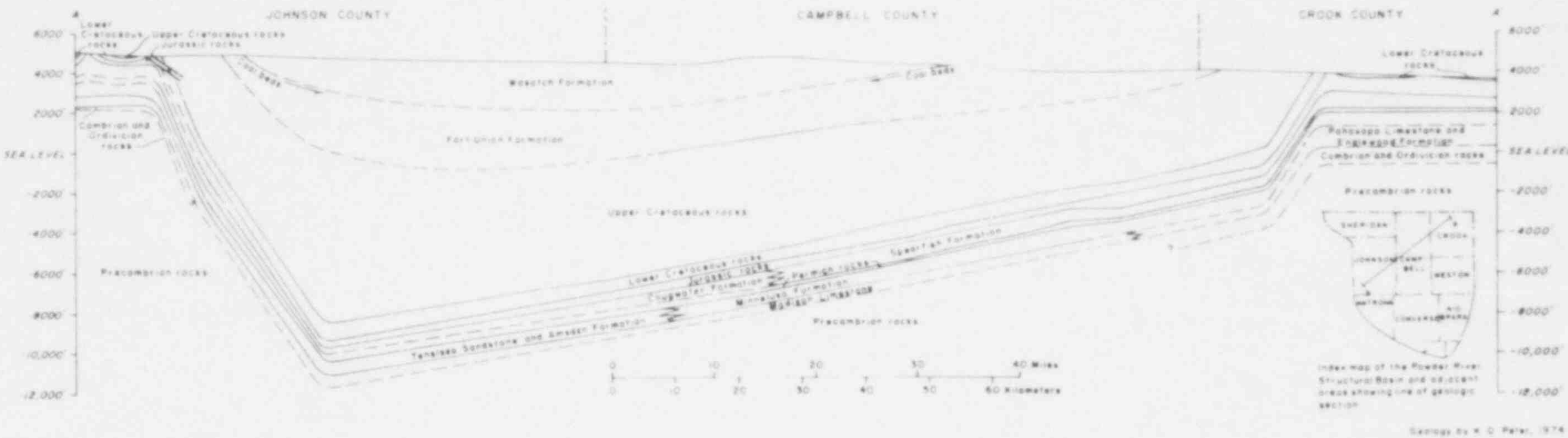

Fig. 5.5. Generalized Geologic Cross Section of the Powder River Structural Basin and Adjacent Areas, Northeastern Wyoming. (From "Draft Environmental Impact Statement, Development of Coal Resources in the Eastern Powder River Coal Basin of Wyoming," U.S. Dept. of Interior et al., 1974.)

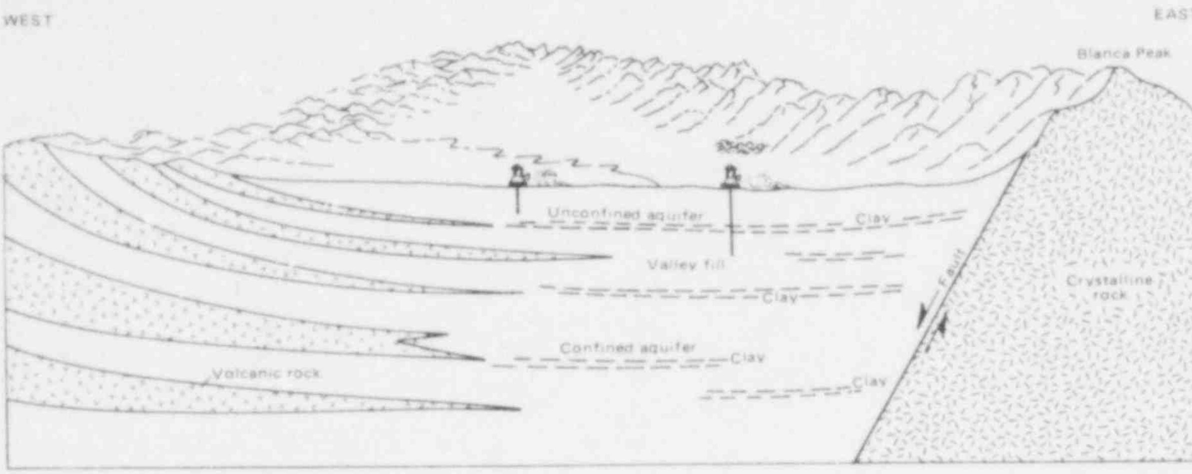

Fig. 5.6. Cross Section of the San Luis Valley, Bounded by High Mountains and Underlain by Valley Fill and Volcanic Rocks. (From S. W. West and W. L. Broadhurst, "Summary Appraisals of the Nation's Ground-Water Resources--Rio Grande Region," U.S. Geological Survey, 1975.)

The geology of the uranium mining areas in the Colorado Plateau region is described in many publications, such as those of the U.S. Geological Survey[1] and of the New Mexico Bureau of Mines and Mineral Resources.[2] The uranium occurs primarily in sandstones of the Jurassic Morrison formation, at many places deep enough to require underground mining. A schematic geologic cross section through the Grants Mineral Belt area in New Mexico is presented in Figure 5.7.

5.1.6 Texas Coastal Plains

The rocks of the Texas Coastal Plains region consist of marine sediments ranging in age from Paleocene to recent and dip gently to the southeast (see Figs. 5.1 and 5.8). These sediments were deposited as a regressive sequence as the shoreline retreated. The rocks are largely semi-indurated siltstones, clay, and sand.

The uranium deposits in the Texas region typically occur in sands and sandstones of Eocene, Oligocene, and Miocene age about 80 to 160 km (50 to 100 miles) south of San Antonio.[3] The host rocks typically are very permeable and are interbedded with clays and tuffaceous silt of volcanic origin.

5.2 SEISMICITY

The locations (epicenters) and intensities of major recorded earthquakes in part of the western conterminous United States are shown in Figure 5.9. Intensity is a parameter used to describe the observed effects of an earthquake at a given location. Earthquakes of intensity VI or less on the Modified Mercalli scale cause only slight damage, such as broken windows. Damage to well-built structures may result from quakes of intensities greater than VI.[4] Zones of relative seismic risk in the United States are shown in Figure 5.10; designation of these zones is based on known active faults, historic earthquakes, and susceptibility of rocks to seismic wave motions.

5.2.1 Northern Rocky Mountains

The Northern Rocky Mountains region has had the greatest number and the largest earthquakes of the six regions. Many large earthquakes have occurred in northwestern Wyoming near Yellowstone Park.[5] Kalispel, Montana, has had a history of damaging earthquakes. On 28 March 1975, Malad City, Idaho, was hit by an earthquake which reached intensity VIII, causing about $1 million in damage.[6] Principal uranium mining areas, however, are not near centers of high earthquake

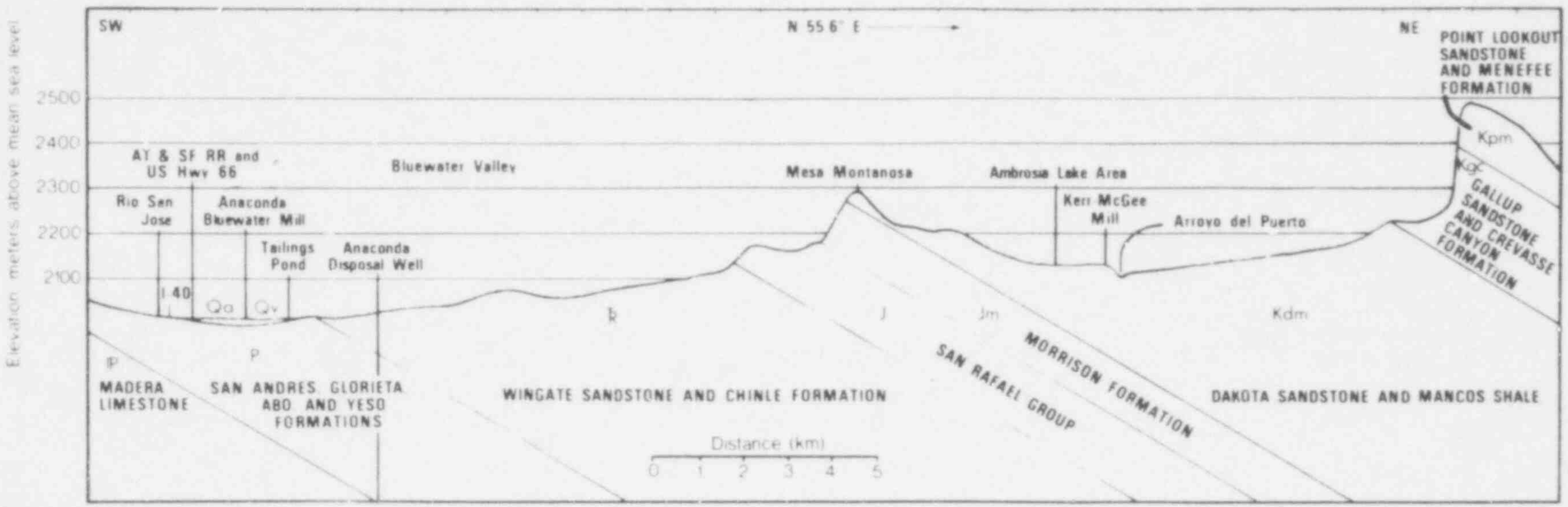

Fig. 5.7. Geologic Cross Section through the Grants, New Mexico, Mineral Belt Area. (From R. F. Kaufmann et al., "Effects of Uranium Mining and Milling on Ground Water in the Grants Mineral Belt, New Mexico," in: Ground Water 14(5), 1976.)

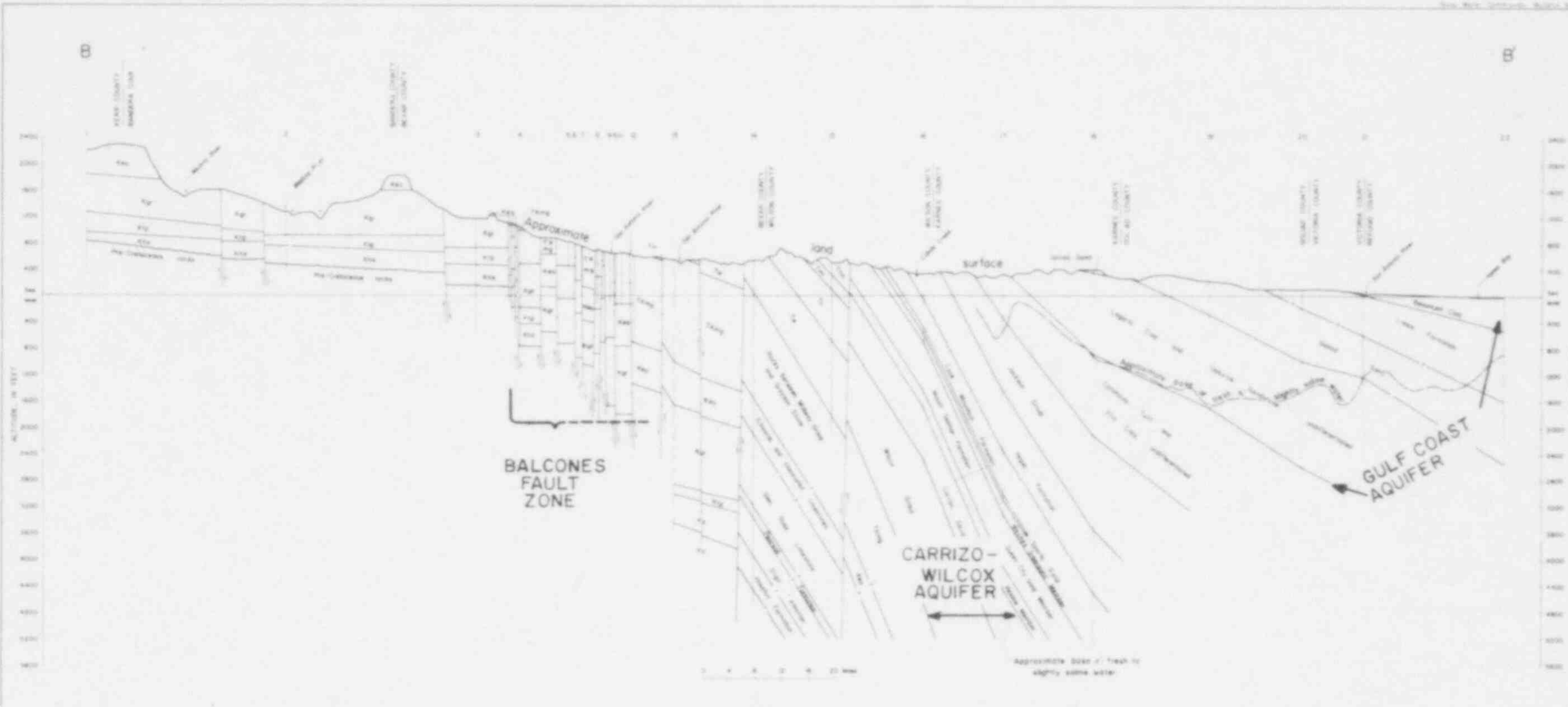

Fig. 5.8. Geologic Cross Section of the Texas Gulf Coast Region from San Antonio Bay to San Antonio. (Modified from W. H. Alexander et al., "Reconnaissance Investigation of the Ground-Water Resources of the Guadalupe, San Antonio, and Nueces River Basins, Texas," August 1964.)

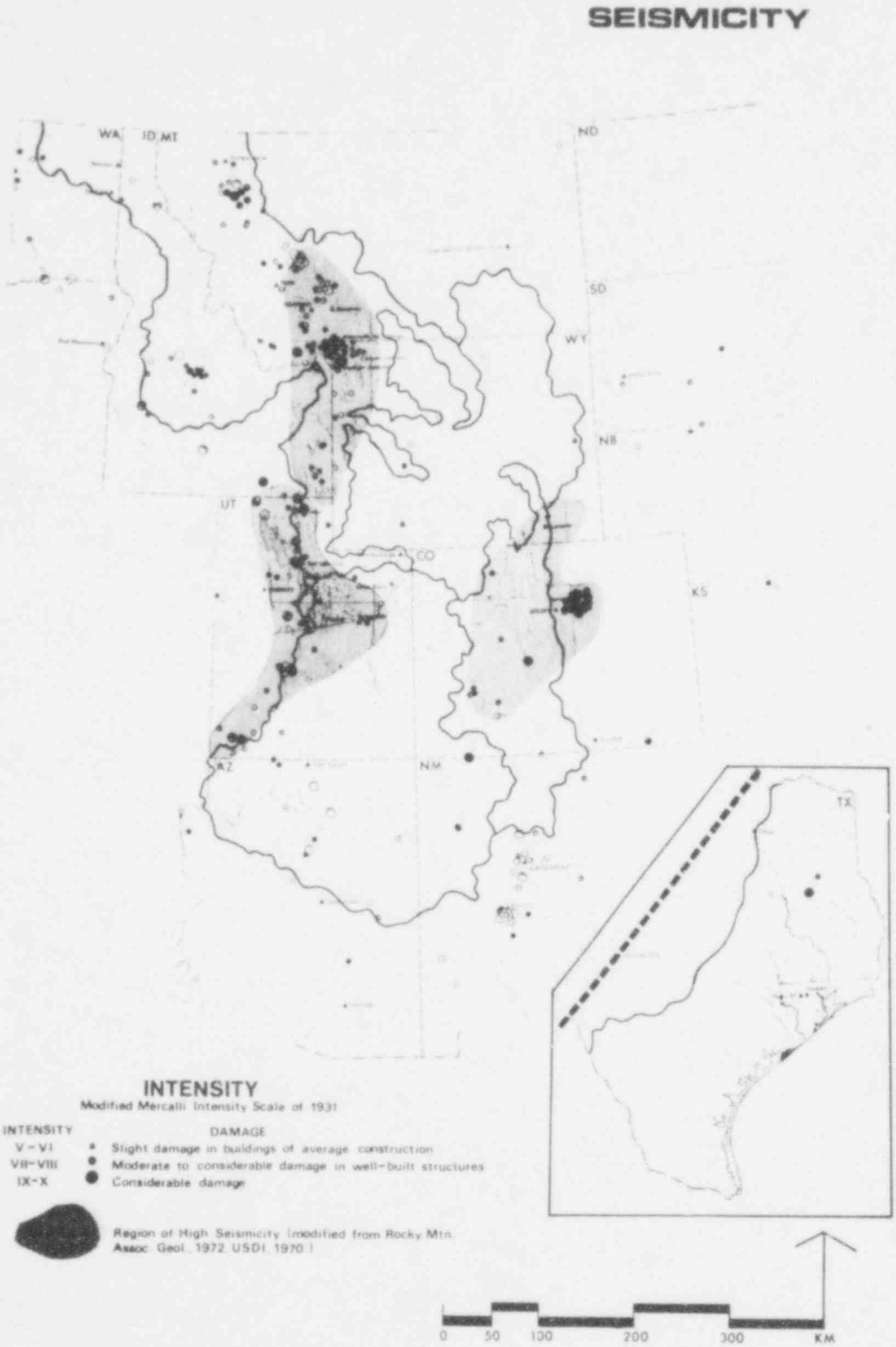

Fig. 5.9. Major Earthquakes Recorded through June 1975. (Modified from "Geologic Atlas of the Rocky Mountain Region," Rocky Mountain Association of Geologists, Denver, Colorado, 1972.)

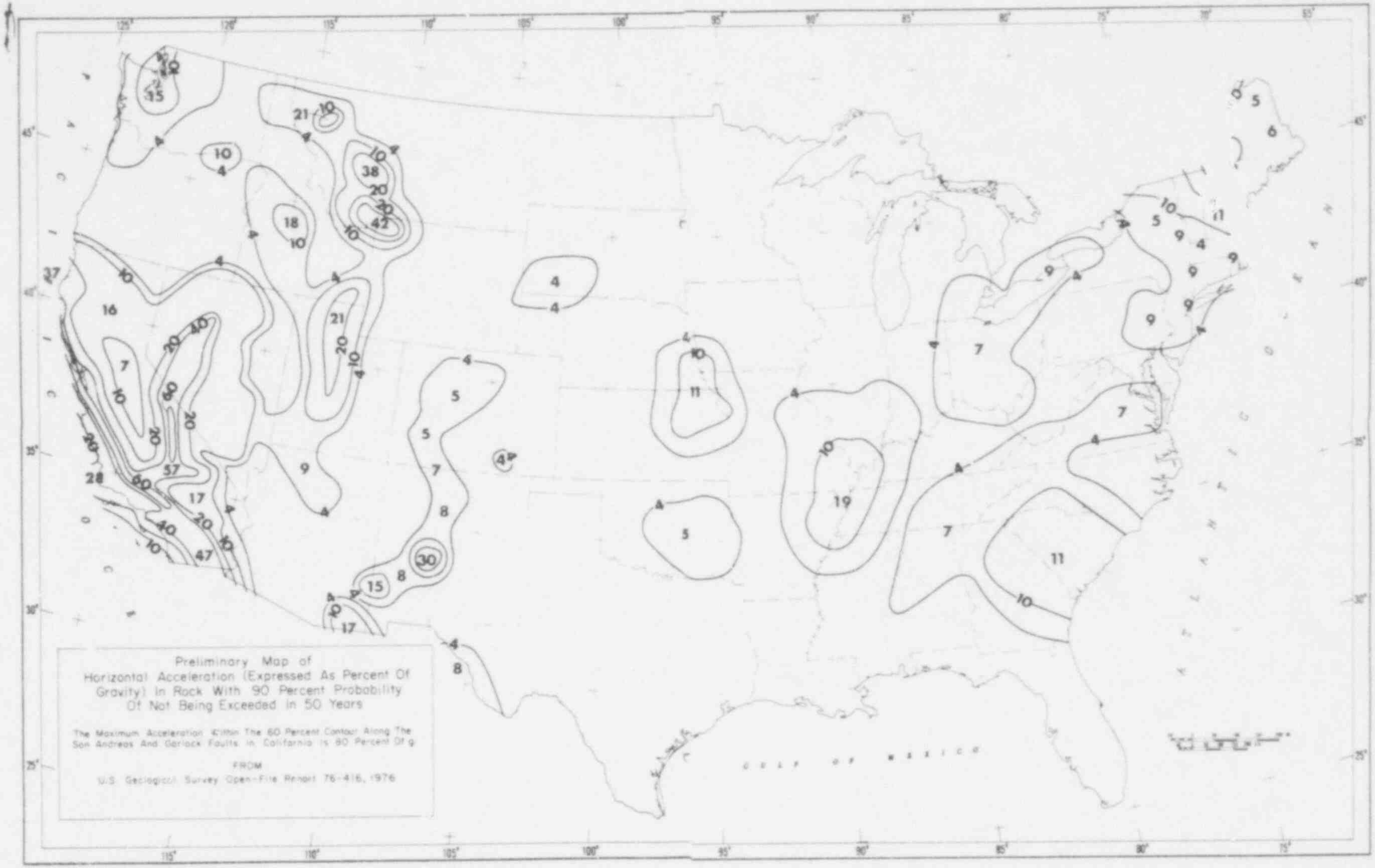

Fig. 5.10. Map of Horizontal Acceleration in Rock. (From U.S. Geological Survey Open File Report 76-416, 1976.)

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activity. No earthquakes greater than intensity VI have occurred within 200 km (120 miles) of Spokane, Washington (see Fig. 5.9). The nearest earthquakes to the Sherwood Uranium Project (east of Spokane) of sufficient intensity to endanger uranium milling operations occurred 300 km (200 miles) away in the Puget Sound area.[7]

5.2.2 Western Great Plains

The Western Great Plains region is one of the least seismically active; no earthquakes greater than intensity VI have ever been recorded (Fig. 5.9). The north-central United States is part of the "stable shield" geologic province and has not been subjected to the tectonic events which have affected the edges of the continent. The only area of the region where seismic activity has occurred to any significant extent is near the Front Range at Denver, Colorado, far from the principal uranium mining areas in South Dakota.[8] On 26 June 1966, an earthquake of intensity VI occurred in the Black Hills, probably near Keystone, South Dakota.[9] This seismic event, while small and isolated, shows that minor earthquakes can occur in the uranium-producing areas of South Dakota.

5.2.3 Wyoming Basin

No earthquakes greater than intensity VI have been recorded in the uranium-producing areas of the Wyoming Basin region. One earthquake, interpreted as intensity VII, occurred in 1897 near Casper, which is about 80 km (50 miles) southwest.[10] Because few people lived in the Casper area in 1897, the interpretation may be inaccurate. In general the region has low seismic risk (see Fig. 5.10).

5.2.4 Southern Rocky Mountains

Several earthquakes large enough to cause considerable damage to structures have occurred in the Southern Rocky Mountains; earthquakes greater than intensity VI have occurred near Leadville, Colorado, and in the Albuquerque-Socorro, New Mexico, area. Because of the history of Cenozoic tectonism and volcanism, the presence of many faults, and the past history of earthquakes, the northern part of this region has been designated as a "region of great seismicity" (see Fig. 5.9). Structures in this area should be designed to withstand major earthquakes.

5.2.5 Colorado Plateau

The Colorado Plateau region has had scattered earthquakes during historic time. Several earthquakes greater than intensity VI have occurred near Albuquerque, New Mexico, Flagstaff, Arizona, and Salt Lake City, Utah. Because of the number of uranium mills, the history of earthquakes, and the presence of Quaternary volcanism which indicates crustal unrest, it is appropriate to examine the earthquake hazard potential in this region in more detail.

According to a report by United Nuclear Corp.,[11] earthquakes have occurred along the New Mexico-Colorado border southeast of Durango, Colorado, and that region represents the largest potential source of future seismic events which could affect the Grants-Gallup, New Mexico, area. The seismic events in the Durango area were apparently related to the faults along the boundary of the San Juan Basin.

A large earthquake occurred near Grants, New Mexico, on 23 December 1973. The earthquake originated at a depth of about 18 km (11 miles) and was felt over a wide area. The maximum intensity of the earthquake was VI at Grants.[12]

As shown on Figures 5.9 and 5.10, the Grants uranium mineral belt is not considered to be in a zone of great seismicity. According to the current Uniform Building Code, this area is Zone 2 on the Seismic Risk Map, which corresponds to negligible damage to well-built structures. Nevertheless, the 1973 event at Grants indicates that damaging earthquakes can occur in the area.

5.2.6 Texas Coastal Plains

The Texas Coastal Plains region is in one of the least seismically active areas; there have been no recorded earthquakes of intensity V or greater in the Texas Gulf Coast region (Fig. 5.9). Although there are numerous faults, such as the Balcones Fault Zone, which trends along the northwestern edge of the region (Fig. 5.8), the faults have not been active in recent time.

References

1. M. W. Cooley, J. W. Harshbarger, J. P. Akers, and W. F. Hardt, "Regional Hydrogeology of the Navaho and Hopi Indian Reservation, Arizona, New Mexico, and Utah," U.S. Geological Survey, Professional Paper 521-A, 1969.

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6. R. B. Simon, C. W. Stover and W. J. Person, "Earthquakes in the United States, January-March 1975," U.S. Geological Survey, Circular 749-A, 1977.

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8. D. M. Evans, "The Denver Area Earthquakes and the Rocky Mountain Arsenal Disposal Well," The Mountain Geologist 3(1):23-26, 1968.

9. C. A. von Hake and W. K. Cloud, "United States Earthquakes, 1966," U.S. Dept. Commerce, 1968.

10. "Final Environmental Statement related to the Rocky Mountain Energy Company's Bear Creek Project, Converse County, Wyoming," U.S. Nuclear Regulatory Commission, Docket No. 40-8452, NUREG-0129, June 1977.

11. "Applicant's Environmental Report on the Church Rock, New Mexico, Uranium Mill and Mine," United Nuclear Corporation, UNC-ER-1, Richland, WA, 1975.

12. J. L. Coffman and C. A. von Hake, "United States Earthquakes, 1973," U.S. Dept. Commerce, 1975.

6. MINERAL RESOURCES AND USE

6.1 GENERAL ASPECTS

The mineral resources of the six regions are considerable and have contributed significantly to the development of this nation. Gold and silver rushes of the last century led to the settlement of large areas of the West. In this century, coal and petroleum, as well as copper, lead, and molybdenum, resources have been developed. Nonmetallic mineral resources, such as trona, potash, limestone, and bentonite, and such energy resources as uranium, coal, oil, and gas, presently contribute significantly to the mineral economy of this area.

The locations of important mineral resources in the six-region study area are shown in Figures 6.1 through 6.5. Major mining districts for gold, silver, lead, zinc, copper, and molybdenum are shown in Figure 6.1. About $150 million per year in copper is mined at Bingham, Utah, and $75 million per year is mined at Butte, Montana. Molybdenum valued at about $80 million per year is recovered at Climax, Colorado, and gold worth $25 million is recovered each year at Lead, South Dakota. The mines at Coeur d'Alene, Idaho, produce about $20 million per year each in silver, lead, and zinc.

Fields of crude oil and natural gas are shown in Figures 6.2 and 6.3. Several billion barrels of oil and several trillion cubic feet of natural gas have been obtained from a region encompassing the Pocky Mountain and central Texas area;[1] however, it is probable that production will gradually decline in future years. Oil shales, found in the Green River formation in the Green River and Uinta Basins of Wyoming and Utah (refer to Fig. 6.4) contain an estimated 4 trillion barrels of oil.[1] Although the oil is not presently economical to recover, someday this shale may be a major world source of hydrocarbons.

Coal fields, including lignite, are shown in Figure 6.4. During the past 20 years, there has been a rapid increase in coal mining in the Rocky Mountain region. Current annual production of coal in the region is about 30 million tons, and proven reserves and additional resources are estimated at over 2 million tons.[1] According to a 1975 report by the National Academy of Sciences, "Reserves and resources of coal in the United States are about 5,800 times the annual production," and "the amount of energy available from coal is ... enormously greater than the total available from oil and gas." Many of the coal deposits in the Rocky Mountains are located close to uranium deposits, and in some cases (Fort Union lignite beds) the uranium occurs in the coal.

Uranium deposits are shown in Figure 6.5. About 65% of domestic production of U_3O_8 has come from Mesozoic-aged sandstone beds in the Four Corners area and about 20% has come from early Cenozoic-aged sandstone beds in the Wyoming Basins.[2-4] Some small high-grade uranium veins are found in eastern Colorado. It currently is not economical to recover uranium deposits found in lignite coal in northwestern South Dakota.

6.2 THE SIX REGIONS

6.2.1 Northern Rocky Mountains

6.2.1.1 General

The Northern Rocky Mountains region contains major deposits of metallic ores and industrial minerals. In many places various economically important minerals occur in close association with each other in highly complex mineralized zones. Examples are the major mining districts, such as Butte district, Montana; Coeur d'Alene district, Idaho; and Metaline district, Washington, where two or more ores are mined within a single area. The large metal mines at Butte, Montana, and Coeur d'Alene, Idaho, are not near the large uranium deposits (Fig. 6.5). Very little oil, gas, or coal is produced in this region.

6.2.1.2 Uranium

Uranium minerals are known to occur within this region, but the grade and extent of potential ore bodies are generally not sufficiently well known to permit accurate estimation of the amount

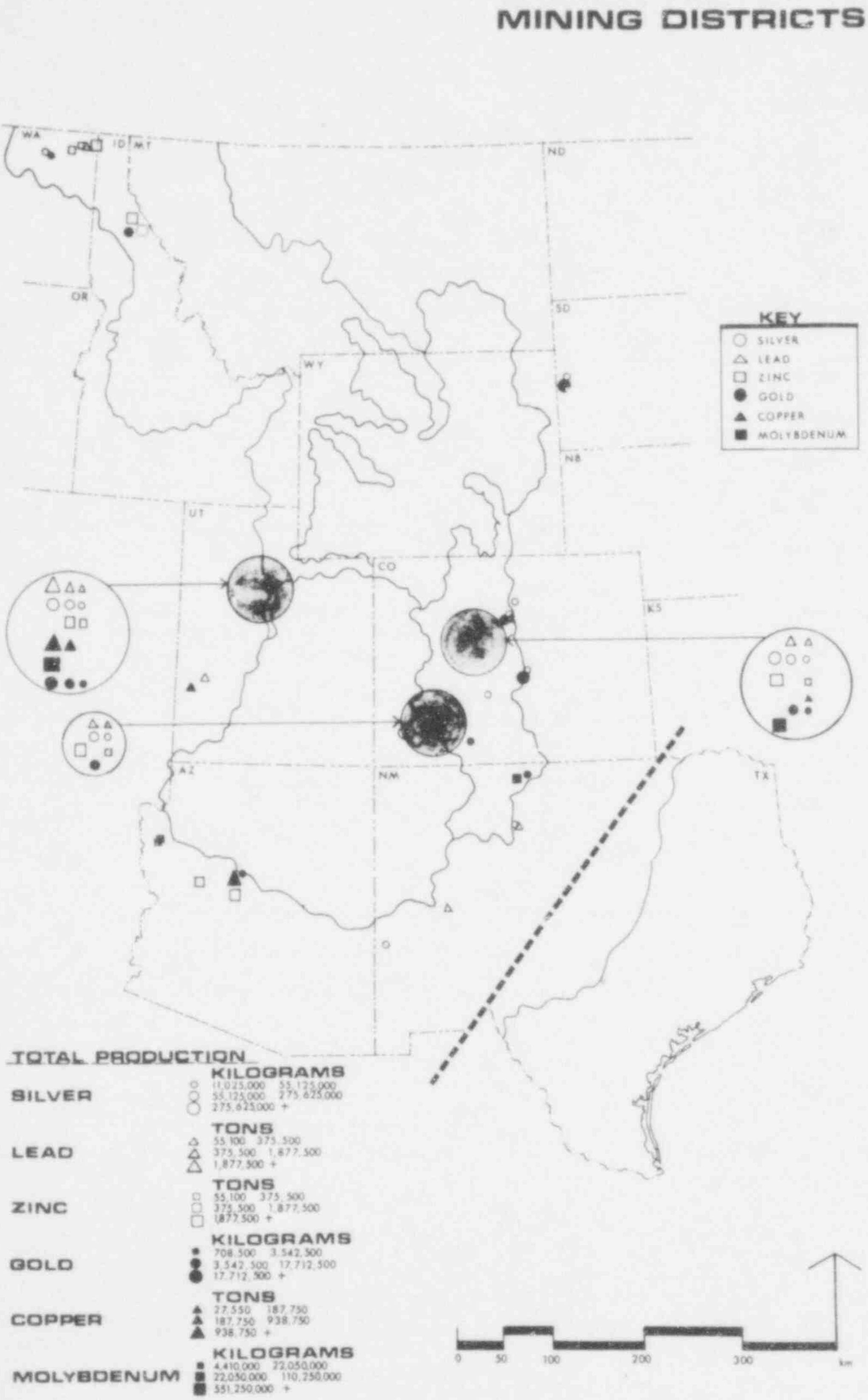

Fig. 6.1. Major Metallic Mining Districts in the Six Regions. (Modified from: "Geologic Atlas of the Rocky Mountain Region," Rocky Mountain Association of Geologists, Denver, Colorado, 1972.)

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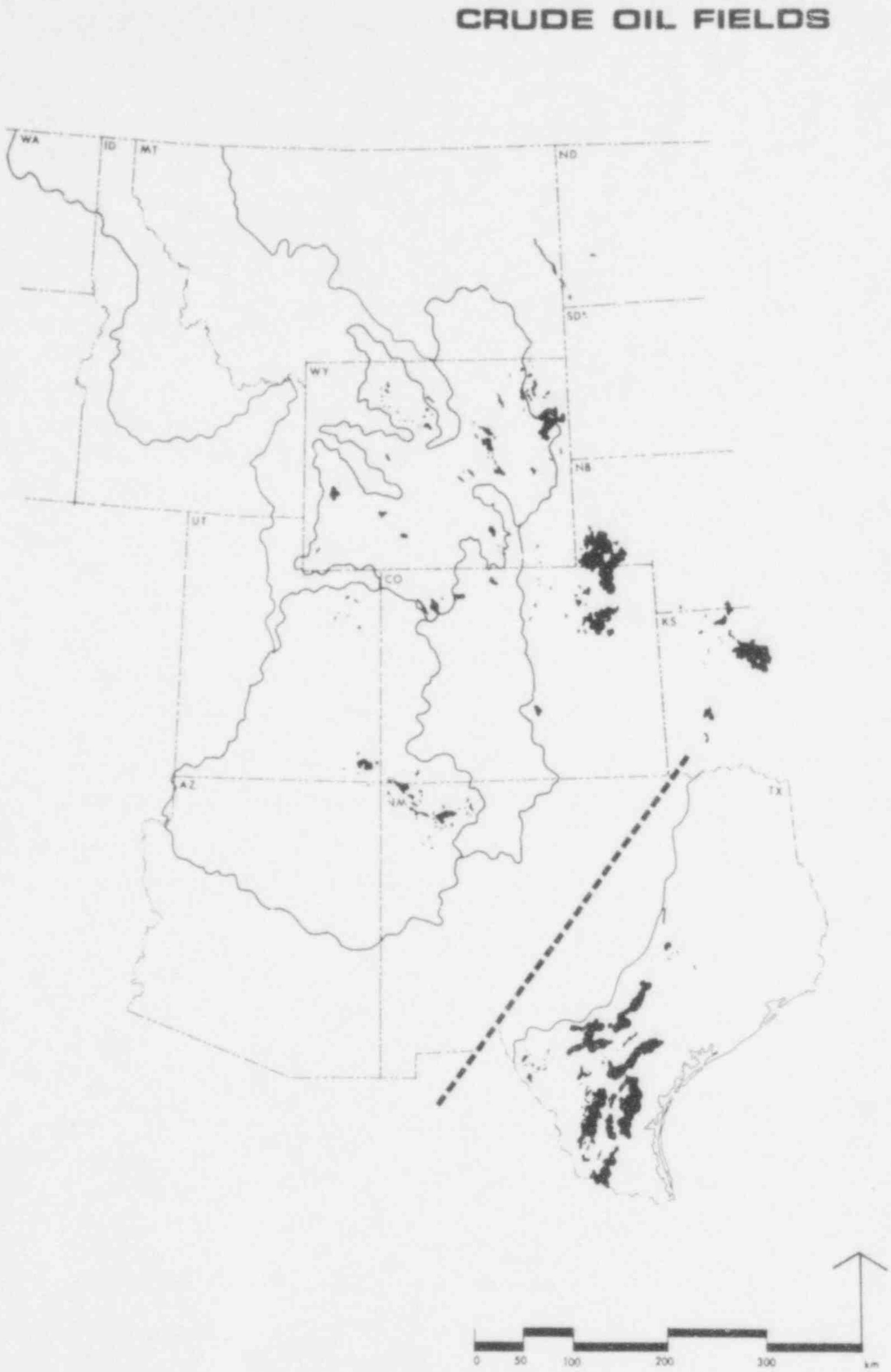

Fig. 6.2. Crude Oil Fields in the Six Regions. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

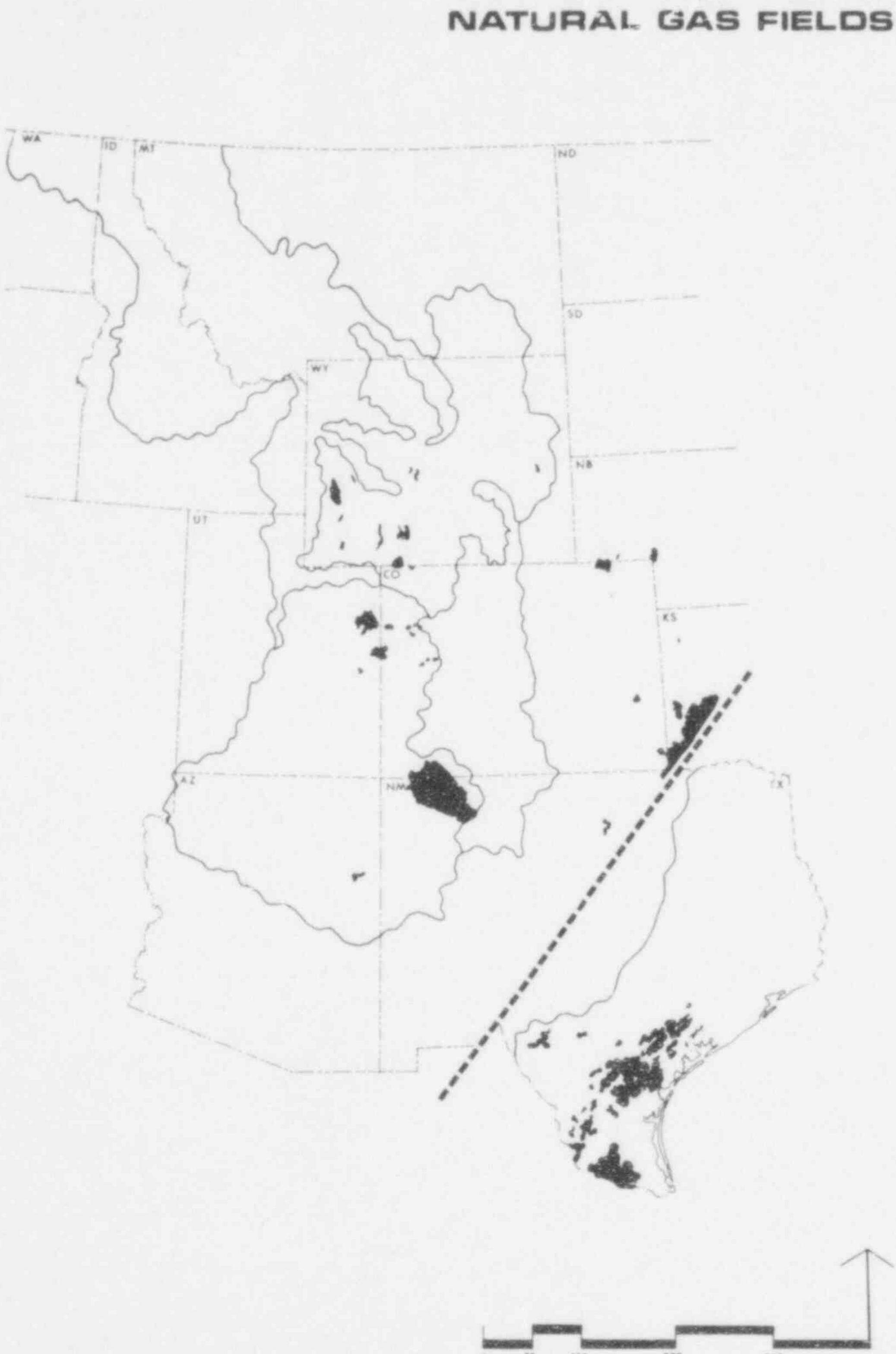

Fig. 6.3. Natural Gas Fields in the Six Regions. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

COAL FIELDS

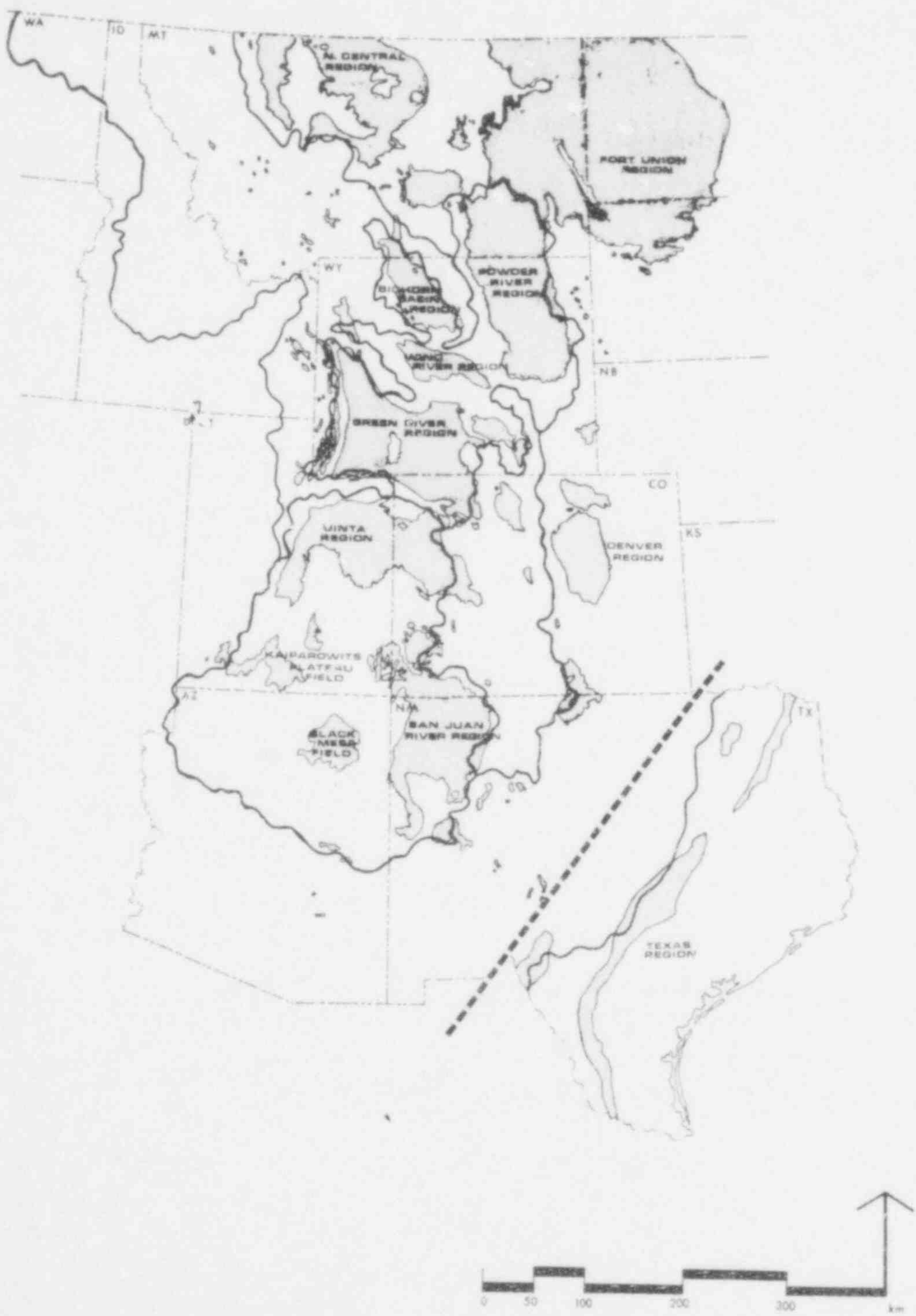

Fig. 6.4. Coal Fields in the Six Regions. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

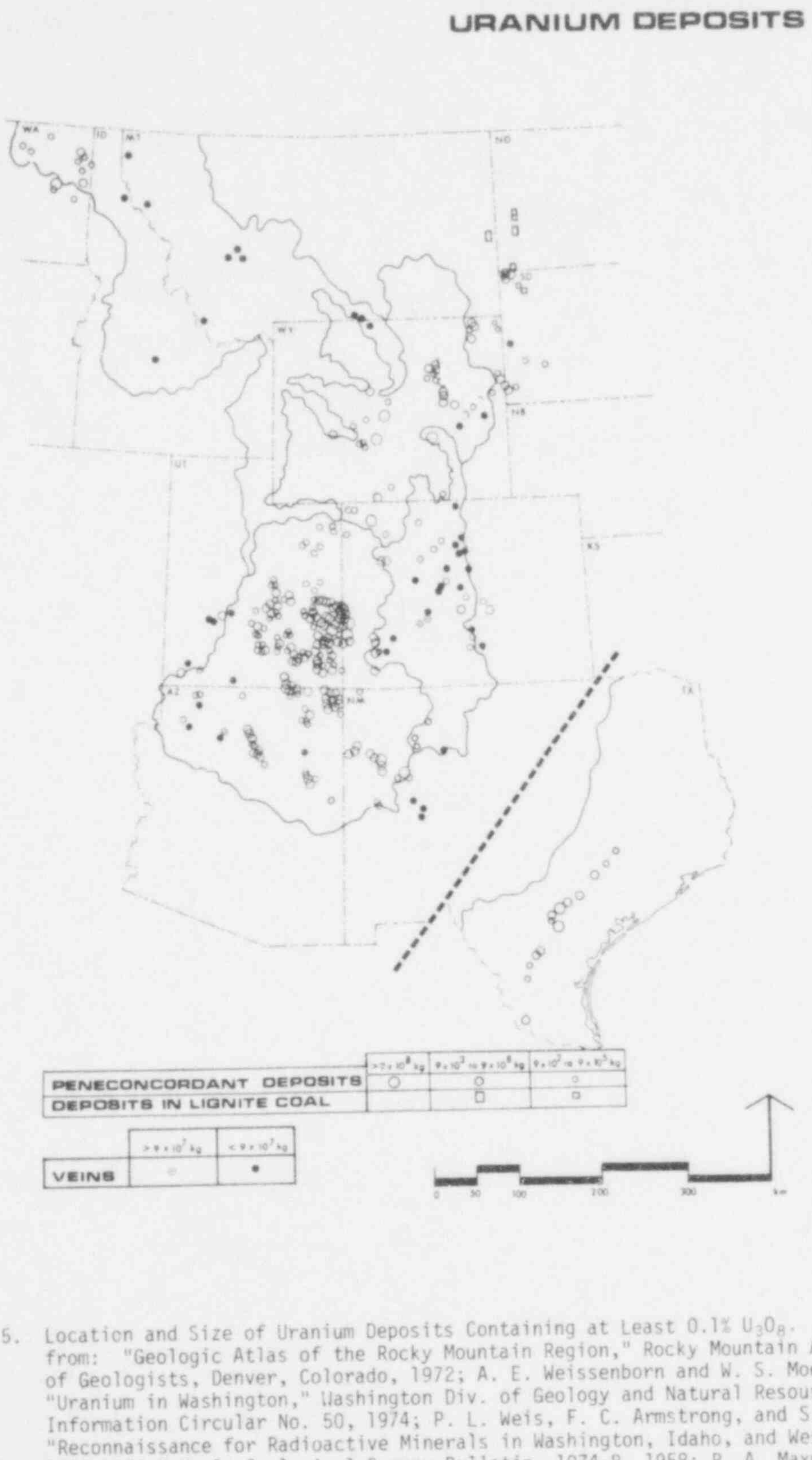

Fig. 6.5. Location and Size of Uranium Deposits Containing at Least 0.1% U_3O_8. (Modified from: "Geologic Atlas of the Rocky Mountain Region," Rocky Mountain Association of Geologists, Denver, Colorado, 1972; A. E. Weissenborn and W. S. Moen, "Uranium in Washington," Washington Div. of Geology and Natural Resources, Information Circular No. 50, 1974; P. L. Weis, F. C. Armstrong, and S. Rosenblum, "Reconnaissance for Radioactive Minerals in Washington, Idaho, and Western Montana, 1952-1955," U. S. Geological Survey Bulletin, 1074-B, 1958; R. A. Maxwell, "Mineral Resources of South Texas: Region Served through Port of Corpus Christi," Report of Investigations No. 43, Texas Bureau of Economic Geology, Austin, TX, 1962.)

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of resources. Uranium minerals also occur in veins mined for other metals, such as copper or lead, in Washington, Idaho, and Montana.[5-8] Uranium deposits occur in igneous, metamorphic, and sedimentary rocks (Fig. 6.6). The principal uranium minerals may occur as pitchblende nodules, as cavity fillings, or in alteration zones where metamorphic or sedimentary materials are in contact with igneous rocks.[9] The largest known uranium deposits in the region are those in northeastern Washington. Major veins occur in the Midnight area of southern Stevens County and in the Mount Spokane area of northern Spokane County. The deposits are primarily hexavalent uranium minerals, such as autunite and coffinite.

In the Midnight area, uranium ores occur in metasedimentary rocks close to faults and shear zones. During a 6½-year period from 1955 to 1962, the Midnight mine produced about 1 million MT (1.1 million ST) of ore, all of which was processed at Dawn Mining Company's Ford mill. Since 1969, about 100,000 MT (110,000 ST) of ore have been mined annually.[10]

In the Mount Spokane area, uranium deposits occur as fillings in fractures and in open spaces in the host rock. Autunite is the major uranium mineral present. To date, uranium deposits found in the Mount Spokane area have been in or adjacent to masses of alaskite.[9,10]

All uranium deposits in Washington are mined by open-pit methods. At other localities within the region, lesser known deposits of a more speculative nature may require the development of underground mines where quadrivalent uranium minerals may exist below the deep-oxidation zone. Because the extent of these deposits is not known, estimates of future development cannot be made.

Reserves data indicate that approximately 23,000 MT (25,000 ST) of U_3O_8 remain in the Northern Rocky Mountains region. Probable potential resources amount to an additional 24,000 MT (27,000 ST).[2] Because uranium minerals found in the region generally are associated with a variety of other minerals of varying economic importance, the composition of ore may differ markedly from site to site. Tailings from the milling of specific ores thus differ in terms of chemical composition and presence of potentially toxic elements. Some of the substances associated with uranium deposits in the region are oxides or sulfides of such elements as magnesium, molybdenum, zinc, arsenic, titanium, selenium, cadmium, gallium, mercury, and indium. The distribution of each is so sporadic that generalizations cannot be made for the region or even for the northeastern Washington production center.

6.2.2 Western Great Plains

6.2.2.1 General

The Western Great Plains region contains deposits of economically important energy and industrial minerals in the Fort Union Basin region and the Black Hills area. The Williston Basin roughly coincides with the Fort Union region and is a major petroleum and natural gas producing area (Figs. 6.2 and 6.3). Exploration and production activities in the region have increased in recent years as a result of discoveries of economically recoverable oil pools. Large reserves of lignite in the Fort Union region (Fig. 6.4) are being mined to provide low-sulfur fuel for electric power plants; another potential use of lignite is for coal gasification to provide pipeline-quality synthetic natural gas. Gold and silver, mined in the Northern Black Hills (Fig. 6.1), are the only metallic ores except uranium mined in the region. Industrial minerals, such as halite, gypsum, construction stone, sand, and gravel, are extracted at several locations within the region.[1]

6.2.2.2 Uranium

Uranium deposits (Fig. 6.7) occur at several locations (principally the southwestern and northwestern edges of the region) in the Black Hills in a belt of rocks dating from the early Cretaceous period. In this belt, uranium typically occurs as black unoxidized uranium minerals (uraninite and coffinite) found in association with vanadium minerals. Some oxidized uranium minerals may also be present.[11,12]

Uraniferous lignites occur in the Fort Union formation (Paleocene) in North and South Dakota. Potentially minable deposits have been found in the Cave Hills and Slim Buttes areas of Harding County, South Dakota, and as far north as HT Butte in Bowman County, North Dakota. Uranium deposition in the lignite beds is thought to have been caused by the movement of uranium-bearing groundwater through overlying permeable sandstones.[12-14] The principal uranium minerals include uranophane, carnotite, and tyuyamunite. Concentrations of up to 5.0% U_3O_8 have been found in some lignite seams.[13]

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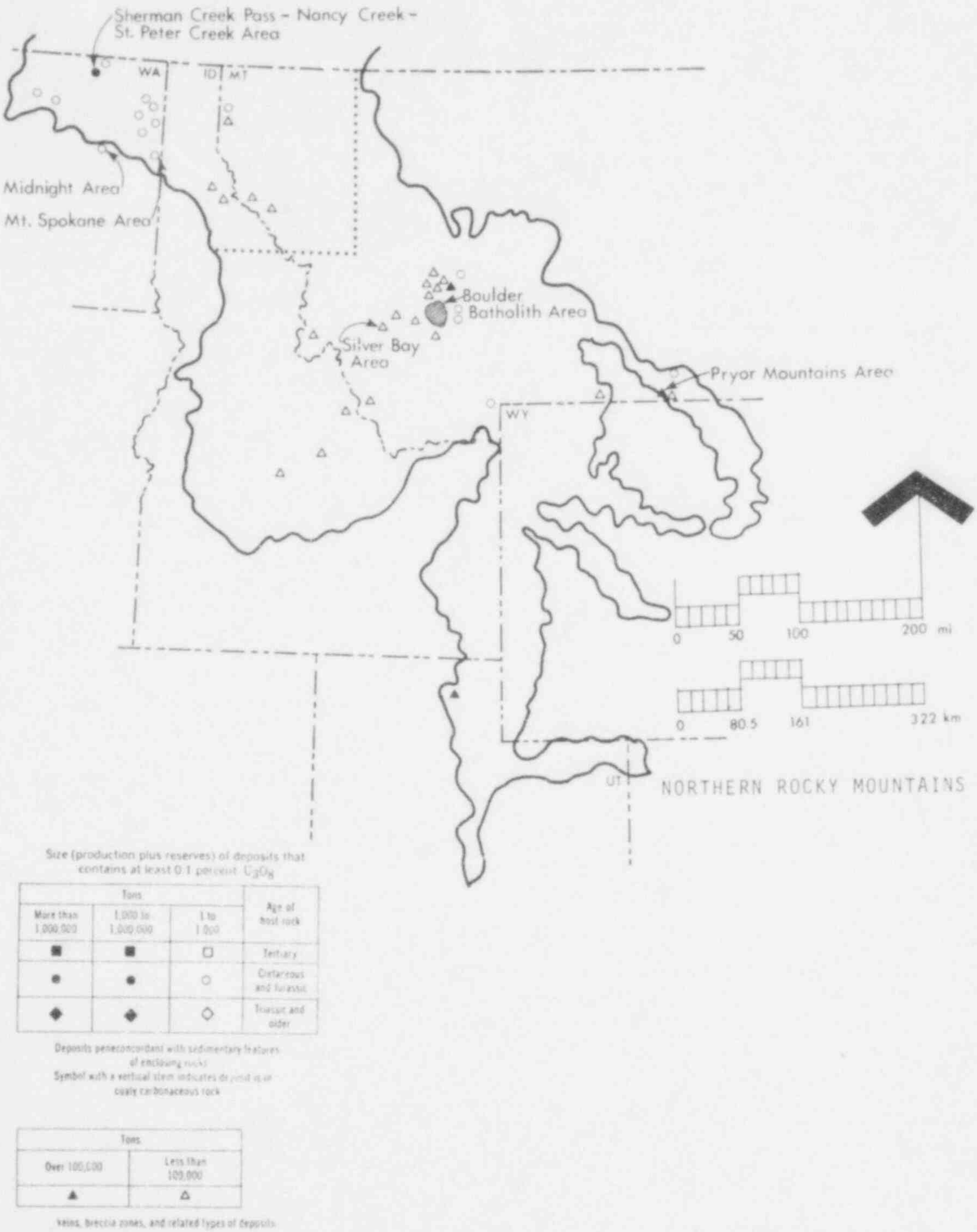

Fig. 6.6. Principal Uranium Deposits in the Northern Rocky Mountains Region. (Modified from: "Geologic Atlas of the Rocky Mountains Region," Rocky Mountain Association of Geologists, Denver, Colorado, 1972; A. F. Weissenborn and W. S. Moen, "Uranium in Washington," Washington Div. of Geology and Natural Resources, Information Circular No. 50, 1974; P. L. Weis, F. C. Armstrong, and S. Rosenblum, "Reconnaissance for Radioactive Minerals in Washington, Idaho, and Western Montana, 1952-1955," U.S. Geological Survey Bulletin, 1974-B, 1958.)

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Fig. 6.7. Principal Uranium Deposits in the Western Great Plains Region. (Modified from: "Geologic Atlas of the Rocky Mountain Region," Rocky Mountain Association of Geologists, Denver, Colorado, 1972.)

The ores have been extracted predominantly by surface mining. Potentially toxic minerals may be associated with the uranium ore deposits and thus are likely to be deposited in mill tailings. Arsenic, molybdenum, vanadium, copper, and fluorine are among substances that may contribute to ground- or surface-water contamination from tailings areas.[15]

6.2.3 Wyoming Basin

6.2.3.1 General

The Wyoming Basin region contains important deposits of industrial minerals, fossil fuels, and metallic ores. Industrial minerals mined within the region include bentonite deposits near Rock Creek, in the vicinity of the Bighorn Mountains, and in a belt surrounding the western edge of the Black Hills. Gypsum and anhydrite are extracted in north-central, northwest-central and southwestern Wyoming. Sodium sulfate is produced from surface crusts on dry lake beds in central Wyoming, and trona is mined for sodium carbonate from deposits in the Green River formation of southwestern Wyoming.[16] No metallic minerals other than those containing uranium are mined in this region (see Figs. 6.1 and 6.5), although iron is mined at Atlantic City and Guernsey, Wyoming, just outside the region.

There are extensive reserves of coal, oil, natural gas, and uranium in the Wyoming Basin region (see Figs. 6.2 through 6.5). Oil fields in the Powder River, Bighorn, and Wind River basins are producing from stratigraphic horizons ranging from Upper Cretaceous to Ordovician in age. In Powder River Basin, oil and gas fields border the western edge of the uranium-mining district and extend from Johnson County through northeastern Natrona County into southwestern Converse County. Similarly, oil fields in the Bighorn Basin are adjacent to the uranium deposits. In the Wind River Basin, additional oil and gas fields occur around the sides of the basin and include the Muskrat field, which lies in the same general area as the Gas Hills uranium mining district. Smaller oil and gas fields occur along the edges of the Green River, Red Desert, Washakie, and Laramie basins.[1]

The subbituminous coal deposits of the Wyoming Basin region represent some of the largest reserves of low-sulfur coal in the nation. Campbell County in the Powder River Basin contains more than 17 billion MT (19 billion ST) of strippable low-sulfur coal.[17] Coal also is mined in the Wind River, Bighorn, Hanna, Rock Springs, Kemmerer, and Green River basins. The oil shale found in the Green River region is expected to be of value for energy production in the future.

6.2.3.2 Uranium

Numerous uranium deposits occur in the Wyoming Basin region. The major areas of known reserves and resources include the southern Powder River Basin, the Gas Hills area of the Wind River Basin, the Shirley Basin, and the Crooks Gap area (Fig. 6.8). Additional deposits have been identified in the Bighorn, Poison, and Red Desert basins in Bighorn, Sweetwater, and Carbon counties, respectively.[11] In general, sandstone deposits are located within basins; vein-type deposits are found along the edges of basins or in hilly to mountainous interbasinal areas. Total reserves for this region in 1978 were estimated at over 240,000 MT (264,000 ST) of U_3O_8.[2]

Uranium production in the southern Powder River Basin is principally from deposits at the juncture of Campbell, Johnson, Natrona, and Converse counties. The deposits are near the southwestern edge of the basin in a curved band from the Pumpkin Buttes area on the north to central Converse County on the south. The deposits, principally tyuyamunite and carnotite, occur in the Wasatch formation.

The Gas Hills uranium mining district of Wyoming contains large deposits of such uranium minerals as uraninite and coffinite in the upper part of the Wind River formation. Extensive deposits also occur in the Shirley Basin, south of Casper, Wyoming, in sandstones of the Wind River formation. The principal uranium mineral is uraninite.[18] Additional deposits of uranophane occur at Crooks Gap (a few kilometers south of the Sweetwater River in southeastern Fremont County).[19]

Uranium deposits in the Wyoming Basin region are mined primarily by surface methods, but underground mining is used in some places, depending on the position and grade of the ore body. In the Shirley Basin, for example, the grade of mined ore ranges from 0.1 to 0.7% U_3O_8, and most mining there is by surface techniques.[18] In addition, solution mining is also used in the region by at least one company.[20]

Because the numerous potentially toxic substances associated with uranium minerals in the ore bodies remain in the tailings when uranium is separated from ore materials in the milling

Fig. 6.8. Principal Uranium Deposits in the Wyoming Basin Region. (Modified from: "Geologic Atlas of the Rocky Mountain Region," Rocky Mountain Association of Geologists, Denver, Colorado, 1972.)

process, it is possibile for these substances to reach groundwater and surface water. Metals found in tailings in the Wyoming Basin region include manganese, molybdenum, selenium, vanadium, iron, and arsenic, as well as radioactive substances.

6.2.4 Southern Rocky Mountains

6.2.4.1 General

The Southern Rocky Mountains region has long been known for its mineral resources; mining was an important factor in the early settlement of the region. Gold and silver were mined in vein and placer deposits at numerous localities, such as near Central City and Cripple Creek. Other metallic ores currently mined in the region include lead, manganese, molybdenum, titanium, tungsten, uranium, and zinc (Fig. 6.1). Molybdenum resources in Colorado include the two largest deposits in the world--at Climax in Lake County and Urad-Henderson in Clear Creek County. The combined output of the two mines represents about 35% of the world's production of molybdenum, with the Climax mine processing about 40,000 MT (44,000 ST) of ore per day.[21]

Energy resources in the region include some bituminous and subbituminous coal deposits in the intermontane basins of North, Middle, and South Parks of Colorado (Fig. 6.4). Numerous industrial minerals occur in the region. The principal occurrences are in the Rocky Mountain ranges of central Colorado (including the Front Range mineral belt).

6.2.4.2 Uranium

Uranium deposits occur at several locations in the region (Fig. 6.9). The largest mines extract ores from mineralized vein deposits in fractured rocks of varying ages. Numerous mines exist in the Front Range from the northern boundary of Colorado south to Canon City and in the Sangro de Cristo and Culbera Ranges south of Canon City. Others occur at scattered locations in the Park Range, in the area west of Ouray (in the southwestern portion of the state) and at Juniper, Hot Springs, Uranium Peak, and Newcastle.[22]

Pitchblende is the dominant uranium mineral in the vein at Los Ochos mine in Sagnache County. The uranium minerals uranophane, autunite, and torbernite are found in sandstone where the vein crops out in the Morrison formation.[23] At the Schwartzwalder mine near Golden (in Jefferson County), pitchblende, torbernite, and autunite are mined from the Idaho Springs formation. Mines also exist along the Front Range near Idledale and Kassler.[8,22]

In the Central City district and adjoining areas of Clear Creek and Gilpin counties, pitchblende occurs in veins. These deposits, as well as those in Jefferson and Boulder counties, are in the Front Range mineral belt. At some places in this belt, uranium-bearing veins also contain gold, silver, copper, lead, and zinc. The ore grade is quite variable. In the past, known uranium deposits in the Central City district have been selectively mined and hand sorted; the highest grade ores being sought. Secondary uranium minerals in the Central City area deposits include torbernite and autunite.[24]

In the Golden Gate Canyon district (Boulder County), pitchblende and secondary uranium minerals occur along metavolcanic rocks.[25] In the area of the Colorado-Front Range, pitchblende veins occur in intimate association with, and are probably related to, uranium-bearing minerals known as quartz bostonites. A few veins also occur in the vicinity of pegmatites (exceptionally coarse-grained igneous rocks) of the Precambrian era.

In the Placerville district of San Miguel County (southwestern Colorado), thucholite (a black hydrocarbon with varying amounts of ash rich in thorium, uranium, and other radioactive elements) is mined from the Dolores formation.[26]

Both open-pit and underground mining is used in the Southern Rocky Mountains region.[20] Underground mining is more prevalent because the deposits often are in mineralized veins situated so as to make open-pit mining uneconomical. Existing reserves of U_3O_8 in the region have been estimated at approximately 24,000 MT (26,000 ST), with an additional probable resource of about 51,000 MT (56,000 ST).[2]

Because of the nature of mineralization in the Colorado vein-type deposits, accessory minerals may present environmental problems when deposited as mill tailings. Some of the metallic minerals, such as copper, lead, zinc, molybdenum, and antimony, occur as sulfides, arsenates, and oxides that may cause water quality deterioration if water percolating through tailings enters ground- or surface-water systems. Sulfides in fine-grained tailings, for example, may be soluble in groundwater, introducing potentially toxic metallic elements into the groundwater system.

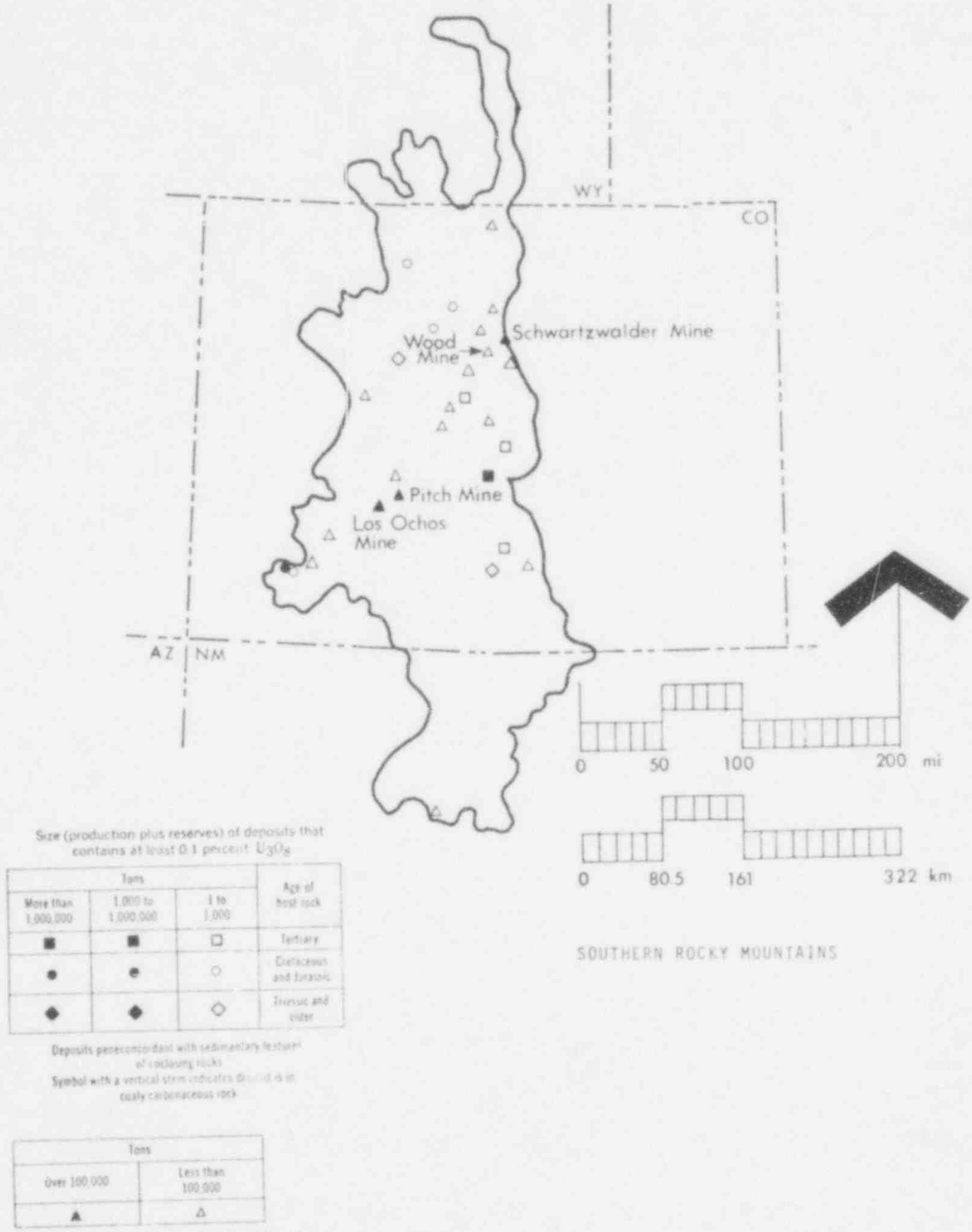

Fig. 6.9. Principal Uranium Deposits in the Southern Rocky Mountains Region. (Modified from: "Geologic Atlas of the Rocky Mountain Region," Rocky Mountain Association of Geologists, Denver, Colorado, 1972.)

6.2.5 Colorado Plateau

6.2.5.1 General

The Colorado Plateau region, which includes portions of Arizona, Utah, Colorado, and New Mexico, contains substantial reserves of energy and industrial minerals; however, little metal other than uranium is mined (Fig. 6.5). Energy resources include petroleum, natural gas, oil shale, coal, and uranium. The major known petroleum and natural gas resource areas are in the Uinta, Piceance Creek, Paradox, and San Juan basins (Figs. 6.2 and 6.3). The deposits of oil shale in the Green River formation in the Uinta and Piceance Creek basins have become important in recent years because of interest in their potential for crude-oil extraction. Large deposits of bituminous and subbituminous coal occur in several areas of the region, the major ones being those of the Uinta, Piceance Creek, San Juan, Black Mesa, Kaiparowits, and eastern Paradox basins (Fig. 6.4).

6.2.5.2 Uranium

Uranium deposits occur at many localities in the Colorado Plateau (Fig. 6.10). The Uravan mineral belt of southwestern Colorado and eastern Utah is a major resource area; vanadium-uranium ore deposits occur in sandstone and mudstone beds of the Salt Wash and Brushy Basin members of the Morrison formation. The belt is about 80 km (50 miles) long, varies from 2 to 8 km (1 to 5 miles) in width, and curves from southwest to northeast and to northwest. Ore bodies in the belt tend to be clustered. The uranium ore minerals generally occur as the vanadates carnotite and tyuyamunite in association with small amounts of iron and manganese. Trace amounts of lead, cobalt, nickel, molybdenum, chromium, arsenic, and selenium commonly occur in association with ore minerals.[27-30]

Large uranium deposits occur in the Brushy Basin member of the Morrison formation in the Grants mineral district of McKinley and Valencia counties in northwestern New Mexico. Most of the larger deposits have been found in the Poison Canyon and Jackpile sandstone units of the Brushy Basin.[29,31,32] The district extends from Gallup to the western edge of Bernalillo County and includes the important Ambrosia Lake, Gallup, and Laguna districts. About 75% of the uranium ore deposits occur in oxidized forms.

Uranium ore has been found in sandstone and limestone in the Ambrosia Lake and Laguna districts.[32] Similar deposits occur at several localities in the Chama Basin and in the Chuska district of the Four Corners area. Another large deposit occurs as coffinite in impure coals and carbonaceous shales at the LaVentana Mesa area in Sandoval County.[32]

Uranium ores occur at numerous locations in northern and northeastern Arizona as deposits in sandstone, as mineralizations in diatremes (volcanic vents or pipes) and as vein-type deposits. Numerous deposits have been found in the Chinle formation in the Monument Valley district of northeastern Arizona.[33] There the deposits occur predominantly as uranium-vanadium minerals. Deposits also occur in sandstone in several other districts, including the Cameron, Chinle Valley, Northern Mohave, and Little Colorado River districts. Uranium ore minerals also have been found in economic quantities in diatremes in north-central Arizona, the best mineralized being that at the Orphan Mine on the South Rim of the Grand Canyon. The mineralization is quite complex, with copper and iron sulfides in association with uraninite and secondary uranium minerals.[34]

In Utah, the Moab uranium belt in Grand and San Juan counties contains numerous uranium deposits in the Chinle formation. A large number of deposits also occurs in the Slick Rock and Lisbon Valley areas of San Juan County in the Morrison formation and in the Shinarump conglomerate. The deposits contain substantial amounts of vanadium and copper in association with the uranium.[28,29,35-37] Other important uranium deposits occur in the Temple Mountain district in the Chinle formation.[37,38] Vein-type deposits in the Marysvale uranium area of Piute and Sevier counties contain fluorite-bearing uranium ores that include pitchblende and secondary uranium oxides.[37]

Depending upon their geologic settings, Colorado Plateau uranium deposits are mineable by both surface and underground methods. Most of the sandstone and limestone deposits are amenable to surface mining; many of the vein-type deposits are mined by underground techniques. At Marysvale, Utah, for example, uranium-bearing veins have been mined to a depth of about 250 m (800 ft).[37]

NURE reserves data indicate that approximately 440,000 MT (485,000 ST) of U_3O_8 remain in the Colorado Plateau region. Probable potential resources amount to an additional 603,000 MT (665,000 ST).[2]

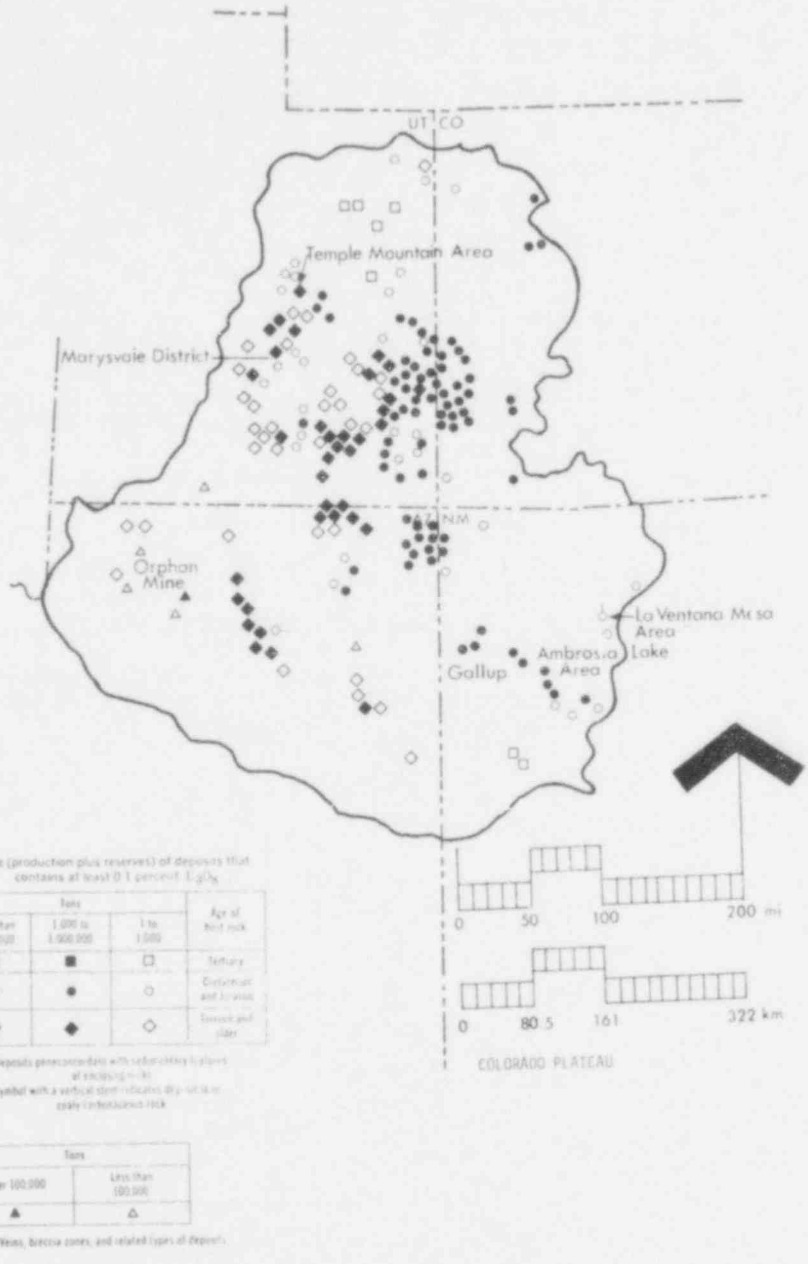

Fig. 6.10. Principal Uranium Deposits in the Colorado Plateau Region. (Modified from: "Geologic Atlas of the Rocky Mountain Region," Rocky Mountain Association of Geologists, Denver, Colorado, 1972.)

Because uranium minerals found in the region generally are associated with a variety of accessory and trace minerals, tailings from different ores would differ in their content of potentially toxic elements.

6.2.6 Texas Coastal Plains

6.2.6.1 General

Major deposits of crude oil and natural gas occur in the Texas Coastal Plains region (Figs. 6.2 and 6.3). The region also contains minor amounts of metallic mineral resources (Fig. 6.1), notably manganese and titanium. (Commercial grades of manganese occur in Val Verde County.) Clay is mined for a number of uses, including manufacture of brick and tile, and drilling needs. Stone, sand, and gravel are mined for building materials in most counties of the region. Industrial sand is mined at several places for glass, refractories, and other uses. Lignite deposits in the Wilcox and Jackson formations are of great current interest as fuel for electric power generation in southern Texas (Fig. 6.4); mines are planned in Atascosa and McMullen counties.[39]

6.2.6.2 Uranium

Uranium of mineable grade occurs in sandstone deposits at several locations in the Texas Coastal Plains region (Fig. 6.11). In recent years, mining has been concentrated in the area of Karnes, Live Oak, and Atascosa counties, where deposits occur in the late Eocene Jackson formation and overlying early Oligocene strata. The strata consist largely of marine and terrestrial sandstones and sandy clays. Uranyl phosphates and silicates occur in interstices between grains, often associated with arsenic and molybdenum. The lateral extent of deposits ranges from a few meters to several hundred meters. The larger deposits may contain many thousands of metric tons of ore. For example, the deposit being mined at the Harper No. 1 mine, in the Harmony Hills area of Karnes County has been estimated to contain approximately 45,000 MT (50,000 ST) of ore with an average grade of 9.13% U_3O_8. In the important Fordilla Hill deposits, also in Karnes County, mineralization consists of carnotite, tyagaminite, autunite, and uranophane.[40-42]

In the past, most of the ore was extracted by surface mining techniques; however, nearly 50% of current production results from in-situ leaching of uranium.[43] Uranium ores in Texas are often associated with arsenic, molybdenum, and other toxic substances; there is thus potential for contamination of groundwater, regardless of the method of mining.

Uranium reserves in the Texas Coastal Plains region have been estimated at about 49,000 MT (54,000 ST) of U_3O_8, with a probable additional resource of about 163,000 MT (180,000 ST).[2]

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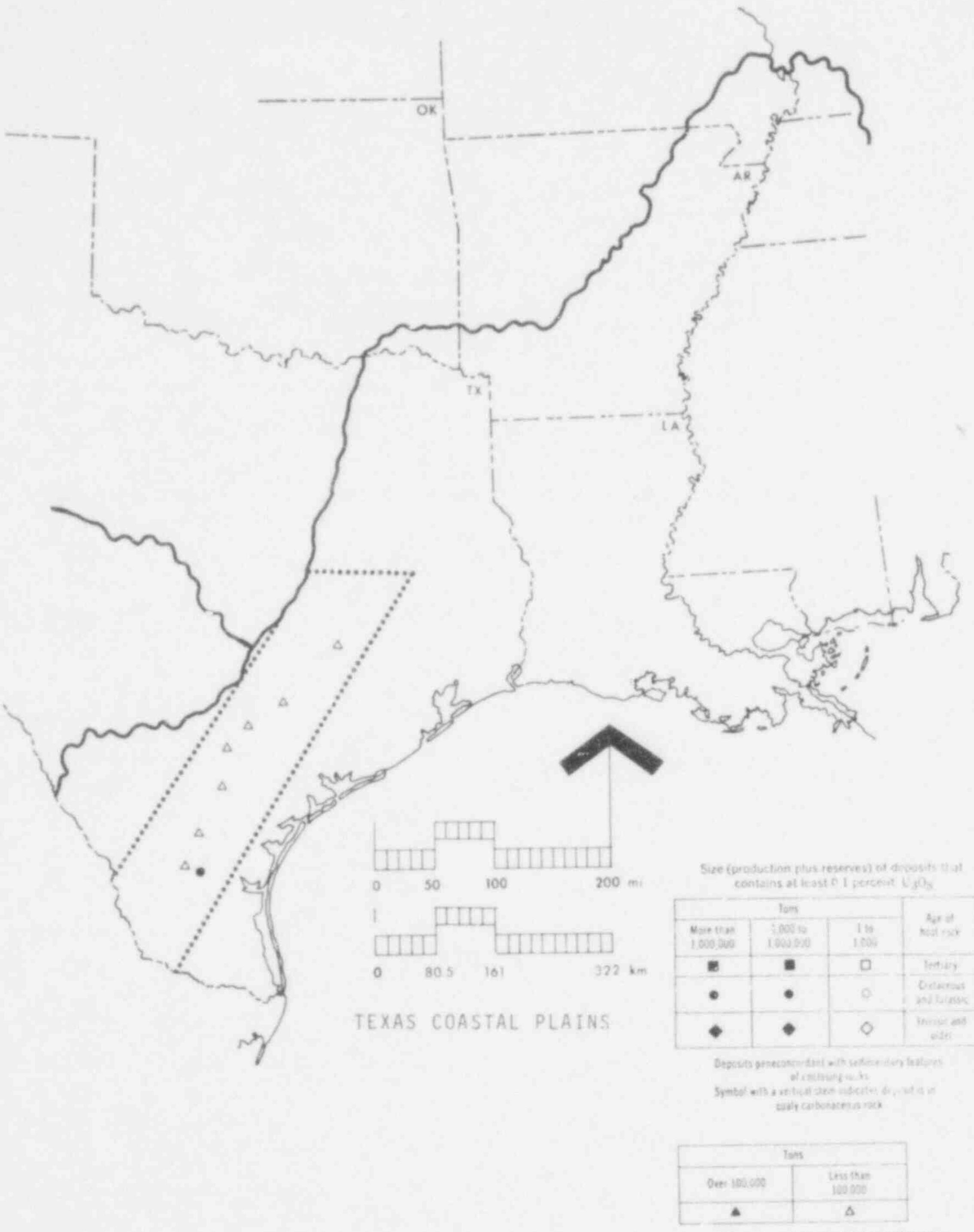

Fig. 6.11. Principal Uranium Deposits in the Texas Coastal Plains Region. (Modified from: R. A. Maxwell, "Mineral Resources of South Texas: Region Served through the Port of Corpus Christi," Report of Investigations No. 43, Texas Bureau of Economic Geology, Austin, Texas, 1962.)

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7. SURFACE WATER RESOURCES

7.1 GENERAL ASPECTS

A total of eight river drainages were selected for study in order to facilitate the characterization of surface water resources in uranium-bearing areas of the western United States. These eight rivers were selected from among the important rivers in the six regions (Table 7.1) on the basis of five criteria: (1) presence of uranium ore in the drainage basin, (2) availability of hydrological, chemical, and biological data, (3) geographical location of the river relative to the rivers selected for study in other regions, (4) presence of uranium milling activity, and (5) potential for expanded milling activity as predicted from projected uranium requirements. Some characteristics of the eight rivers selected are given in Table 7.2. The selected rivers were also considered typical aquatic systems containing representatives of the variety of habitat types within each region. Geographical locations of the selected rivers are shown in Figure 7.1.

7.2 THE SIX REGIONS

7.2.1 Northern Rocky Mountains

The Pend Oreille River, a tributary to the Columbia River, is a major drainage feature in the Northwest (Figs. 7.1 and 7.2). Although there are three other rivers, the Okanogan, Sanpoil, and Colville, in the Northern Rocky Mountains region, the Pend Oreille River was selected as the representative watershed (Table 7.1). Flow data for the Pend Oreille River given in Table 7.2 indicate a wide range in discharge. This is typical of rivers with their source tributaries in mountains, where much of the flow depends upon precipitation at the higher elevations. The water resources of this region vary from almost pristine mountain tributaries to grossly polluted mining district rivers. Natural recovery in undisturbed reaches of the mainstem and tributaries contributes to the generally good water quality. However, in some cases, local mining activities threaten the quality of the water and its subsequent use by man.

Many of the Pend Oreille River tributaries are classified as Class A (excellent quality) waters. Headwater streams flow over gravel and cobble substrates through sparsely populated areas where degradation of the water quality is minimal.[1] In the Idaho panhandle, which is part of the Pend Oreille basin, water quality is influenced in general by chemical contamination and high sediment load, although some areas also experience biological problems (algal blooms and reduced secondary production). Most streams that drain forested areas are of high quality; occasional sediment problems are associated with lumbering and livestock grazing. Streams flowing through irrigated lands are of poorer quality, and the poorest quality water is associated with areas of industrial and, especially, mining activities. Aquatic biota are more severely stressed in these regions of the Pend Oreille River.[1]

Although the panhandle section of Idaho has three of the state's largest recreational lakes, it also contains the world's most productive mining area, the Coeur d'Alene district.[2] The district produces gold, silver, lead, zinc, copper, nickel, and molybdenum (see Ch. 6). The mining of these metals contributes to the degradation of [illegible] lakes and rivers in the Pend Oreille River drainage basin (Table 7.3), e.g., the Coeur d'Alene River.[2,3] Coeur d'Alene Lake is a major recreational center; however, its water is [illegible] with heavy metals (Table 7.3).

In the lower stretches of the Pend Or[illegible] water quality of the river varies, with alternating regions of recovery and local [illegible]. In [illegible], 17.4 × 10^9 L (4.6 × 10^9 gallons) of water were withdrawn for municipal use, [illegible] of a lower quality when returned to the river. Withdrawals for industrial [illegible] uses during the same period amounted to approximately 7.6 × 10^{10} L (2.0 × 10^{10} gallons). In addition, natural perturbations due to erosion and irrigation water returns (although irrigation is not a major use) subject the river to additional stress.

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Table 7.1. Important Rivers in the Six Regions

Northern Rocky Mountains
Okanogan River
Sanpoil River
Columbia River[a]
Colville River
Pend Oreille River[a,b]
Western Great Plains
Arkansas River[a]
N. and S. Platte River[a]
Niobrara River
White River
Cheyenne River[a,b]
Moreau River
Grand River[a]
Cannonball River[a]
Heart River[a]
Wyoming Basin
Wind-Bighorn River[a,b]
N. Platte River (Sweetwater River)[a]
Powder River[a]
Green River Headwaters (Colorado River Basin)[a]
Belle Fourche (Cheyenne River Basin)[a]
Southern Rocky Mountains
Rio Grande River
Arkansas River[a,b]
Colorado River[a]
Colorado Plateau
Colorado River[a,b,c]
Green River[a]
San Juan River[a]
Gunnison River[a]
Dolores and San Miguel River[a,b]
Rio Puerco River[a,b]
Texas Coastal Plains
Nueces River[a,b]
San Antonio River[a]
Guadalupe River[a]
Colorado River[a]
Brazos River[a]

[a]River draining a uranium deposit.

[b]River basin selected for extensive characterization.

[c]Between confluence of Green River and Dolores River.

Table 7.2. Some Characteristics of the Eight Selected Rivers

Region/River Basin	Station Location	Drainage Area Above Station, $\times 10^4$ km^2	Period of Record	Average Discharge, m^3/s	Extreme Discharge, m^3/s		Comments
					Maximum	Minimum	
Northern Rocky Mountains							
Pend Oreille River	At int. boundary	6.5	Nov. 1908-Sep. 1910, Oct. 1912-Present	8.2×10^2*	4.9×10^3	3.1	*Ave. discharge from next upstream station, diversions above the Idaho-Wash. border $\approx 1.4 \times 10^5$ km^2
Western Great Plains							
Cheyenne River	Below Angostura Reservoir Dam, WY	2.4	Oct. 1945-Present	2.2	6.9×10^2	0	Flow regulated by Angostura Reservoir
Wyoming Basin							
Wind-Bighorn River	Near St. Xavier, MT	5.1	Oct. 1934-Present	1.0×10^2*	1.1×10^3*	1.4*	Diversions for irrigation $\approx 1.5 \times 10^3$ km^2 above station; *flow includes Bighorn canal
Southern Rocky Mountains							
Arkansas River	Below John Martin Reservoir	4.9	May 1913-Sep. 1955 Apr. 1959-Present	5.9	3.7×10^3	0	Flow regulated by diversions for power, storage reservoirs, groundwater withdrawals and irrigation of $\sim 2.0 \times 10^3$ km^2
Colorado Plateau							
Dolores River	Above confluence with Colorado R., UT	1.2	Oct. 1950-Present	2.0×10^1	3.4×10^2	9.6×10^{-2}	Many diversions for irrigation above this station
Colorado River	Mainstem below confluence of Dolores R., UT	6.2	Jan. 1895-Present	2.2×10^2	2.2×10^3	1.6×10^1	Maximum known high flow 3.5×10^3 m^3/s; water regulated by diversions for irrigation, power; flow regulated by Blue Mesa Reservoir
Rio Puerco River	Near Bernado, NM	1.9	Nov. 1939-Present	1.4	5.3×10^2	0	Diversions for irrigation of $\sim 4.7 \times 10$ km^2, including 15 km^2 irrigation wholly or partly by wells
Texas Coastal Plains							
Nueces River	Near Mathis, TX	4.3	Aug. 1939-Present	2.5×10^1	3.9×10^3	0.19	Flow regulated at Lake Corpus Christi 1 km upstream; numerous diversions above station

References: "Water Resources Data for South Dakota," "Water Resources Data for Idaho," "Water Resources Data for Wyoming," "Water Resources Data for Colorado," "Water Resources Data for New Mexico," "Water Resources Data for Utah," "Water Resources Data for Texas," U.S. Geological Survey, Water Data Reports, U.S. Dept. Interior, 1975.

Fig. 7.1. Surface Water Resources of the Six Regions. (Modified from: "United States Base Map, Edition 1965," U.S. Geological Survey, U.S. Dept. of the Interior, Washington, D.C.)

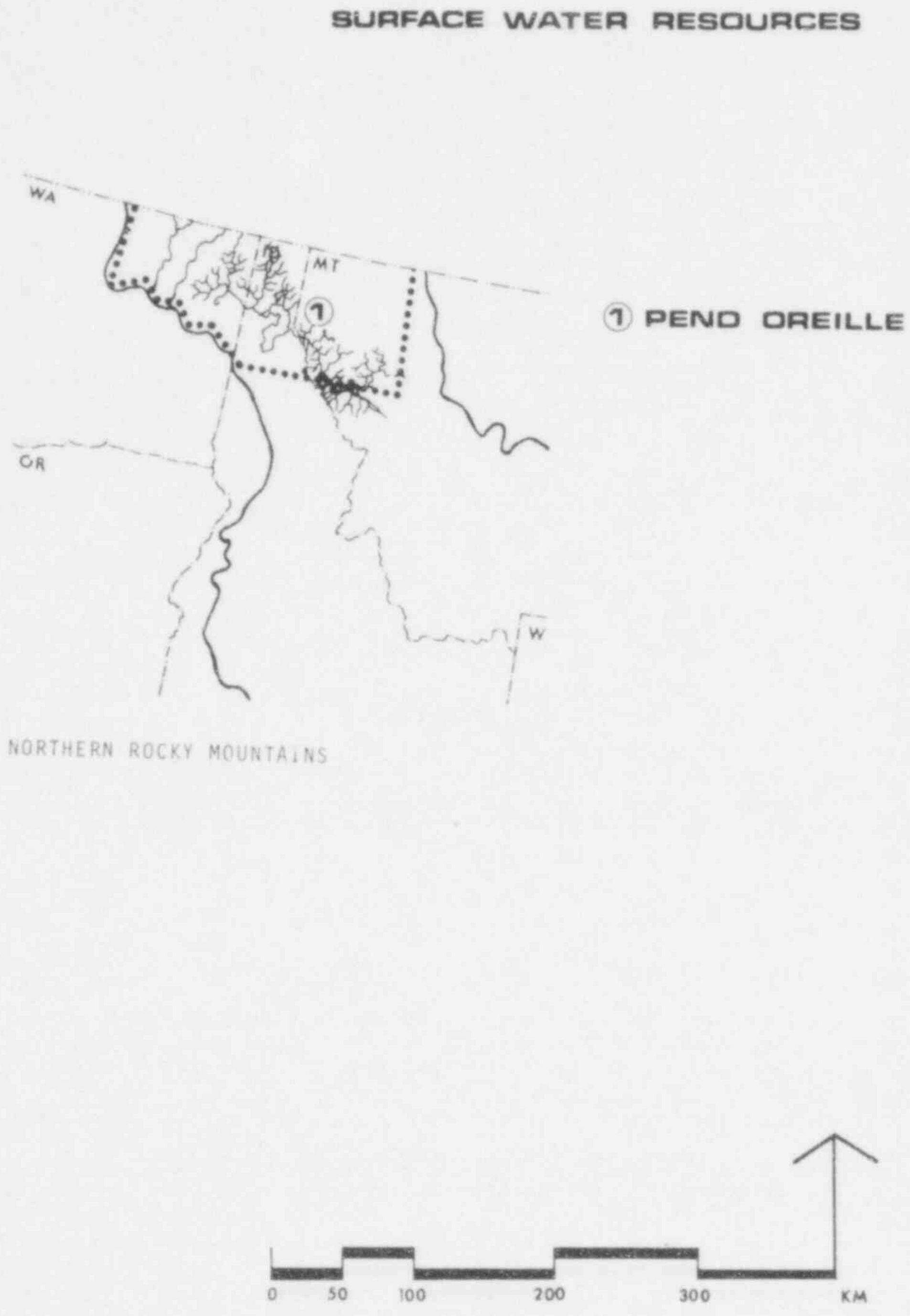

Fig. 7.2. The Pend Oreille River Drainage Basin in the Northern Rocky Mountains Region. (Modified from: "United States Base Map, Edition 1965," U.S. Geological Survey, U.S. Dept. of the Interior, Washington, D.C.)

Table 7.3. Concentration[a] of Chemical Species Dissolved in Waters of Pend Oreille River Basin

Dissolved Chemical Species	Pend Oreille River		Pend Oreille Lake		Tributaries of Pend Oreille River	
	Mean	Range	Mean	Range	Mean	Range
Hg	2.49	0.02-5.14	-	-	0.41	0.41-0.41
As	0.83	0-5.88	18.65	1.38-35.92	1.00	1.00-1.00
Cd	4.81	2.58-6.25	5.58	5.58-5.58	1 60	1.60-1.60
Cr	1.69	1.38-2.50	3.50	3.50-3.50	0.40	0.40-0.40
Cu	5.42	1.33-15.25	8.00	0-16.00	2.95	2.95-2.95
Fe	11.70	3.63-25.00	137.56	13.82-261.30	28.75	28.75-28.75
Pb	59.40	10.00-97.17	1.41	1.41-1.41	3.39	3.39-3.39
Mn	23.52	1.41-29.38	12.80	1.00-34.99	17.27	17.27-17.27
Zn	1.67	1.67-1.67	14.78	4.91-24.65	17.32	17.32-17.32
Se	40.96	8.83-85.58	0.01	0.01-0.01	3.15	3.15-3.15
Mg[b]	0.83	0.83-0.83	5.88	1.80-5.77	4.33	1.92-6.75
SO_4[b]	5.67	5.42-5.77	9.05	1.95-14.80	6.01	2.88-11.28
B	9.45	8.22-10.58	13.08	13.08-13.08	5.99	5.99-5.99
F	4.07	0.01-8.75	0.139	0.11-0.20	0.11	0.08-0.16
NO_3[b]	0.12	0.09-0.15	0.289	0.06-1.10	0.08	0.07-0.08
Mo	0.16	0.08-0.30	9.14	0.21-18.08	0.82	0.82-0.82
Al	-	-	9.26	8.53-10.00	202.00	202.00-202.00
Ba	-	-	40.50	40.50-40.50	246.67	246.67-246.67
Ni	-	-	5.25	5.25-5.25	4.74	4.74-4.74
Po_4[b]	0.01	0.001-0.03	0.02	0.01-0.02	-	-
V	-	-	9.42	9.42-9.42	0.45	0.45-0.45
Be	-	-	-	-	-	-
Li	-	-	-	-	-	-
Conductivity[c]	163.30	156.92-175.74	153.07	151.14-155.00	137.01	76.43-197.50
pH	-	-	8.04	7.95-8.14	7.40	7.27-7.50

[a]Micrograms/liter except as otherwise noted.

[b]Milligrams/liter.

[c]Micromhos.

7.2.2 Western Great Plains

Approximately one-third of the rivers draining the Western Great Plains region receive water from tributaries originating either in the Black Hills (Cheyenne River) or the mountain ranges of Colorado (Arkansas River) and Wyoming (Platte River). The remaining rivers drain the badlands of North and South Dakota (Moreau, Grand, Cannonball, and Heart rivers) and the sand hills of Nebraska and parts of South Dakota (Niobrara and White Rivers) (Table 7.1).

The headwater tributaries of the Platte and Cheyenne Rivers (Fig. 7.3) and the upper stretches of the Arkansas River are characteristically similar to those watersheds discussed for the Southern Rocky Mountains region (Sec. 7.2.4). After leaving the mountain foothills these rivers flow onto the plains. All of the plains rivers flow over sand and gravel substrates (with some sections of silt and mud) and fluctuate widely in flow in response to occurrence of local precipitation and snowmelt. This flow regime is typified for the region by discharge data for the Cheyenne River drainage (Table 7.2).

In general, rivers which flow through this region have similar water quality characteristics. Variation and specific local problems reflect the presence of municipal centers, large irrigation projects, and areas of industrial concentration. Salinity is the major problem in the region, although most of the rivers have been contaminated to varying degrees by soluble substances. This is particularly evident in the headwater regions, where many reservoirs and stockwatering impoundments act as sinks for accumulation of these toxic substances in bottom sediments. Infrequently there are water quality problems in some rivers (e.g., Missouri River) in the northern segment of the region (North and South Dakota). In the southern segment of the region, south of South Dakota, there typically are intermittent water quality problems as a result of local perturbation

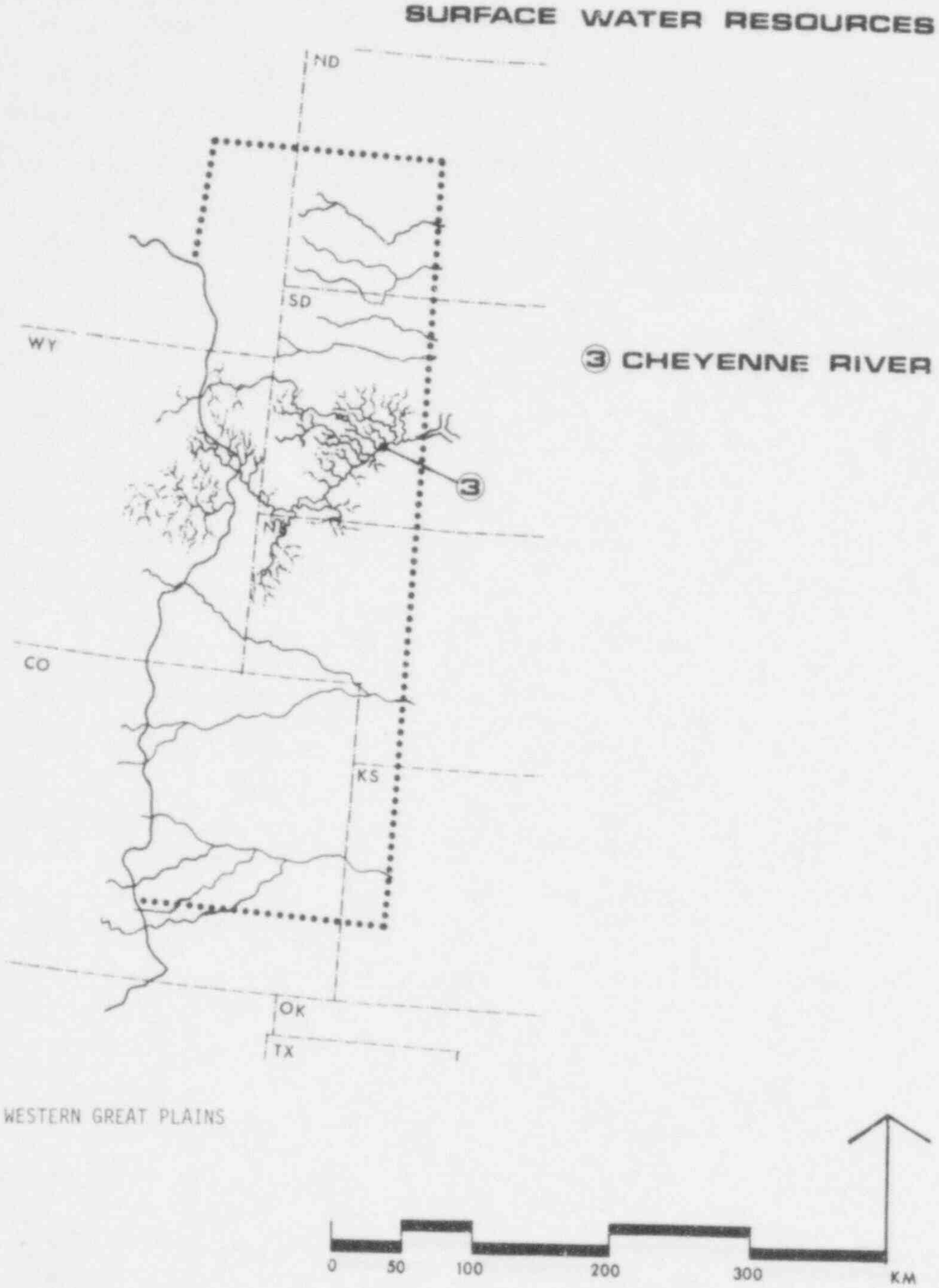

Fig. 7.3. The Cheyenne River Drainage Basin in the Western Great Plains Region. (Modified from: "United States Base Map, Edition 1965," Geological Survey, U.S. Dept. of the Interior, Washington, D.C.)

from industrial or domestic withdrawals and subsequent waste discharges. The remaining rivers have intermittent water qulaity problems, or else insufficient data are available to categorize them.[4]

Rivers north of the Nebraska border join the Missouri River in a section which is almost a continuous impoundment (Figs. 7.1 and 7.3). Irrigation returns on these tributaries add to the phosphorus, salinity, and mercury problems affecting the impoundment. From the Angostura Reservoir on the Cheyenne to the Fall River above the confluence with the Missouri River, water quality is grossly affected by irrigation return. High salinity is routine between the Fall and the Missouri Rivers, and occasions of high concentration of mercury, lead, copper, zinc, aluminum, chromium, nickle, and cyanide are numerous.[4] High concentrations of heavy metals, presumably from industrial activities in the area, suggest that some sections of the Cheyenne and Missouri Rivers may not support desirable fish populations. High salinity may further limit the usefulness for man, e.g., the Cheyenne River arm of Oahe Reservoir (Missouri River) has been closed to commercial fishing because of high concentrations of mercury in fish.[5] Upriver from these areas, the Cheyenne River receives water from the Black Hills and river water quality is somewhat improved. However, at centers of human activity, such as near Edgemont, South Dakota, concentrations of fecal-coliform bacteria, phosphorus, salts, chlorine, and manganese have exceeded standards, and instances of high concentrations of selenium, zinc, and copper are common.[6] These problems may result from extremely low flows. Above the Angostura Reservoir the Cheyenne River meanders through braided channels, and flow may cease during part of the summer. Water quality information for the Cheyenne River, given in Table 7.4, is typical for most of the rivers in the region.

Table 7.4. Concentration[a] of Chemical Species Dissolved in Waters of Cheyenne River Basin

Dissolved Chemical Species	Cheyenne River		Angostura Reservoir		Tributaries of Cheyenne River	
	Mean	Range	Mean	Range	Mean	Range
Hg	0.10	0.02-0.20	-	-	0.03	0-0.10
As	4.95	0.60-10.00	-	-	5.29	0.17-10.00
Cd	1.21	1.00-1.63	-	-	0.11	0-2.00
Cr	1.12	0.25-2.00	-	-	0	-
Cu	9.90	0-25.50	-	-	3.31	0-8.94
Fe	771.60	0.07-2198.12	-	-	191.88	0.26-1440.00
Pb	35.90	0-88.57	-	-	43.34	0-108.00
Mn	172.34	33.33-594.00	-	-	202.44	15.5-620.00
Zn	50.52	10.00-132.13	-	-	58.74	10.00-108.18
Se	17.69	0.68-71.56	5.00	5.00-5.00	2.81	0-10.00
Mg[b]	70.16	43.74-115.04	49.00	49.00-49.00	34.95	0-185.5
SO_4[b]	1006.19	461.50-2040.35	800.00	800.00-800.00	280.13	0.18-1572.18
B	253.89	164.70-346.90	-	-	123.52	10.00-267.39
F	0.67	0.52-1.01	-	-	0.52	0.20-0.96
NO_3[b]	0.96	0.28-2.72	-	-	2.38	0.66-2.00
Mo	2.97	1.80-4.14	-	-	2.00	2.00-2.00
Al	298.33	4.00-740.00	-	-	75.00	0-175.00
Ba	0	-	-	-	0	-
Ni	5.12	3.00-7.37	-	-	2.33	1.67-3.00
PO_4[b]	0.19	0.10-0.45	0.01	0.01-0.01	0.17	0.02-0.64
V	4.04	0.60-8.40	-	-	19.58	0.90-72.25
Be	1.00	0-2.00	-	-	10.00	10.00-10.00
Li	128.00	64.00-234.00	-	-	30.25	10.50-50.00
Conductivity[c]	4731.72	1702.14-10075.00	3812.88	1912.00-5713.25	1777.20	77.29-11500.00
pH	8.17	7.86-8.59	8.1	8.1-8.1	8.07	6.70-12.25

[a]micrograms/liter except as otherwise noted

[b]milligrams/liter

[c]micromhos

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7.2.3 Wyoming Basin

The Wyoming Basin is dissected by four main rivers (Fig. 7.4). Surface water resources range from intermittent tributary streams of the Powder River to spring- and snowmelt-fed tributaries of the Wind-Bighorn River in the Wind Mountain range. Headwater tributaries of the Powder, Belle Fourche, and Green rivers originate in semiarid desert and contain water only during short periods during the spring following thunderstorms. The substrates and banks of these intermittent streams consist almost entirely of sand and clay, with some cobble. Stream banks are subject to erosion and the streams carry high sediment loads during periods of flooding. In contrast, water quality of the Wind-Bighorn River system, located in the northwestern section of the region, is excellent in the swift, gravel-bottomed tributaries originating in the Rattlesnake, Owl Creek, and Bridges Mountains. After the upper stretch of the river flows through a V-shaped valley, it descents to the basin floor, where substrates are principally of sand, gravel, and silt. From here to the Montana state border the water quality decreases with increasing natural and man-made perturbations. Even though the water quality currently is good, impoundments such as the Boysen Reservoir are subject to siltation and algal blooms because of decreased water movement, elevated temperatures, and high nutrient inputs. Streamflow on most of the rivers in the region is variable, although it is controlled somewhat by the many impoundments and diversions (Table 7.2).

A wide range of surface water resources are found in the Wyoming Basin region. Many of the rivers have intermittent tributaries subject to erosion and high turbidity. The water quality of the Wind, upper Green, and Sweetwater rivers is good; however, impoundments for stock watering and domestic use, municipal and irrigation withdrawals and subsequent returns, and natural seepage from springs with high total dissolved solids cause rapid degradation. In some lower sections of the major rivers the water is of questionable quality for domestic, recreational and irrigation uses. In general, however, water quality problems are infrequent throughout the Wyoming Basin region.[6] Most of the problems that do occur are related to periods of low flow when dilution water is insufficient to handle industrial, agricultural, and municipal discharges.

The major nonpoint source of salinity and turbidity is erosion. The hot springs area near Thermopolis, Wyoming, is a natural source of total dissolved solids (TDS). Each day these springs contribute millions of liters of mineralized water (TDS of > 3500 mg/L) to the Wind-Bighorn River.[5] There are approximately 40,000 ha (98,000 acres) of wet and/or saline lands in the river basin which contribute significantly to the salinity.[5] Irrigation return, stock pond evaporation, and municipal and industrial consumption and return result in further degradation. High concentrations of boron and sulfate in some tributaries can cause problems for irrigational use (Table 7.5).[5]

There is evidence of pesticide and chlorohydrocarbon contamination where irrigation and municipal perturbation has been observed. In the Wind-Bighorn basin, concentrations of Chlordane, DDT (and its degradation products DDD and DDE), Dieldrin, PCB's, Diazinon, 2,4-D and 2,4,5-T have been detected.[7] There is evidence of heavy metal contamination, e.g., copper, zinc, iron, and arsenic (Table 7.5) in the Wind-Bighorn basin and other major drainages in the region. Synergistic effects from combinations of these metals (e.g., copper and zinc) may result in biological perturbations and degradation of water quality.

7.2.4 Southern Rocky Mountains

The Southern Rocky Mountains region is drained by three major riversheds--the Rio Grande and upper Colorado River to the west and south, and the Arkansas River to the east (Table 7.1).[8] The Arkansas River (Fig. 7.5) best typifies the surface waters in the area. Similar to the Rio Grande and Upper Colorado, its origin is near the Continental Divide. The Arkansas drains most of the southeastern half of Colorado. For the most part, the flows of the rivers in the region depend on spring and early summer runoff from snowmelt in the mountains. Substrate types are highly variable, but because of the steep gradient in the upper reaches, stream bottoms are mainly gravel and cobble, with occasional pools and slow stretches having accumulations of silt and organic detritus.

Mining for metals and industrial, domestic, and agricultural uses of water are major human activities impacting the rivers of the region. In some areas, seepage from abandoned mines contains trace elements (zinc, iron, copper, manganese, and arsenic) and has significant adverse impact on the water quality of some mountain tributaries, as reflected in the values for mean concentrations of these elements in the Arkansas River tributaries (Table 7.6).[9]

In the lower stretches of the Arkansas River, municipal, industrial, and irrigational uses of the water (e.g., steel mills, sugar beet processing, and cattle feed lots) are of significant impact on water quality. In general, the water quality of the Arkansas River mainstem does not meet state standards. The main problem is the high ammonia content resulting from municipal discharges.[10] Elsewhere in the region, however, water quality in the perennial streams of most

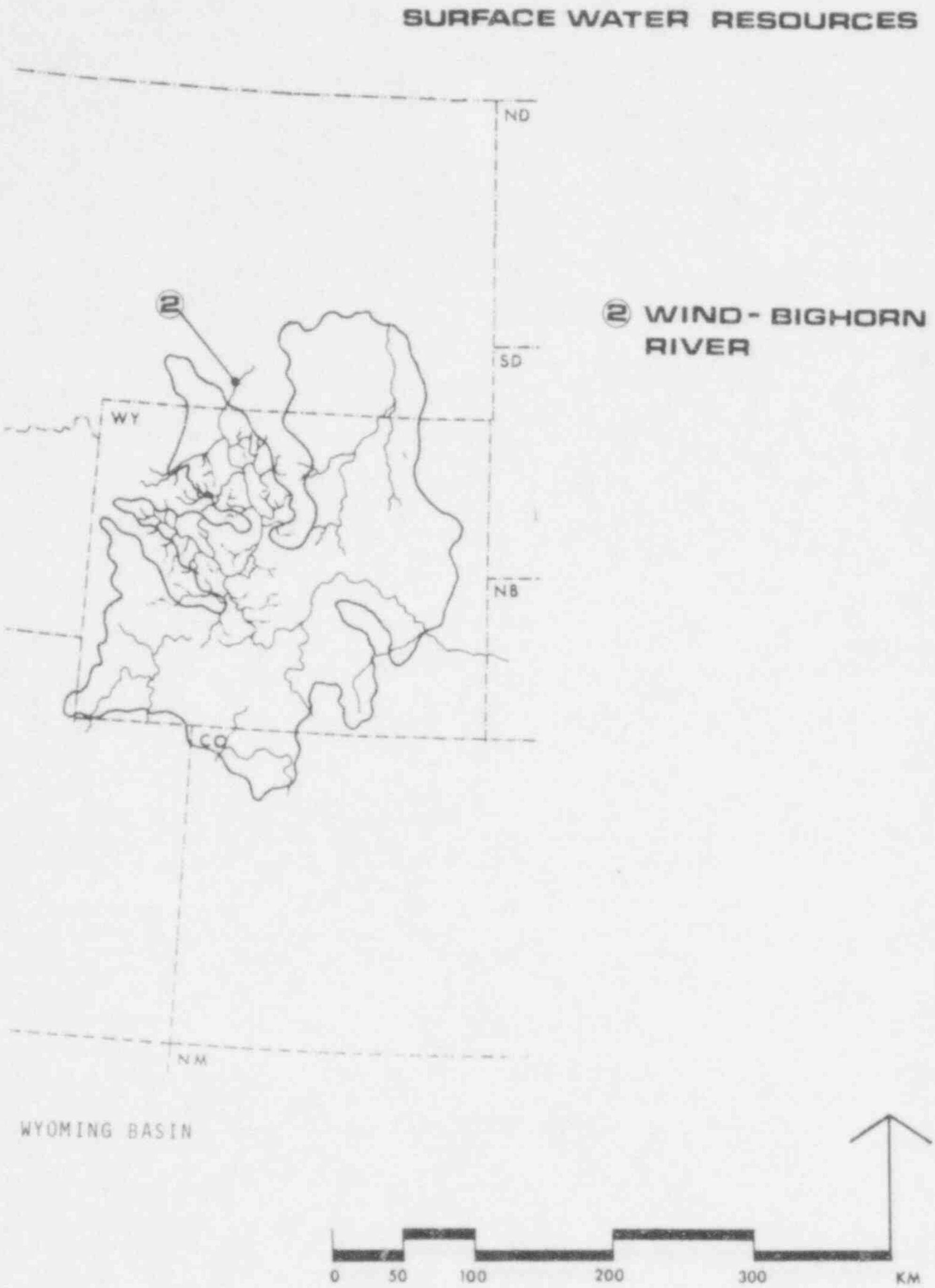

Fig. 7.4. The Wind-Bighorn River Drainage Basin in the Wyoming Basin Region. (Modified from: "United States Base Map, Edition 1965," Geological Survey, U.S. Dept. of the Interior, Washington, D.C.)

Table 7.5. Concentration[a] of Chemical Species Dissolved in Waters of Wind-Bighorn River Basin

Dissolved Chemical Species	Wind-Bighorn River		Tributaries of Wind-Bighorn River	
	Mean	Range	Mean	Range
Hg	5.93	0-11.86	-	-
As	-	-	2.00	2.00-2.00
Cd	0.17	0-0.33	0.10	0.10-0.10
Cr	3.09	0-6.17	-	-
Cu	3.50	3.50-3.50	83.33	0-150.00
Fe	70.30	20.00-106.50	83.09	0-198.75
Pb	3.42	0-6.83	0	-
Mn	9.00	9.00-9.00	100.00	100.00-100.00
Zn	24.50	24.00-25.00	14.00	14.00-14.00
Se	-	-	-	-
Mg[b]	14.11	1.80-26.69	23.73	0.60-149.97
SO_4[b]	148.90	3.30-321.29	308.55	2.04-2452.41
B	76.97	0.80-149.17	109.92	15.00-500.00
F	384.03	0.33-610.00	0.41	0.10-1.35
NO_3[b]	106.95	0.17-550.00	1.51	0.13-13.28
Mo	2.14	2.14-2.14	-	-
Al	42.00	42.00-42.00	-	-
Ba	55.00	55.00-55.00	-	-
Ni	8.67	8.67-8.67	-	-
PO_4[b]	33.50	0.50-70.00	0.33	0.33-0.33
V	10.67	10.67-10.67	-	-
Be	11.67	11.67-11.67	-	-
Li	11.67	11.67-11.67	-	-
Conductivity[c]	596.88	184.57-1008.00	787.07	28.33-4093.98
pH	8.02	7.80-8.65	7.94	6.96-8.80

[a]Micrograms/liter except as otherwise noted.

[b]Milligrams/liter.

[c]Micromhos.

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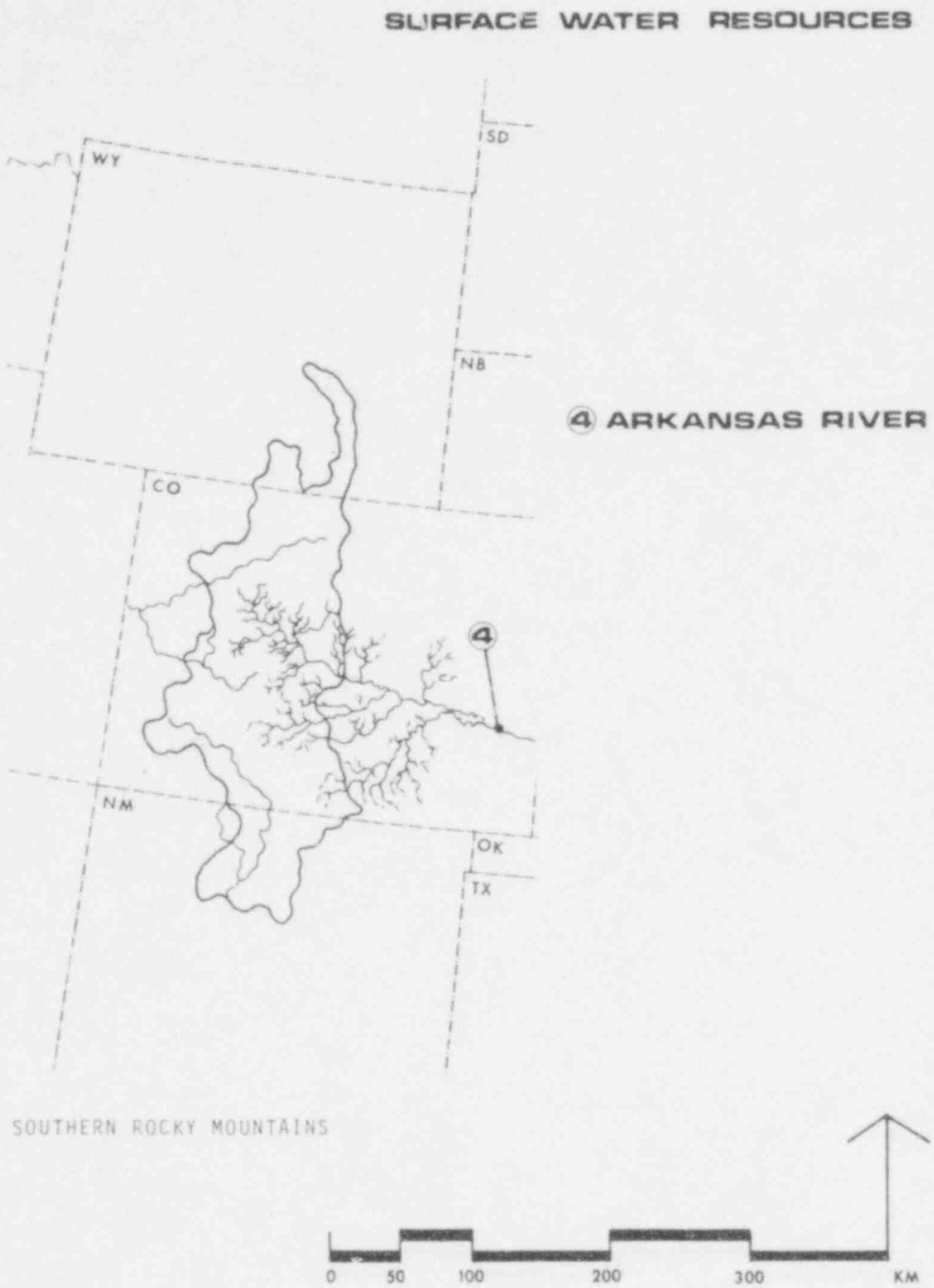

Fig. 7.5. The Arkansas River Drainage Basin in the Southern Rocky Mountains Region. (Modified from: "United States Base Map, Edition 1965," Geological Survey, U.S. Dept. of the Interior, Washington, D.C.)

Table 7.6. Concentration[a] of Chemical Species Dissolved in Waters of Arkansas River Basin

Dissolved Chemical Species	Arkansas River		Tributaries to Arkansas River	
	Mean	Range	Mean	Range
Hg	0.03	0-0.05	0.08	0-0.72
As	0	-	1.33	0-4.00
Cd	0	-	0.14	0-0.50
Cr	-	-	8.90	0-42.50
Cu	-	-	7.81	0-72.67
Fe	26.28	0.23-70.00	55.91	5.00-467.50
Pb	2.00	2.00-2.00	6.32	0-74.50
Mn	126.00	10.00-325.00	101.69	0-440.00
Zn			22.29	0-60.00
Se	4.13	1.50-7.00	6.67	4.00-12.00
Mg[b]	46.20	17.20-97.94	41.10	0.40-184.50
SO_4[b]	615.63	159.60-1324.82	517.50	4.00-1840.00
B	230.98	55.59-382.22	179.25	1.05-230.00
F[b]	0.91	0.59-1.05	1.58	0.72-2.77
NO_3[b]	4.20	1.06-8.38	6.92	0.12-64.29
Mo	-	-	-	-
Al	16.25	0-45.00	39.41	10.00-120.00
Ba	-	-	-	-
Ni	-	-	-	-
Po_4[b]	0.08	0.02-0.14	0.58	0.01-2.55
V	-	-	-	-
Conductivity[c]	1431.72	575.00-2618.91	1599.50	29.70-3370.00
pH	7.80			

[a]Micrograms/liter except as otherwise noted.

[b]Milligrams/liter.

[c]Micromhos.

of the river systems is suitable for a wide range of beneficial uses, including domestic and industrial withdrawals and recreation.[10] Chemical constituents given in Table 7.6 for the Arkansas River basin as a whole are within standards or accepted limits for multiple use as given by the U.S. Public Health Service and other regulatory agencies.

Within the region, including stretches in New Mexico, the Colorado River is hydrologically complex. The region is sparsely populated and in general there are no major water quality problems along the river. As the data indicate, levels of pH are normal, dissolved oxygen is well above the minimum acceptable levels, and chloride and sulfate concentrations are low. Nutrient concentrations are also low, although phosphorus levels in the mainstem are considerably higher than in the tributaries.[10]

7.2.5 Colorado Plateau

The major drainage basin in the Colorado Plateau region is that of the Colorado River. Tributaries originate on the west side of the Continental Divide in mountainous areas of Utah and Wyoming, canyons of Colorado, and high plains of Arizona. The region also includes drainages on the eastern side of the Continental Divide (Rio Puerco-Rio Grande) (Fig. 7.6).[11]

Colorado River headwaters originate in the mountains and are maintained by snowmelt and spring water. Streambed material is primarily gravel and cobble, with occasional stretches of bedrock. These reaches are characterized by clear water of good quality which flows through steep-sided gorges and ravines. High zinc concentrations and excess salinity occur, however, in lower reaches, and excess concentrations of nitrogen and phosphorus exist from Fruita, Colorado, to the Utah border.[12] These portions of the river are also subject to wide variations in flow.

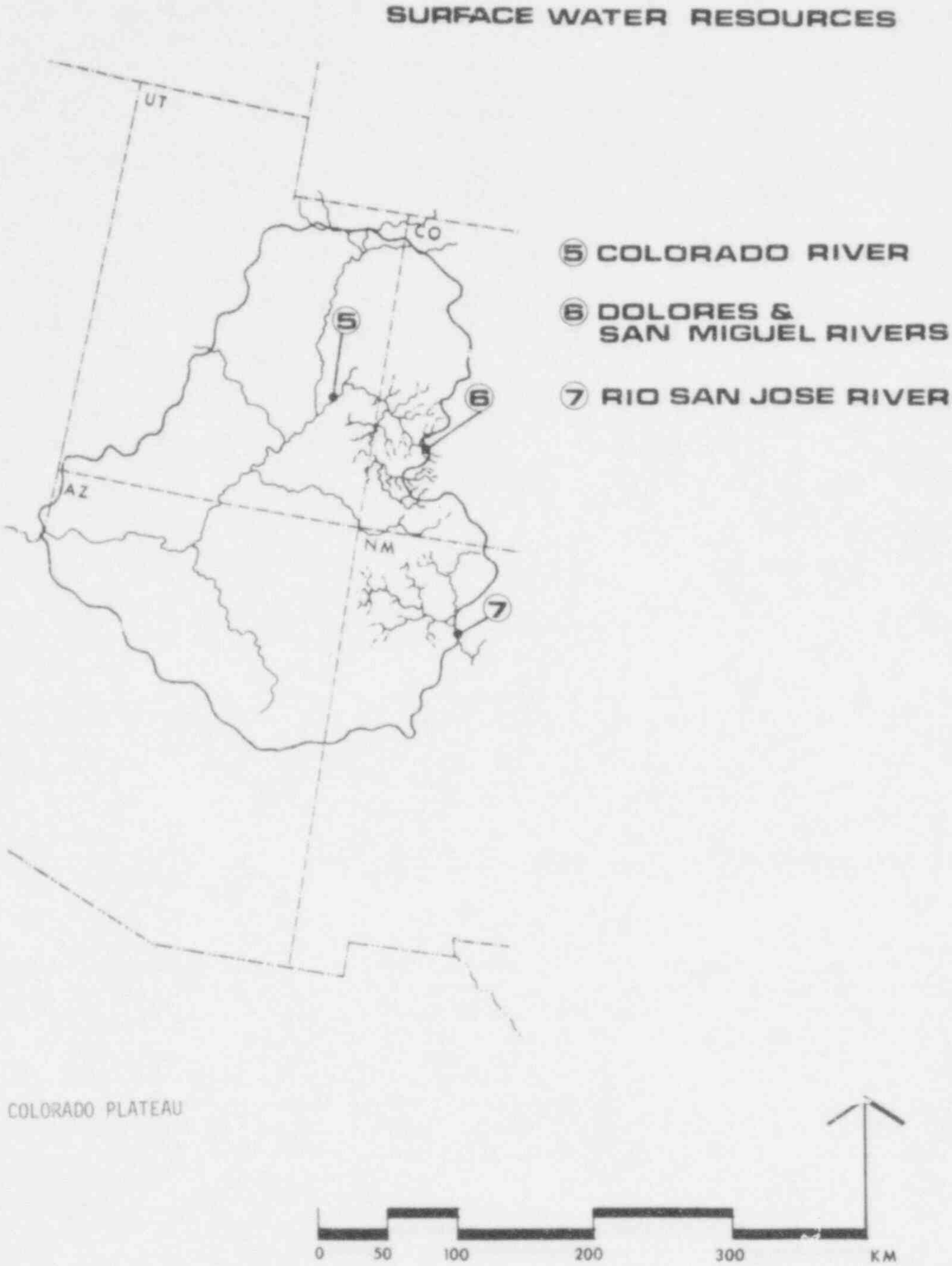

Fig. 7.6. The Colorado, Dolores and San Miguel, and Rio San Jose River Drainage Basins in the Colorado Plateau Region. (Modified from: "United States Base Map, Edition 1965," Geological Survey, U.S. Dept. of the Interior, Washington D.C.)

The Dolores River and the San Miguel tributary drain the southwestern portion of Colorado. Intensive mineral mining and processing and associated pollution occur in the area. As shown in Table 7.7, heavy metal contamination occurs. The San Miguel is subject to copper, iron, manganese, nickel, uranium, and zinc loading as a result of mining operations in the basin; however, the concentrations of metal presently are not high enough to result in any major biological perturbation. The Dolores flows through a salt pan in the Paradox Valley and conductivities greater than 24,000 micromhos/cm have been recorded in the stream. Below the confluence of the San Miguel and Dolores Rivers, increased turbidity occurs as a result of erosion in the canyons.

The Dolores River joins the Colorado River above Moab, Utah. Discharge data for the Dolores and Colorado River given in Table 7.2 indicate wide fluctuations in river flow for both systems. Below the confluence, the Colorado River winds through deep canyons, and the water quality is degraded naturally by heavy sediment loads.

The Colorado River basin, which covers approximately 94,000 km^2 (37,000 mi^2) is the major watershed in Utah. Agricultural use exceeds all other uses of water in the state, with 42% of the 5.9×10^9 m^3 (4.8×10^6 acre-feet) of water withdrawn for irrigation consumed during the operation. Some 6.4×10^8 m^3 (5.2×10^5 acre-feet) of water is withdrawn for municipal and industrial use, with 1.9×10^8 m^3 (1.5×10^5 acre-feet) being consumed.[13] Mining of uranium and phosphate is important in the basin, and Utah is the largest coal-producing state west of the Mississippi River.

Most industries in the Colorado River basin are small, and their discharges, while having local effect on water quality, are acceptable in terms of existing standards. Nonpoint sources of pollution are generally associated with sediment loading and elevated salinity. These two problems are influenced by the climatic and geologic features of the basin, as well as by the man-made problems associated with return of irrigation waters, which contribute large amounts of dissolved salts. The salinity of the Colorado River and its many impoundments presents a major water-use problem In addition, DDT and its degradation products DDD and DDE, as well as Chlordane and PCB's, have been detected in the waters.[7]

The Rio Grande drainage, specifically the tributary Rio Puerco, drains the semiarid region of northwestern New Mexico. As shown in Table 7.2, there is extreme fluctuation in the volume of discharge of this river and its major tributary, Rio San Jose. The Rio Puerco and Rio San Jose are subject to flash flooding. On the Rio San Jose, peak flows of up to 590 times greater than the average flow have been recorded. The Rio Puerco transports the highest sediment load in the nation. On occasion, 50% of this load has been carried in four days in flows as high as 27 m^3/s; the average flow is 1.4 m^3/s.

As in most river systems, water quality in the Colorado Plateau region deteriorates downstream as it gains soluble constituents from surface runoff, irrigation, and municipal treatment plant discharges. Elevated salinity, soluble salts, and metals are the major reasons for the degradation of water quality. Total dissolved solids (TDS) in the Colorado River are high. In the Rio Puerco, TDS levels have been reported as exceeding the standard 58% of the time, with maximum values of six times the standard. In the same river, sulfate levels have exceeded the standard 86% of the time.[11]

Although no pesticides have been detected in the Rio Puerco drainage, special problems related to mining activities have been cited.[6] Zinc, iron, copper, manganese, boron, mercury, and selenium are high; however, they do not exceed levels recommended by the National Academy of Sciences for the beneficial use of the water.[14]

7.2.6 Texas Coastal Plains

The Texas Coastal Plains region is dissected by five major drainage basins (Fig. 7.7). The headwaters begin as springs northwest of the Balcones Fault. The broad coastal plain lies between the fault and the Gulf of Mexico. The rivers in the region are typified by the Nueces River, which originates in the Edwards Limestone region and flows through deeply dissected formations until it reaches the Balcones Fault and recharges the Edwards aquifer. This aquifer is a major source of municipal and industrial waters for San Antonio, Uvalde, and Medina counties. Below the fault, streamflow in the Nueces consists primarily of runoff from periodic precipitation, principally spring rains. In the lower reaches many sections of the river consist of a braided network of channels.

The ions in the water of the Nueces River are derived from the limestone and soluble minerals of the rock formations of the headwaters region. Between the Balcones Fault and the estuarine section of the river, municipal, industrial, and agricultural water allocations and the subsequent return discharges strongly affect the water quality. In general, the Nueces River has relatively good quality water, especially in less inhabited areas. This water quality level is consistent with that of most of the rivers in the region. Except for peculiarities in specific river basins, the chemical constituents of the other rivers are similar to those in the Nueces

Table 7.7. Concentration[a] of Chemical Species Dissolved in Waters of Colorado-Rio Grande Basins

Dissolved Chemical Species	Dolores and San Miguel Rivers		Colorado River[b]		Rio San Jose		Tributaries of Rio San Jose	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Hg	27.67	0-96.46	13.33	Single Sample - No Range	4.00[c]	4.00-4.00[c]	10.00[c]	10.00-10.00[c]
As	3.46	0-8.22	0		-	-	5.00[c]	5.00-5.00[c]
Cd	11.39	0-33.50	0.67		10.00[c]	10.00-10.00[c]	10.00[c]	10.00-10.00[c]
Cr	19.69	8.67-43.50	0		-	-	-	-
Cu	514.20	30.00-1,552.50	0		10.00[c]	10.00-10.00[c]	10.00[c]	10.00-10.00[c]
Fe	33.81	2.33-65.50	0		40.00	40.00-40.00	70.00	70.00-70.00
Pb	169.61	85.00-302.68	0		100.00[c]	100.00-100.00[c]	100.00[c]	100.00-100.00[c]
Mn	42.34	33.33-83.19	0		85.00	60.00-110.00	180.00[c]	180.00-180.00[c]
Zn	2.83	0-7.00	10.00		-	-	-	-
Se	31.09	23.80-51.61	-		-	-	8.00[c]	8.00-8.00[c]
Mg[d]	168.55	0.20-434.93	39.00		61.75	39.50-84.00	41.61	1.00-81.00
SO_4[d]	147.50	90.00-200.00	398.00		620.00	290.00-950.00	812.33	690.00-934.60
B	400.00	400.00-400.00	145.00		370.00	360.00-380.00	207.84	80.00-335.60
F	-	-	0.38		0.83	0.75-0.90	0.70	0.60-0.70
Mo	-	-	-		3.00	3.00-3.00	2.00[c]	2.00-2.00[c]
Al	100.00	100.00-100.00	-		-	-	-	-
Ba	-	-	0		-	-	100.00[c]	100.00-100.00[c]
Ni	24.28	3.00-45.55	-		-	-	-	-
PO_4[d]	0.06	0.01-0.12	0.08		1.42	0.74-2.10	0.03[d]	0.02-0.03
V	8255.95	2.15-65,600.00	8255.95		5.56	3.40-7.70	0.30	0.30-0.30
Li	-	-	-		285.00	280.00-290.00	40.00	40.00-40.00
Conductivity[e]	2308.85	367.79-11,464.50	1335.00		2007.50	1315.00-2700.00	1817.50	1400.00-2235.00
pH	8.56	6.56-8.40	8.10		8.05	7.80-8.30		

[a]Micrograms/liter except as otherwise noted.

[b]Between Moab, Utah and confluence of Green River.

[c]Includes contribution from suspended particulate matter.

[d]Milligrams/liter.

[e]Micromhos.

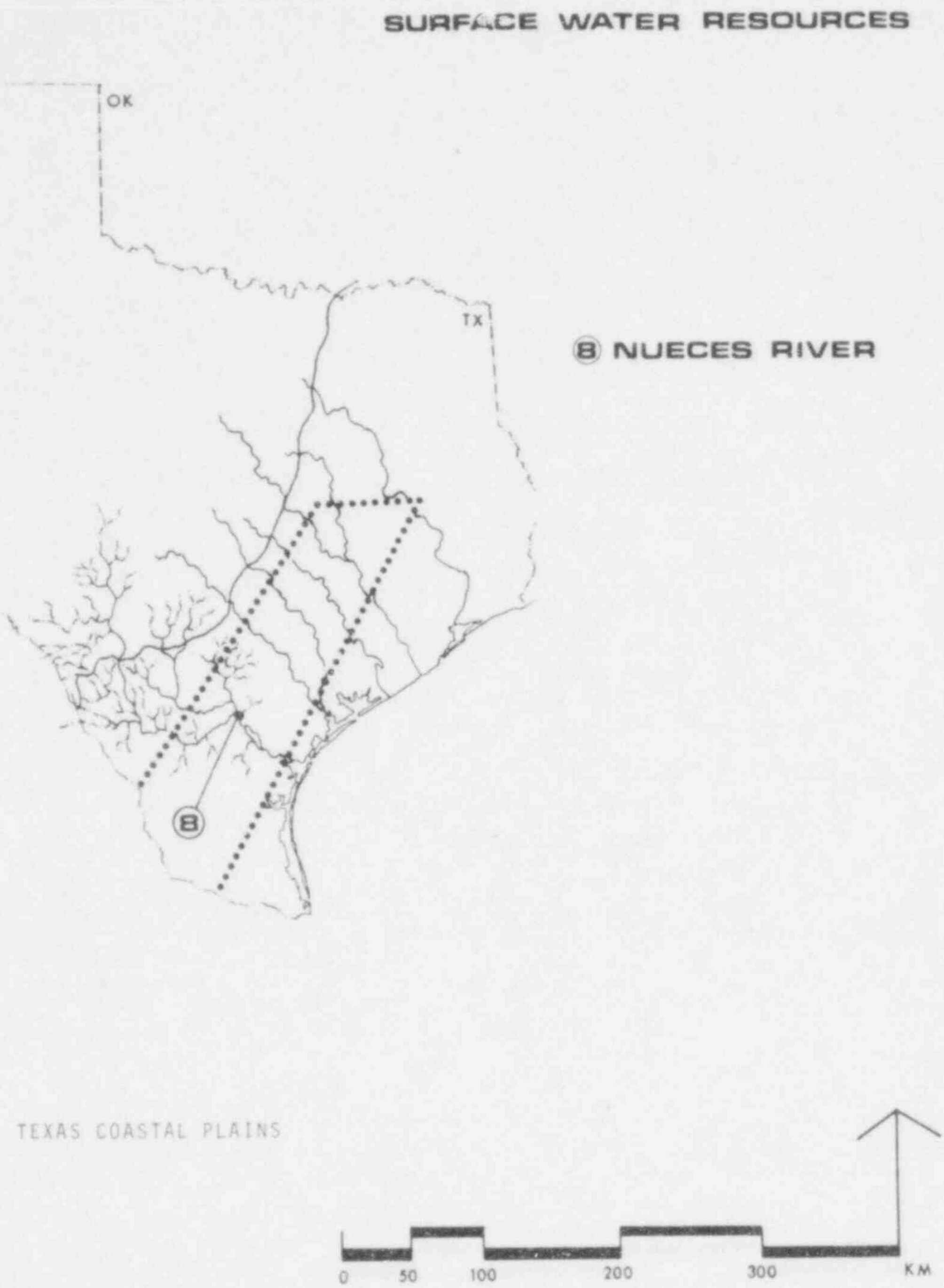

Fig. 7.7. The Nueces River Drainage Basin in the Texas Coastal Plains Region. (Modified from: "United States Base Map, Edition 1965," U.S. Geological Survey, U.S. Dept. of the Interior, Washington, D.C.)

River (Table 7.8). For example, the rivers of the region have high levels of boron. The mean value for the western Gulf Coast is 289 μg/L;[15] the mean for the Nueces River is 194 μg/L. Boron can be toxic to some plants at concentrations approaching 1.0 mg/L, and thus there is concern over use of the water for irrigation.

Man-made water quality problems have been identified for the San Antonio, Cibola, San Jacinto, and Trinity Rivers. These problems are primarily associated with municipal, industrial, and agricultural activities within the basins. At times during summer low-flow periods, the entire flow of the San Antonio River below the City of San Antonio is comprised of effluent water, which has low oxygen concentrations and elevated concentrations of suspended and dissolved solids. Problems of sediment loading and high salinity occur naturally in the Brazos and Trinity rivers, where river water is in contact with gypsum deposits.[16]

Of the man-made water quality problems, agriculture poses a major threat to the rivers of the region, contributing sediments, soluble salts, and pesticides via return irrigation flows. Evidence of Aldrin, Chlordane, DDT (and its degradation products DDD and DDE), Dieldrin, Toxaphene, PCBs, Malathion, Parathion, Silvex; 2,4-D, and 2,4,5-T in the river basins of the region has been cited.[7]

Table 7.8. Concentration[a] of Chemical Species Dissolved in Waters of Nueces River Basin

Dissolved Chemical Species	Nueces River		Lake Corpus Christi		Tributaries of Nueces River	
	Mean	Range	Mean	Range	Mean	Range
Hg	0.19	0.01-0.34	-	-	0.03	0.02-0.03
As	1.93	0.80-3.08	-	-	0.94	0.22-2.30
Cd	0.32	0.21-0.54	-	-	0.41	0.33-0.50
Cr	0.64	0-1.10	-	-	1.42	1.30-1.56
Cu	15.61	1.00-46.67	-	-	1.01	0.80-1.33
Fe	52.37	25.67-90.00	22.00	22.00-22.00	18.81	14.00-24.44
Pb	0.99	0.50-1.60	-	-	1.52	1.40-1.67
Mn	15.90	7.00-27.83	8.00	8.00-8.00	4.44	3.33-6.00
Zn	18.98	3.33-40.00	-	-	89.63	8.00-10.00
Se	0.75	0.50-1.00	-	-	1.00	1.00-1.00
Mg[b]	8.94	3.95-18.80	8.75	8.75-8.75	10.41	2.83-16.08
SO_4[b]	43.09	13.47-150.54	53.67	53.67-53.67	48.81	14.70-143.35
B	194.94	49.88-340.00	-	-	45.06	40.29-49.85
F[b]	0.26	0.15-0.42	0.25	0.25-0.25	0.26	0.15-0.60
NO_3[b]	2.50	1.10-6.75	-	-	2.34	1.14-3.83
Mo	-	-	-	-	-	-
Al	20.70	6.67-28.75	-	-	3.52	2.22-5.00
Be	0	-	-	-	25.00	0-50.00
Ni	2.58	0-6.00	-	-	1.30	1.11-1.67
Li	22.44	3.33-55.42	-	-	1.94	1.11-2.50
Sb	5.00	5.00-5.00	-	-	-	-
Conductivity[c]	546.76	377.96-1320.22	1505.54	678.50-2568.19	617.43	248.25-1286.01
pH	7.50	7.41-7.70	8.07	8.07-8.07	7.60	-

[a]Micrograms/liter except as otherwise noted.

[b]Milligrams/liter.

[c]Micromhos.

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8. GROUNDWATER RESOURCES

8.1 GENERAL ASPECTS

The existing groundwater resources and water use in each of the six regions are briefly described. Areas where uranium mining has occurred, or is likely to occur, are emphasized. The discussion of groundwater in each region is divided into three parts: (1) groundwater resources (aquifers), (2) groundwater use, and (3) groundwater in uranium-producing areas. An aquifer is defined as a stratum of permeable rock capable of yielding useable amounts of water. Areas underlain by aquifers capable of yielding at least 3.5 L/s [50 gpm] of fresh water to a well are shown in Figure 8.1.

8.2 THE SIX REGIONS

8.2.1 Northern Rocky Mountains

Groundwater resources in the Northern Rocky Mountains region are great and virtually untapped. The small population and minor irrigation result in a low demand on the groundwater supply. Limited studies of this region indicate that the aquifers contain groundwater of good quality and have high recharge capacity.

8.2.1.1 Aquifers

Most of the Northern Rocky Mountains region is mountainous with crystalline or dense metamorphic rocks, such as the Precambrian Belt series and Precambrian and Cretaceous igneous rocks (Fig. 5.1). These rocks yield only small amounts of water to wells; however, the volcanic rocks in the area of Yellowstone Park and the carbonate rocks in the Wasatch Range do contain some bedrock aquifers.

Wide intermontane valleys are underlain by deposits of sand and gravel that are largely saturated and constitute the best aquifers in the region. Some of the sand and gravel deposits in northern Idaho and northwestern Montana are glaciofluvial in origin. Others are fluvial and occur along major rivers.

8.2.1.2 Use

The total annual groundwater withdrawal from the Northern Rocky Mountains region is slightly over 10^8 m^3 (8×10^4 acre-ft) (Fig. 8.1). Most of this is pumped from sand and gravel in the Spokane area. As the populations of the larger cities increase, pumpage can be expected to increase. On the other hand, abundant precipitation and surface water, a short growing season, and limited arable ground obviate the necessity of irrigation; thus, this competitive use is not expected to be great.

8.2.1.3 Uranium-Producing Areas

The area of immediate interest in terms of uranium mining is northeastern Washington, northern Idaho, and northwestern Montana. This mountainous area is underlain largely by dense igneous or metamorphic rocks of low permeability and porosity. Meltwaters from Pleistocene glaciers deposited vast amounts of sand and gravel in the intermontane valleys, such as the valley from Spokane, Washington, to Lake Pend Oreille, Idaho. Some of the largest permeability values ever obtained occur in gravel deposited near Spokane as the result of floodwaters from the ice dam collapse of Pleistocene Lake Missoula. The gravel in the Spokane Valley is clean and extremely permeable. The gravel yields very large quantities of water to wells even though they extend only a few feet below the water table. Yields of more than 500 L/s (9000 gpm) have been reported from wells tapping these deposits.[1] Southwest of Spokane the Columbia River Plateau is underlain by basalt lava flows and interbedded fluvial sand and gravel beds; this region also has vast groundwater resources.

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Fig. 8.1. Aquifers and Some Groundwater Withdrawals in the Six Regions. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

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Substantial uranium reserves are known to occur in only one area--near Wellpinit, Washington, on the Spokane Indian Reservation. A geologic cross section of the tailings pond area for the uranium mill at this location is presented in Figure 5.3. The geology consists simply of sand and gravel on top of Cretaceous "Loon Lake" granite bedrock. The bedrock consists of dense crystalline rock with essentially zero primary (pore) permeability.[2] This is overlain by up to 200 m (600 ft) of clean, highly permeable sand and gravel. The water table is near the gravel-bedrock contact. The gravel, part of the Pleistocene Lake Missoula flood deposits, would constitute an aquifer if it were saturated.

8.2.2 Western Great Plains

The area of the Western Great Plains included in the uranium milling region extends about 300 km (200 miles) east from a north-south line from Fort Peck, Montana, to Pueblo, Colorado (Fig. 1.1). This region is largely rangeland, and there has been little development of groundwater resources except where irrigation is practiced in the Platte River Valley and the Sand Hills of Nebraska. The area is semiarid (the average annual precipitation is about 60 cm, or 24 inches) and sparsely populated (except for the Denver area).

8.2.2.1 Aquifers

The rocks underlying this region are mostly Cretaceous and Tertiary sediments that dip to the east. A geologic cross section through portions of South Dakota showing the general geology of the region is given in part A of Figure 5.4.

The central Black Hills consist of Precambrian crystalline rocks of low permeability and porosity that nonetheless contain groundwater of good quality. Around the edges of the Black Hills the rocks are largely Paleozoic carbonates, including the Madison Limestone, which is an aquifer of great potential.[3] The Madison aquifer contains large amounts of hot water, up to 60°C (140°F). There has been little use of this hot water resource, either as a water supply or thermal source.

The Cretaceous Dakota Sandstone and its equivalents also crop out around the Black Hills and dip easterly under the prairie, forming one of the world's most famous artesian aquifers.[4] The areas where the Madison and Dakota aquifers can be utilized in the Great Plains region are shown in Figure 8.1. As the beds dip down into the Williston Basin, the aquifers are too deep and the water too saline to be of use.

Because of good quality water, shallow drilling depths, and relatively abundant recharge (13 cm, or 5 inches, annually in the Sand Hills),[5] the Arikaree, Ogalla, and Sand Hills formations in the southern part of this region are among the more important aquifers in the United States.

8.2.2.2 Use

Most domestic and municipal water for this region is obtained from groundwater sources. An estimated 30×10^8 m^3 (24×10^5 acre-ft) of groundwater is withdrawn annually in the Western Great Plains region, mostly from shallow wells in alluvium along the North and South Forks of the Platte River. Most ranches and stock tanks are supplied by shallow wells. In North Dakota and South Dakota this shallow groundwater is typically of poor quality and wells are not very productive; in Nebraska and Colorado the quality and quantity improve. Municipal wells are deeper and many communitites in North and South Dakota are supplied by the artesian Dakota Sandstone aquifer. Because of declining pressure in these wells and the poor quality of the water,[3] many municipalities are seeking other water sources. Consortia of municipalities are now considering importation of water from the Missouri River through large pipelines.

It is doubtful that large amounts of groundwater will ever be used for irrigation north of the Sand Hills (roughly the South Dakota-Nebraska border). The quality is very poor and the aquifers are too deep and are of insufficient size and permeability. On the other hand, use of groundwater in the Sand Hills and to the south is increasing markedly. Rangeland is being transformed to cropland because the abundance of good-quality groundwater at shallow depths has allowed use of center-pivot sprinkler irrigation systems.

8.2.2.3 Uranium-Producing Areas

The largest known uranium deposits in the Western Great Plains region are in the southern Black Hills, near Edgemont, South Dakota, and in the lignite coal area of northwestern South Dakota and southwestern North Dakota. Mining and milling in these locales does not occur near any aquifers from which substantial amounts of groundwater are withdrawn.

Northwest of Edgemont (Part B of Fig. 5.4), uranium in the Dakota Sandstone has been mined both by surface and underground methods. Milling operations occur at the town of Edgemont on alluvium along the Cheyenne River. Only small amounts of groundwater are used for stock or domestic purposes within about 15 km (10 miles) of the Edgemont mines.

The northwestern South Dakota uraniferous lignite beds are found in the Fort Union group (Part C of Fig. 5.4), and while thin sand beds (and in some places lignite beds) in the group are used to supply water for stock and ranches, these generally are not considered a valuable source of groundwater.

8.2.3 Wyoming Basin

In the Wyoming Basin region water is the limiting factor of the agricultural economy. Most of the area is rangeland, but dryland farming is practiced in some locales. Irrigation, largely from stream diversions and reservoirs, occurs along many rivers. Groundwater withdrawals are small and limited principally to domestic and stock wells.

8.2.3.1 Aquifers

The areal distribution of large aquifers is shown in Figure 8.1. Paleozoic carbonate rocks typically crop out at the edges of the basins. The rocks include the Madison Limestone and Tensleep-Minnelusa formations. Two wells near Newcastle flow at 35 L/s (580 gpm) and 90 L/s (1400 gpm) from cavernous zones in the Madison Limestone.[5] These yields and the presence of large springs, such as those at Thermopolis and around the Black Hills,[6] illustrate the potential of this aquifer. Sediments include the Dakota Sandstone and related sandstone aquifers of Cretaceous age. Both the Paleozoic carbonate and Cretaceous sandstone aquifers typically dip down into the basins, where they are usually at depths too great, with quality too poor, to be useful for domestic purposes.

The Wyoming basins are filled with Tertiary sediments containing some semiconsolidated fluvial sandstone beds which supply water for many domestic and stock wells. The scant information available suggests that well yields in the Tertiary and upper Cretaceous sediments are typically less than 3 L/s (50 gpm). Because of low yields of wells and high mineralization of groundwater, basin communities such as Gillette face chronic water supply problems.

Quaternary alluvial deposits along the major rivers constitute limited aquifers (Fig. 8.1). The highest permeability and quality of groundwater occur in areas near the mountains, where surface water also is available.

8.2.3.2 Use

The estimated withdrawal of groundwater from the Wyoming Basin region is less than 10^8 m^3 (8×10^4 acre-ft) annually (Fig. 8.1). The largest known single-point withdrawal is at Midwest, Wyoming, where approximately 1.8×10^7 m^3 (1.5×10^4 acre-ft) are withdrawn annually from the Madison Limestone for use in the secondary recovery of petroleum.[7] A possible withdrawal of 590 L/s (9300 gpm) may occur in Niobrara County, Wyoming, where Energy Transportation Systems, Inc., plans to withdraw water from the Madison Limestone to supply a coal slurry pipeline that would transport coal from Wyoming to Arkansas.[8] Other slurry pipelines, lignite gasification plants, and coal-burning electric power stations may tax this aquifer in the future.

8.2.3.3 Uranium-Producing Areas

Use of groundwater in the uranium districts is small and generally for stock watering. The water, withdrawn from widely scattered wind-pump wells, is of poor quality; total dissolved solids range from less than 500 ppm to more than 2000 ppm.[9] Well depths range from about 30 m (100 ft) to 150 m (500 ft). Most wells are not free flowing, although some of the deeper wells at lower topographic positions are free flowing at the land surface. Very limited hydrologic data are available to indicate the potential long-term availability of groundwater from the sediments, but large production seems unlikely.

8.2.4 Southern Rocky Mountains

The groundwater supplies in most of the Southern Rocky Mountains region are limited because of the high density of rocks underlying a large portion of the region. Some intermontane valleys contain sizable groundwater resources, the largest being the San Luis Valley of the upper Rio Grande.

8.2.4.1 Aquifers

This region includes the Front Range and other high mountains in Colorado, Wyoming, and New Mexico. These mountains contain complexly folded and faulted rock layers of all types and ages, including volcanic rocks, consolidated sedimentary rocks, and crystalline rocks. The volcanic rocks are not significant aquifers except where they are interbedded with or overlie valley fill. The consolidated sedimentary rocks form most of the hills and low mountains. Generally, these rocks are poor aquifers, but locally, beds of limestone containing extensive fractures and solution channels lie below the water table and yield large supplies of water. In many areas the consolidated sedimentary rocks contain soluble minerals, such as halite and gypsum--the principal sources of dissolved solids in groundwater. The crystalline rocks generally are dense and yield insignificant quantities of water to wells.[10]

Several large intermontane valleys underlain by Cenozoic "valley fill" contain sizable groundwater supplies. The valley fill typically contains unconsolidated sand and gravel interbedded with clay, silt, and some volcanic rocks such as basalt or tuff (Fig. 5.8). In the most important valley fill area, the San Luis Valley, Colorado, the fill is more than 9000 m (30,000 ft) thick and comprises the principal groundwater reservoir in the Colorado Rocky Mountain region.

In the mountainous areas, most of the groundwater used is from the productive aquifers in alluvial deposits (sand and gravel).

8.2.4.2 Use

As shown in Figure 8.1, more than 10^9 m^3 (8×10^5 acre-ft) of water is withdrawn annually from the San Luis Valley. This water supports a vast irrigation area. The combined withdrawal of all other areas in the Colorado Rockies is estimated to be less than 10^8 m^3 (8×10^4 acre-ft) annually.

8.2.4.3 Uranium-Producing Areas

Uranium mining has occurred in the Swartzwalder and Wood Mines near Boulder and in the Pitch and Los Oches Mines near Gunnison, Colorado. These isolated uranium deposits are small, and additional mining or milling operations are not likely in the future. These uranium deposits are in mountainous areas and not near the San Luis Valley aquifers.

8.2.5 Colorado Plateau

The rocks underlying this arid region typically consist of flat-lying sedimentary strata, chiefly interbedded sandstone and shale of Paleozoic and Mesozoic age (Fig. 5.1). Most of the aquifers are sandstone, although limestone and alluvium yield large amounts of water in some places. Large groundwater use has not occurred.

8.2.5.1 Aquifers

The areas in this region that are underlain by large aquifers are shown in Fig. 8.1. The largest aquifers are within 300 km (200 miles) of the Four Corners area. The yield of wells is generally unpredictable since a rock unit may be a good aquifer at one place and not at another because it is fractured in one area and not in the other.[11] The best aquifers are sandstone beds such as the Navajo and Wingate (Glen Canyon group) or Mesa Verde and Dakota formations, and the deeper Madison limestone. The most important aquifer in the Colorado Plateau is the Coconino sandstone of Permian age, which yields "several hundred gallons per minute" to some wells.[12]

The quality of the water is good to fair in the southern part of this region, but poor to the north, such as in the Uinta Basin. Nevertheless, there are areas within this region where small amounts of fresh water can be found almost everywhere.

In the mountainous areas such as Uravan, Colorado, saturated deposits of alluvium constitute a valuable local water source.

8.2.5.2 Use

Large amounts of groundwater have not been withdrawn from the Colorado Plateau area (Fig. 8.1). Currently the total annual use of groundwater from the Upper Colorado River drainage basin (which slightly exceeds the area of the Colorado Plateau region) is approximately 1.5×10^8 m^3 (1.2×10^5 acre-ft), which is only about 2% of the amount of surface water used in the same area.[13]

The amount of groundwater presently used is apparently only a small percentage of that available. Increased use of groundwater for agricultural purposes may be limited in the future because of the small areas of arable soil and the high costs of pumping from the deep water tables. Withdrawals by industry will probably increase as energy resources are developed. For instance, in 1974, about 4.2×10^6 m^3 (340 acre-ft) were withdrawn from the Mesa Verde formation to supply water for the 400-km (250-mile) Black Mesa coal slurry pipeline from northeastern Arizona to southern Nevada.

8.2.5.3 Uranium-Producing Areas

The principal uranium-mining areas are within 200 km (120 miles) of the Four Corners area. Only limited hydrogeologic information is available for this area, but it is generally acknowledged that low precipitation, rugged topography, and rocks of low permeability result in a generally unfavorable groundwater situation.

Cooley et al. studied the hydrogeology of the Navajo and Hopi Indian Reservation, which includes most of the important uranium areas in the Colorado Plateau region. It is pointed out in the study that the aquifers are composed of beds of sandstone between nearly impermeable layers of siltstone and midstone. The main aquifers are in the Coconino Sandstone, Navajo Sandstone, and the alluvium. For the most part, the aquifers in the consolidated sedimentary rocks are fine grained and do not transmit water rapidly. Coefficients of permeability are reported to be generally less than 10 gpd per square ft.[14]

Water in northwestern New Mexico is obtained from fine-grained sandstone, alluvium, and basalt. According to one study, "The groundwater varies widely in quality, but in most of the area water that is acceptable for domestic and stock use can be obtained. Yields range from 1 to 250 gpm; most are less than 50 gpm and a typical well might yield 5 or 10 ... The area of heaviest pumping is Gallup and vicinity in McKinley County, where industrial growth associated with coal and uranium mining and establishment of government offices have placed heavy demands on generally meager water supplies."[5]

Groundwater withdrawals also occur in the uranium-producing areas, such as near Grants, because deep underground mines must be dewatered constantly. The extent of the drawdown in the sandstone aquifers near these mines is not known. Hydrogeology of the mill effluent well injection disposal site at the Bluewater uranium mill of the Anaconda Company near Grants, New Mexico, has been studied by West.[15] Exactly how such disposal techniques will affect local aquifers is not known.[16]

8.2.6 Texas Coastal Plains

A vast amount of water is stored in the rocks of the Coastal Plains region of Texas. The water is in Cenozoic sediments that generally yield abundant amounts of water to wells (as shown in Figs. 5.1 and 8.1).

8.2.6.1 Aquifers

The rocks making up the Texas Coastal Plains region include sediments forming a huge seaward thickening wedge of generally unconsolidated sand, silt, and clay. They range in age from older (Paleocene) in the northwest near San Antonio, to younger (Pleistocene) in the southeast along the Gulf coast.

A geologic cross section through this region is presented in Figure 5.8. The rocks crop out in belts roughly parallel to the coast and dip to the southeast, where they contain groundwater under artesian pressure. These sediments were deposited in seawater; however, since the time of their origin, fresh groundwater originating from precipitation falling on the outcrop areas has migrated seaward and now occupies the upper parts of the sediments (Fig. 5.8).

The major aquifers occurring in this region are:

1. Wilcox-Carrizo Aquifer--The Carrizo Sand and the sands in the Wilcox group are interconnected hydrologically and can be treated as a single aquifer. The permeability is quite good; the coefficient of transmissivity (a measure of the productivity of the aquifer), determined from 35 well pump tests, averaged 620 m^2/day (50,000 gpd per foot).[17] Some large-capacity wells in the Carrizo-Wilcox aquifer discharge nearly 200 L/s (3000 gpm).[18]

2. Gulf Coast Aquifer--The sediments of this aquifer, including the Catahoula Tuff, Oakville Sandstone, Lagarto Clay, Golilad Sand, Lissie formation, and Beaumont Clay, are interconnected hydrologically and are referred to as the Gulf Coast aquifer (Fig. 5.8).

It is the largest aquifer in Texas. The most intensive and concentrated development of this aquifer is in the Houston area, where the yields of large-capacity wells average about 130 L/s (2000 gpm).[18] The aquifer dips very gently seaward and is of moderately good quality, but, as in most places in Texas, the quality decreases with depth. The quality of groundwater is generally better in the Houston area, where the precipitation averages about 120 cm (48 inches) annually, than in the Brownsville area, where the annual precipitation average is about 60 cm (24 inches).

In addition to the two aquifers described above, there are smaller sand beds, such as the Queen City and Sparta Sands (Fig. 5.8), that serve as local sources for water. Alluvial deposits along major stream courses (Fig. 8.1) are additional sources of groundwater.

8.2.6.2 Use

Approximately 1.9×10^{11} m^3 (1.5×10^8 acre-ft) of water in the Carrizo-Wilcox aquifer and 5.6×10^{11} m^3 (4.5×10^8 acre-ft) of water in the Gulf Coast aquifer are recoverable from storage above a depth of 120 m (400 ft) within the entire Texas Gulf region, which very nearly coincides with the Texas Coastal Plains region.[18] From Figure 8.1 it can be seen that the present withdrawal of water in this region is about 10^9 m^3 (8×10^5 acre-ft) annually, which is approximately 0.1% of the total recoverable water.

In spite of the vast reserves of groundwater available in this region, problems have resulted from intense local use of groundwater. In Houston, for example, drawdown has increased pumping costs or has caused saltwater intrusion or land subsidence.

8.2.6.3 Uranium-Producing Areas

Most of the uranium deposits of the region are in Karnes and Live Oak Counties. Most of the known uranium ore in Karnes County occurs at depths not exceeding 12 m (40 ft) in tuffaceous sandstones and siltstone within the Jacson group.[19] Although detailed groundwater studies of Karnes County are not available, the Texas Water Development Board has completed studies of Duval and Live Oak Counties, where uranium deposits are known to occur.[20,21]

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9. SOILS

9.1 GENERAL ASPECTS

Soil, as defined for the purposes of this statement, consists of the unconsolidated layer above bedrock that contains evidence of biological activity. Certain aspects of soil are obvious to the casual observer, for example, soil is a medium for plant growth and is thus an essential component of the biosphere, and it is subject to erosion by wind and water, resulting in loss of land productivity. Less obvious to the casual observer is that in general, hundreds to thousands of years are required for a soil to develop from its parent material. Also, an interplay among parent material, vegetation, topography, climate, and time results in literally thousands of "kinds" of soil that can bear little resemblance to each other and that will respond differently to given impacts and management schemes. For these and other reasons, it is important that the characteristics of soils be considered on a site-specific basis if impacts due to a given human activity are to be correctly assessed and successful mitigative measures determined.

Detailed descriptions of all the soils in each of the six regions will not be presented here; many such descriptions can be found in soil survey reports published on a county basis by the U.S. Soil Conservation Service.* The major soils of each region are described on the basis of their Order, Suborder, and Great Group. These are major classes of soils that can be further subdivided.[1] Several major soils within a few selected counties are discussed, with emphasis placed on soil characteristics which are directly related to the assessment of impacts from milling of uranium ore and which are important to subsequent tailings management and reclamation. Details of individual soils (e.g., depth to water table, soil depth, texture, reaction, permeabilities, water-holding capacities, topsoil suitability) are listed. (Definitions of the various symbols used in subsequent tables on soil characteristics are given in Table 9.1.) In most counties the parent materials from which the soils are derived are listed in the detailed tables of soil characteristics. However, this information is not given in some of the tables. In these cases, a brief discussion of parent materials is presented in the text. The bases for selection of particular counties were the existence of a published soil survey report, the extent to which the county fell within a given uranium resource region, and proximity of the county to probable or possible sources of uranium ore as presented in the NURE survey. In those cases where a soil survey of an uranium-producing county was available, the discussion of the soils is based on that survey. In those cases where no soil survey was available for the uranium-producing county, a discussion of the soils of the closest county in the uranium resource region for which a soil survey was available is given. The soils selected for discussion are representative of the uranium-bearing portions of the region but do not necessarily represent all soils of a given region. Generalized soil maps, redrawn from the USGS National Atlas,[2] are presented for each region.

The descriptions of soils are followed by a brief discussion of the regional occurrence of selenium, molybdenum, arsenic, and vanadium in rocks and soils; these are elements that can occur with the uranium in ores and that could be of environmental concern.

9.2 THE SIX REGIONS

9.2.1 Northern Rocky Mountains

The Northern Rocky Mountains region is characterized by soils classified as Inceptisols. These are wet-region soils that have lost bases (e.g., calcium and magnesium) or iron or aluminum due to leaching, but still retain some weatherable minerals. These soils may have layers where translocated silica, iron, or bases have accumulated, but do not have a layer of silicate clay accumulation. Most Inceptisols occur in the Cascade Mountains and are mapped with the prefix I in Figure 9.1. Inceptisols in this region are usually freely drained and have low bulk densities. They have an appreciable amount of allophane (a clay mineral) that has a high cation exchange capacity. Most of the surface soils are dark brown to dark reddish brown. Many have buried horizons due to repeated ash falls from volcanic activity. Vegetation is predominantly coniferous forest.

*To date detailed soil surveys have not been prepared for all counties in each state.

Table 9.3. Definitions for Headings and Symbols for Tables on Soil Characteristics

Symbol	Texture
Co	Cobbles, or cobbly
Cs	Coarse
F	Fine
G	Gravel, or gravelly
L	Loam, or loamy
C	Clay
S	Sand, or sandy
St	Stones, or stony
Si	Silt, or silty
V	Very
Ci	Cinders, cindery
M	Medium

Available Water Capacity -- The estimated amount of water available to plants for the soil profile to a depth of 60 inches or to bedrock or indurated layer. Estimates are based mainly on soil texture, as modified by amount of rock fragments and bulk density, and are expressed as:

Class	Inches of Water
High	Greater than 7.5
Moderate	5.0 - 7.5
Low	2.5 - 5.0
Very low	Less than 2.5

Topsoil Suitability -- The rating is affected mainly by ease of working and spreading of soil material, by natural fertility of the material, or the response of plants when fertilizer is applied, by absence of substances toxic to plants, by texture and content of stone fragments, by damage that will result at the area from which the soil is taken, and by ease of vegetating the borrow area.

There are smaller areas of Mollisols (mapped with the prefix M in Fig. 9.1) on gently or moderately sloping areas of the region, east and west of the mountains. These soils have relatively high organic matter in the surface layer, are dark brown, and have a high proportion of exchangeable bases. Most Mollisols have a thin layer of silicate clay accumulation (argillic horizon) and a subsurface layer where calcium carbonate or calcium and magnesium carbonates have accumulated (calcic horizon). Some soils may have high exchangeable sodium in layers close to the surface. Vegetation is mainly grasses.

The uranium resource counties selected for further description are Spokane in Washington and Bonner in Idaho. A soil survey report has not been published for Stevens County, in which much of the future uranium milling activity is expected to occur.

9.2.1.1 Spokane County, Washington

Spokane County occupies about 457,000 ha (1,128,000 acres) in the east-central part of Washington, bordering Idaho. The southwestern part of the county is a broad basalt plateau of channeled scablands that was stripped of soil by glacial floodwaters. The southeastern part of the county is rolling to hilly, with deep soils that formed in wind-deposited silty material. The northern part of the county is in the Okanogan Highlands, consisting of mountains, foot slopes, glaciated valleys, broad glacial lake terraces, and outwash terraces. The average annual precipitation ranges from 38 to 58 cm (15 to 23 inches) in the lowland agricultural areas

SOILS

A3-1 Cryoboralfs + Cryorthods, steep
I1-1 Cryandepts + Cryochrepts and Cryothods, steep
I1-2 Cryandepts + Cryorthods, Eutrandepts, Xerochrepts, and Haploxerolls, steep
M5-1 Haploborolls, gently sloping
M5-5 Haploborolls + Natriborolls, gently sloping
M15-1 Argixerolls + Argialbolls and Haploxerolls, gently or moderately sloping
M15-5 Argixerolls + Haploxerolls moderately sloping
M16-7 Haploxerolls + Haplaquolls, Durixerolls, and Rock land, moderately sloping

NORTHERN ROCKY MOUNTAINS

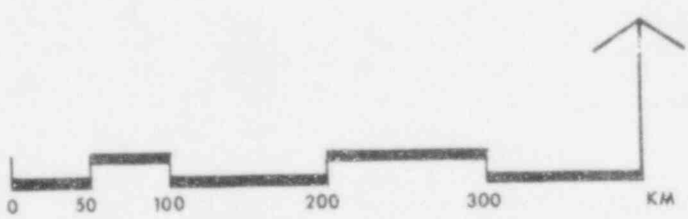

Fig. 9.1. Soils of the Northern Rocky Mountains Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

to 100 to 125 cm (40 to 50 inches) on slopes and near the summit of Mount Spokane in the northern part of the county.[3] Vegetation of the county is predominantly grassland, with some shrubs. The northern portion of the county also includes forest, particularly on steep mountain lands.

In the southeast, loess is the dominant parent material; on the northeastern hills, most of the soils are formed from granite. Sandstone and shale are dominant parent materials on promontories south of the Spokane River. Other parent materials of importance are glacial till, glacial outwash, lake sediments, volcanic ash, stream sediments, and organic matter.

The soils of Spokane County can be grouped as follows (names in parentheses refer to associations):[3]

1. Medium-textured to fine-textured soils on rolling loessal uplands, glacial till plains, and mountain footslopes (Naff-Larkin-Freeman).

2. Somewhat excessively drained, and excessively drained, sandy and gravelly soils formed in glacial outwash (Garrison-Marble-Springdale).

3. Shallow to deep, medium-textured soils formed in material weathered from acidic igneous rock on mountain foot slopes (Spokane-Dragoon).

4. Deep, well-drained and moderately well-drained soils formed chiefly in glacial lake sediments and glacial till on uplands (Bernhill).

5. Dominantly moderately deep to shallow, gravelly or rocky soils of the channeled scablands (Hesseltine-Cheney-Uhlig).

6. Moderately deep and deep, medium-textured soils on the hilly and mountainous areas (Moscow-Vassar).

7. Medium-textured and moderately fine-textured soils formed chiefly in loess (Athena-Reardan).

8. Very deep, medium-textured and moderately coarse-textured soils on terraces (Clayton-Laketon).

9. Gravelly and sandy soils formed in glacial materials (Bonner-Eloika-Hagen).

Some details of these major series are listed in Table 9.2.

Most Spokane County soils have moderate surface soil permeabilities, but subsoil permeabilities are rapid to very rapid because of the coarser subsoil texture. Water-holding capacities range from low to high, and topsoil suitabilities are mostly fair to good. Erosion hazards range from slight to severe, depending on slope. Most of the soils are neutral to mildly alkaline, except for a soil strongly alkaline in the scablands association.[3]

9.2.1.2 Bonner County, Idaho

Bonner County extends across the narrow northern panhandle section of Idaho. Its 453,000 ha (1,119,000 acres) include most of the large Pend Oreille Lake. For the most part, the rest of the county is mountainous, with flat-bottomed valleys between the larger mountain ranges. Outwash plains and terraces are found at various elevations; some valleys contain glacial terrace deposits. The mean annual precipitation is about 84 cm (33 inches), falling mostly from November to April in the form of snow. Native vegetation consists mainly of conifers.

The soils of the county can be grouped as follows:[4]

1. Light-colored soils of well-drained forested uplands. These soils (formed mainly from loessal silt) are by far the most extensive soils in the county. They are low in organic matter, slightly acid, and usually silty in texture, except where coarse and gravelly or stony because of underlying glacial materials. Wind erosion is appreciable.

2. Dark-colored soils of the comparatively small and scattered areas of poorly drained or excessively wet lowland. These soils are relatively fertile and have a good supply of moisture because of their low-lying position along stream channels or basins. Most require artificial drainage.

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Table 9.2. Major Soils of Spokane County, Washington[a,b]

Series Name	Soil Depth, cm.	Texture		Subsurface Permeability, cm/hr	pH		Available Water Capacity	Topsoil Suitability
		Surface	Subsurface		Surface	Subsurface		
Naff	152	SiL	SiCL	0.5-2	6.1-6.5	6.6-7.3	High	Good
Larkin	183	SiL	---	---	6.1-7.3	---	High	Good
Freeman	183	SiL	SiCL	0.1	6.6-7.3	6.6-7.3	High	Fair to poor
Garrison	152	SiCL, GL, VGL	SiC, SiCL, VCL	0.1-13	6.1-7.3	6.6-7.3	Moderate to high	Fair
Marble	152	LS, LCsS, SL	CsS, S	>25	6.1-6.6	6.1-7.3	Low to high	Fair
Springdale	117	GCsSL	GCsS	>25	5.6-6.0	6.1-6.5	Low to moderate	Fair
Spokane	64	L, GSL	GCsLS	13-25	6.1-6.5	6.6-7.3	Low to moderate	Good
Dragoon	91	SiL, StSiL	IIL, CsS	2-13	6.6-7.3	6.6-7.3	Moderate to high	Good to poor
Bernhill	152	SiL, GSiL	L, GL	2-6	6.1-6.5	6.6-7.3	High	Good to poor
Hesseltine[c]	91	SiL	GL, VGSL	2->25	6.1-7.3	6.6-7.3	Low to high	Good
Cheney	89	GSiL, StSiL	VGSL	13-25	6.6-7.3	6.6-7.8	Low to high	Good
Uhlig	152	SiL, VFSL	---	---	6.6-7.3	---	High	Good
Moscow	68	SiL	L	6-13	5.6-6.0	5.0-5.5	High	Fair
Vassar	140	SiL	GL	6-13	6.1-6.5	5.6-6.0	High	Fair to poor
Athena	152	SiL	---	---	6.6-9.0	---	High	Good
Reardan	152	SiL	SiC, SiL	0.1-6	6.6-7.3	6.6-8.4	High	Good
Clayton	190	FSL, L, SL	SL, LFS	2-13	6.6-7.8	7.4-7.8	High	Fair
Laketon	152	SiL, FSL	SiCL, SiL	0.5-2	6.6-7.3	6.1-7.3	High	Good
Bonner	152	SiL, GSiL, L	GL, GCsS	2->25	6.6-7.3	6.1-7.3	Low to high	Good to poor
Eloika	135	SiL, VStSiL	GL, VGSL	2-25	6.1-6.5	6.1-7.3	Low to high	Fair
Hagen	152	LFS, LS, SL	S, LS	13->25	6.1-6.6	6.1-7.3	Low to high	Fair to poor

[a]Modified from: N.C. Donaldson and L.D. Giese, "Soil Survey of Spokane County, Wasington," Soil Conservation Service, U.S. Dept. of Agriculture in cooperation with Washington Agricultural Experimental Station, 1968.

[b]Definitions of symbols used are given in Table 9.1.

[c]This series has stony and gravelly phases and rocky complexes.

3. Miscellaneous land types that include coastal beach, riverwash, and rough land. The soil on the mountainous land is largely of glacial origin and varies greatly in texture and depth.

9.2.2 Western Great Plains

Most of the soils in the Western Great Plains region fall under the general category of Mollisols (map prefix M in Fig. 9.2). Smaller areas of Entisols (map prefix E) are scattered throughout the region. Sizeable areas of Aridisols (map prefix D) are in the Wyoming and Colorado extensions, and an Alfisol area (map prefix A) is in the Black Hills between Wyoming and South Dakota.

Mollisols in this region are mainly dark-colored soils rich in bases (calcium, magnesium). They are found on gently to moderately sloping topography. The surface horizon of virtually all Mollisols is deep and rich in humus. Mollisols in the northern third of the region have developed under a continental climate and commonly have a clay layer (argillic horizon) close to the surface, underlain by a layer of calcium carbonate accumulation (calcic horizon). Some of these soils have a sandy layer within rooting depth or contain an argillic horizon with an accumulation of sodium. Mollisols toward the central and southern part of the region have developed under subhumid to semiarid climates. Most of these soils have a clay layer close to the surface, with or without an accumulation of sodium. Others of these soils may contain a sandy or loamy layer at rooting depth.

Entisols have little horizon development. Most of the Entisols are found on recent erosional surfaces and have developed under conditions of limited moisture. Most of these soils are shallow and are found on slopes greater than 25%. Entisols of Nebraska, Kansas, and Colorado have developed on sands or sandy parent material, have poor water-holding capacity, and are subject to blowing and drifting. In the Dakotas and Montana, Entisols are found on steep slopes and badlands.

Aridisols have developed under arid to semiarid climates and do not contain water available to mesophytic plants for long periods. When the soil is warm enough for plant growth, water is in short supply, or is salty, or both. Aridisols are found in Wyoming and Colorado on gently to moderately sloping topography. These soils have a layer of clay accumulation (argillic horizon), which is not compact and does not have large amounts of sodium. A layer of calcium carbonate accumulation commonly lies below the argillic horizon, but the soils are noncalcareous above the clay horizon. Soils with poor horizon development are often found associated with these Aridisols.

Alfisols can have low organic matter content in the surface soil, can be shallow, and can have a layer of clay accumulation (argillic horizon) in the subsoil. They generally have moderate to high base saturation and available water during at least three months of the year when the soil is warm enough for plant growth. The single area of Alfisols in this region is in the Black Hills between Wyoming and South Dakota on gently sloping to steep topography under pine forest.

The uranium-resource counties selected for further discussion are Bowman in North Dakota, Butte in South Dakota, Kimball in Nebraska, and Douglas in Colorado. A soil survey report for Fall River County, South Dakota, where much of the current uranium milling activity is occurring, has not been published.

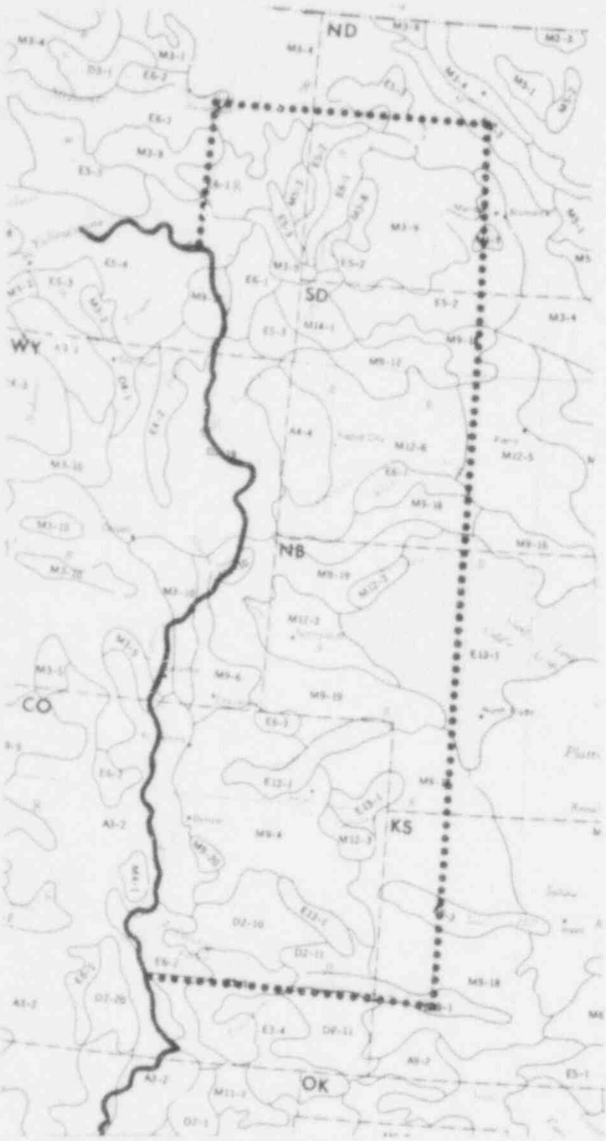
9.2.2.1 Bowman County, North Dakota

Bowman County is in the extreme southwestern corner of North Dakota within the Missouri Plateau physiographic area. The soils have formed under a continental, semiarid climate in which the average annual precipitation ranges from 38 to 40 cm (15 to 16 inches) in the eastern part of the county, to less than 36 cm (14 inches) in the western part. The climate favors the accumulation of organic matter and the retention of bases (calcium, magnesium, etc.) close to the surface. Natural vegetation is mainly mid- and short grasses, with tall grasses on some steep east-facing slopes.[5]

The western third of the county is characterized by badlands and uplands. Soils in this portion of the county are underlain by soft shale or soft sandstone, except for soils on terraces and bottomlands of the Little Missouri River. The central and eastern two-thirds of the county, on nearly level to steep topography, are characterized by soils underlain by soft sandstone and shale on uplands, and soils that have a claypan underlain by soft shale. Deep, well-drained loamy soils have developed along the bottomland of the North Fork of the Grand River. Saline and alkali soils occur on alluvial land in the central portion of the county.[5]

SOILS

A3-2 Cryoboralfs + Cryorthods, Cryoborolls, Cryaquolls, and Rockland steep.
A4-4 Eutroboralfs + Haplustolls, Ustorthents and Rockland, gently sloping to steep.
D2-10 Haplargids + Torriorthents and Argiustolls, gently or moderately sloping.
D2-11 Haplargids + Torriorthents, Argiustolls and Torripsamments, gently sloping.
D2-19 Haplargids + Torriorthents, Torriorthents (shallow) and Paleargids, gently or moderately sloping.
E5-2 Ustorthents + Argiborolls and Natriborolls, moderately sloping
E5-3 Ustorthents + Haploborolls, moderately sloping or steep
E6-1 Ustorthents (shallow to soft bedrock) + Badlands, steep
E6-3 Ustorthents (shallow) + Ustorthents, moderately sloping
E13-1 Ustipsamments, moderately sloping
M3-8 Argiborolls + Natriborolls and Haploborolls, gently sloping
M3-9 Argiborolls _ Ustorthents, gently sloping
M5-3 Haploborolls + Argiborolls, moderately sloping
M9-4 Argiustolls + Haplargids, Ustorthents and Paleustolls, gently sloping
M9-6 Argiustolls + Haplustolls, gently sloping
M9-12 Argiustolls + Natrustolls, gently or moderately sloping
M9-18 Argiustolls + Ustorthents, gently sloping
M9-19 Argiustolls + Ustorthents (shallow), gently sloping
M12-3 Haplustolls + Argiustolls and Ustorthents, gently sloping
M12-6 Haplustolls + Ustorthents and Camborthids, moderately sloping
M14-1 Natrustolls + Argiborolls, gently sloping
M9-20 Argiustolls + Usthorthents, gently sloping



WESTERN GREAT PLAINS

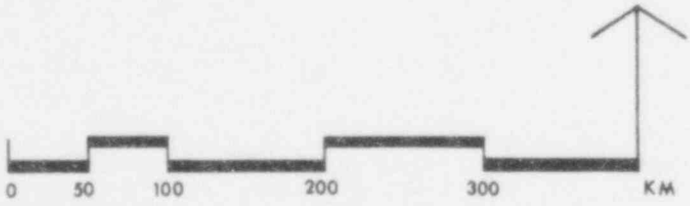


Fig. 9.2. Soils of the Western Great Plains Region (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

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In general, the soils of Bowman County can be grouped as follows (names in parentheses refer to associations):[5]

Soils underlain by soft shale

1. Nearly level to strongly sloping, moderately deep and shallow, well-drained loamy soils (Amor-Reeder-Cabba).

2. Nearly level to gently sloping, moderately deep and shallow, well-drained, loamy and clayey soils (Regent-Moreau-Cabba).

3. Hilly to steep, shallow and deep, moderately well-drained and well-drained, loamy soils and loamy soils that have a claypan (Cabbart-Absher).

4. Gently sloping to hilly, shallow, well-drained, clayey soils and shale outcrops (Dilts-Lisam-Shale outcrops).

5. Steep to very steep, shallow, well-drained, loamy and clayey soils and badlands (Cabbart-Badlands-Yawdim).

6. Gently sloping to strongly sloping, moderately deep and shallow, well-drained and excessively drained, loamy soils (Reeder-Brandenburg-Cabba).

7. Rolling to hilly, shallow and moderately deep, well-drained, loamy soils (Cabba-Amor-Chama).

Soils underlain by soft sandstone

1. Nearly level to gently undulating, moderately deep, well-drained, and shallow, excessively drained, sandy and loamy soils (Vebar-Flasher).

2. Nearly level to gently undulating, moderately deep, well-drained, loamy soils, and shallow, excessively drained, sandy soils (Rhame-Fleak).

3. Nearly level to gently undulating, deep and moderately deep, well-drained loamy soils and loamy soils that have a claypan, and deep, excessively drained, sandy soils (Ekalaka-Rhame-Zeona).

Soils on terraces and bottomlands

1. Nearly level, deep, well-drained, loamy soils (Havre-Toby-Glendive).

2. Nearly level, deep, well-drained and moderately well-drained, loamy soils (Korchea-Straw).

Soils that have a claypan, underlain by soft shale

1. Nearly level to gently sloping, deep and moderately deep, well-drained and moderately well-drained, loamy soils and loamy soils that have a claypan (Belfield-Rhoades-Amor).

2. Nearly level to gently sloping, deep and moderately deep, moderately well-drained, loamy soils that have a claypan and clayey soils (Roades-Moreau).

3. Nearly level to gently sloping, deep and moderately deep, well-drained and moderately well-drained, loamy soils that have a claypan (Roades-Absher).

Some details of these major soils are listed in Table 9.3.

The soils are generally from 1 to 3 m (3.3 to 10 ft), or occasionally higher, above the seasonal water table, have light- to heavy-textured surface soils, and are slightly acid to moderately alkaline. They have slow to moderate permeabilities and few are saline.

9.2.2.2 Butte County, South Dakota

Butte County occupies about 590,000 ha (1,450,000 acres) in northwestern South Dakota, part of the Great Plains physiographic province. The average annual precipitation ranges from about 33 cm (13 inches) in the northern part to about 38 cm (15 inches) in the south-central part.[6]

Table 9.3. Major Soils of Bowman County, North Dakota[a,b]

Series Name	Parent Material	Depth to Bedrock, cm	Depth to High Seasonal Water Table, m	Dominant Surface Texture	pH	Subsoil Permeability, cm/hr	Salinity mmhos/cm	Available Water Capacity	Topsoil Suitability
Amor	Shale, siltstone, sandstone	30-95	>1.8	L	6.6-7.3	1.6-5	<2	High	Good to poor, depending on slope
Reeder	Shale, siltstone, sandstone	52-100	>1.8	L, SiL	6.6-7.3	0.5-5	<2	Moderate to high	Good to fair
Cabba	Shale, siltstone, sandstone	<46	>3	SiL, L	7.9-9.0	0.1-0.5	<2	Low	Poor
Regent	Soft shale	52-100	>1.8	SiCL, SiC	6.6-7.3	0.1-0.5	<2	Moderate to high	Fair to poor
Moreau	Clay shale	61-79	>1.8	SiC	7.9-8.4	<0.1-0.5	2-4	Moderate	Poor
Cabbart	Shale, siltstone, sandstone	<46	>3	SiL, L	7.4-8.4	0.1-0.5	<2	Low	Poor
Absher	Soft shale	106-182	>1.8	SiCL, SiC	7.9-8.4	<0.1	4-8	Moderate	Poor
Dilts	Pierre shale	<46	>3	C	5.1-6.0	<0.1	2-4	Low	Poor
Lisam	Pierre shale	<46	>3	C	7.9-8.4	<0.1	2-4	Low	Poor
Badlands	Soft shale	0-49	>3	Properties too variable		---	---	---	---
Yawdim	Soft shale	>46	>3	SiC	7.9-8.4	0.1-0.5	4-16	Low	Poor
Brandenburg	Soft shale	<46	>3	GL	7.4-7.8	1.6-51	<2	Very low	Poor
Chama	Soft shale	49-100	>2.4	SiCL	6.6-7.8	0.1-0.5	<2	Moderate	Fair
Vebar	Sandstone	49-100	>2.4	FSL, LFS	6.1-8.4	0.5-1.6	<2	Low to moderate	Fair
Flasher	Sandstone	<46	>3	FSL, LFS	6.6-8.4	0.5-1.6	<2	Very low	Good to 8"
Rhame	Sandstone	49-100	>2.4	FSL	6.8-8.4	0.5-1.6	<2	Low to moderate	Good to poor, depending on slope
Fleak	Sandstone	<46	>3	LFS or FSL	6.6-8.4	0.5-1.6	<2	Very low	Poor
Ekalaka	Sandstone	>107	-1.8	FSL or LFS	6.8-8.4	0.1-0.5	2-4	Moderate to low	Good to 12"
Zeona	Eolian sands	>107	>3	LFS or FS	6.1-7.3	16-51	<2	Very low to low	Poor (sandy)
Havre	Alluvium	>183	>1.5[c]	L or CL	7.4-7.8	1.6-5	<2	Moderate to high	Good
Toby	Alluvium	>107	>1.5[c]	FSL, L	6.6-7.3	5-16	<2	Moderate	Poor (sandy)
Glendive	Alluvium	>183	>1.5[c]	FSL	7.4-8.4	5-16	<2	Moderate	Good
Korchea	Alluvium	>183	>1.5[c]	L, SiL, FSL	7.9-8.4	1.6-5	<2	High	Good
Straw	Alluvium	>183	>1.5	L or SiL	6.6-8.4	1.6-5	<2	High	Good
Belfield	Soft shale	>107	>1.8	SiL, SiCL	6.1-6.5	0.5-1.6	<2	Moderate	Fair to 12"
Rhoades	Soft shale	>61	>1.8	L, SiL, SiCL	6.1-6.5	<0.1	2-4	Low	Poor (claypan)

[a]Modified from: "Soil Survey of Bowman County, North Dakota," U.S. Dept. of Agriculture, Soil Conservation Service in cooperation with North Dakota Agricultural Experiment Station, 1975.

[b]Definitions of symbols used are given in Table 9.1.

[c]Subject to flooding.

The soils of Butte County can be grouped as follows (names in parentheses refer to associations):[6]

Soils derived from clay shale

1. Moderately deep and shallow, nearly level to moderately steep clayey soils (Winler-Lismas).

2. Moderately deep and deep, nearly level to moderately steep clayey soils (Pierre-Cyle).

3. Shallow, gently sloping to steep clayey soils over acid clay shale, and shale land (Grummit-Shale land).

4. Shallow, gently sloping to steep clayey soils over saline clay shale (Epsie).

Soils derived from shale and limestone

1. Shallow, gently sloping to moderately steep silty soils (Midway-Penrose).

Soils derived from siltstone, sandstone, and shale

1. Shallow, sloping to steep loamy soils, and deep, nearly level to sloping loamy soils that have a claypan (Cabbart-Absher).

2. Moderately deep, gently sloping to moderately steep loamy soils over stone, and deep, nearly level to sloping loamy soils that have a claypan (Twilight-Absher).

3. Shallow to deep, sloping to very steep loamy and silty soils (Butche-Colby).

Soils formed in alluvium on terraces and bottomlands

1. Deep, nearly level silty soils that have a claypan, and deep, nearly level clayey soils (Arvada-Stetter).

2. Deep, nearly level silty and loamy soils (Lohmiller-Glenberg-Harverson).

3. Deep, nearly level to sloping loamy soils on high terraces (Caputa-Satanta).

4. Deep, nearly level to gently sloping loamy soils that have a claypan (Sorum).

Some details on these major soils are listed in Table 9.4.

The surface soils are generally of medium to heavy texture, and slightly acid to moderately alkaline. They have, in general, poor topsoil suitability, and erosion hazards are high to severe. Natural vegetation of the county is mostly mid- and short grasses.[6]

9.2.2.3 Kimball County, Nebraska

Kimball County occupies an area of about 247,000 ha (610,000 acres) in the extreme southwestern corner (panhandle) of Nebraska, in the high plains of the Great Plains physiographic province. The climate is seimarid and continental, with an average annual precipitation of about 42 cm (16.5 inches). Elevation of the county ranges from about 1500 to 1600 m (4800 to 5300 feet). Vegetation of the county is mainly short and mid-grasses, except along streams and draws, where trees such as cottonwood, boxelder, ash, willow juniper and stunted pine are found.[7] The soils of the county have formed from a variety of sedimentary material, including limestone. Because the soils are seldom wet below rooting depth, many of the younger soils have free lime throughout the profile.[7]

The soils of the county can be grouped as follows (names in parentheses refer to associations):[7]

1. Deep loamy soils on high tableland (Rosebud).

2. Loamy soils and soils on caliche (Rosebud-Canyon).

3. Gently sloping loamy soils and sloping to steep shallow soils (Altavan-Rosebud-Dix).

4. Steep soils with rock outcrops and gently sloping loamy soils (Rockland-Canyon-Rosebud).

Table 9.4. Major Soils of Butte County, South Dakota[a,b]

Series Name	Parent Material	Depth to Bedrock, cm	Dominant Texture: Surface	Dominant Texture: Subsurface	pH	Subsoil Permeability, cm/hr	Salinity, mmhos/cm	Available Water Capacity	Topsoil Suitability
Winler	Shale	51-102	C		6.6-7.8	<0.1	2-4	Moderate	Poor
Lismas	Clay shale	15-51	C		6.6-7.8	<0.5	2-4	Moderate	Poor
Pierre	Shale	51-102	C		6.6-8.4	<0.1	2-4	Moderate	Poor
Kyle	Shale	101	C		7.4-8.4	<0.1	2-4	Moderate	Poor
Grummit	Acid shale	13-51	C		3.5-5.0	1.5-5	2	Moderate	Poor
Shale land	Shale	No estimates were made			---	---	---	---	---
Epsie	Saline shale	15-51	C		6.6-7.8	<0.1	16	Moderate	Poor
Midway	Shale	15-51	SiCL		6.6-7.3	0.1-0.5	2-4	High	Poor
Penrose	Shale and limestone	20-51	SiCL		7.4-8.4	0.1-1.5	2	High	Poor
Cabbart	Sandstone, siltstone, shale	20-51	L		7.4-8.4	1.5-5	2	High	Poor
Absher	Sandstone, siltstone, shale	101	FSL	Cl, SCL	6.1-7.3	<0.1-5	2-4	Moderate to high	Poor
Twilight	Sandstone	51-102	FSL		6.6-8.4	5-15	2	High	Fair
Butche	Siltstone, sandstone, shale	15-51	VFSL		6.6-7.3	3-5	2	High	Poor
Colby	Calcareous silt	101	SiL	LVFS	6.6-7.8	<15-25	2	Moderate to high	Poor to fair
Arvada	Clayey alluvium	152	SiL	SiC, SiCL	6.1-6.6	<0.1-15	2	Moderate	Poor
Stetter	Non-calc. alluvium	152	C		6.6-7.8	0.1-0.5	2-4	Moderate	Poor
Lohmiller	Calcareous alluvium	152	SiCL	SiCL	6.6-7.8	0.1-0.5	2	High	Fair
Glenberg	Alluvium	152	FSL	LS	6.6-7.8	15-25	2	Moderate to high	Good
Haverson	Alluvium	152	L, SiL		7.4-7.8	1.5-5	2	High	Fair
Caputa	Clayey alluvium	152	L	Cl, SCL, L	6.1-7.3	0.5-1.5	2	High	Good to 9"
Satanta	Alluvium	152	L	L, CL	6.1-6.6	1.5-5	2	High	Good to 8"
Sorum	Alluvium	152	FSL	CL, SL	6.0-7.8	<0.1-15	2	Moderate to high	Good to 15"

[a]Modified from: P. R. Johnson et al., "Soil Survey of Butte County, South Dakota," Soil Conservaton Service, U.S. Dept. of Agriculture, in cooperation with South Dakota Agricultural Experiment Station, 1976.

[b]Definitions of symbols used are given in Table 9.1.

5. Nearly level to gently sloping loamy soils (Bridgeport-Tripp).

6. Shallow and moderately deep soils and rock outcrops (Canyon-Vebar).

7. Deep silty or loamy soils on tableland and on slopes to streams (Keith-Rosebud).

Surface soils of the major series are generally medium textured, neutral to alkaline, and with some exceptions, of low to moderate permeabilities. A number of soils have fair to good topsoil suitabilities, while others are unsuitable because of the presence of a caliche layer. Hazards from wind erosion are generally high.

9.2.2.4 Castle Rock Area, Douglas County, Colorado

The Castle Rock area occupies about 146,000 ha (360,000 acres) in Douglas County in north-central Colorado. Elevation ranges 1700 to 2100 m (5500 to 7000 ft). Average annual precipitation varies from nearly 38 cm (15 inches) to more than 46 cm (18 inches). The greatest precipitation falls during spring and summer, but because evapotranspiration exceeds rainfall, by mid- or late July the soils are dry except for brief periods following summer rains.[8] The area is in a transitional zone between grassland and forest, with the grasses occurring primarily in the northern and eastern portions of the area.[9]

The soils of the area can be grouped as follows (names in parentheses refer to associations):[8]

1. Deep, nearly level to gently sloping, loamy and sandy soils on floodplains and terraces (Loamy alluvial land-Sampson).

2. Deep and moderately deep, gently sloping to moderately steep, loamy soils on uplands (Fondis-Kutch).

3. Deep, gently sloping to moderately steep, sandy and gravelly soils on uplands (Bresser-Newlin-Stapleton).

4. Deep and moderately deep, gently sloping to steep, clayey soils on uplands (Razon-Denver).

5. Deep, gently sloping to moderately steep, sandy soils on uplands (Peyton-Kettle-Crowfoot).

6. Deep, gently sloping to steep, loamy soils on tablelands (Brussett-Jarre).

7. Deep to shallow, gently sloping to steep, sandy and gravelly soils on terraces, fans, and valley side slopes (Garber-Kassler-Rockland).

8. Shallow, steep, gravelly soils and rock in mountainous areas (Juget-Rockland).

Details of these major soil series are listed in Table 9.5.

Most of these soils are relatively deep, well above the seasonal water table. Surface horizons are generally medium textured, ranging from slightly acid to strongly alkaline, with generally moderate to rapid permeabilities. Erosion hazards range from slight to severe, depending on the slope.

9.2.3 Wyoming Basin

The Wyoming Basin region is characterized by soils formed under arid to semiarid conditions. Precipitation ranges from 12 to 25 cm (about 5 to 10 inches) per year in the basins, 25 to 35 cm (about 10 to 14 inches) per year in foothill areas, to over 50 cm (about 20 inches) per year in the mountains. Where the soils have developed distinct layers (horizons), the surface layers are normally light in color, with little organic matter content (less than 0.6%). Subsurface layers commonly include a layer of clay accumulation (argillic horizon) and below it a layer in which calcium carbonate, or calcium and magnesium carbonates, have accumulated (calcic horizon). The surface soils are generally fine to medium textured, and periods of continuous moisture always last less than three months. These soils are classified as Aridisols (map prefix D in Fig. 9.3). Soils that do not have distinct horizon development are commonly found in zones where precipitation is 12 to 23 cm (about 5 to 9 inches) per year; these soils can have relatively

Table 9.5. Major Soils of the Castle Rock Area, Douglas County, Colorado[a,b,c]

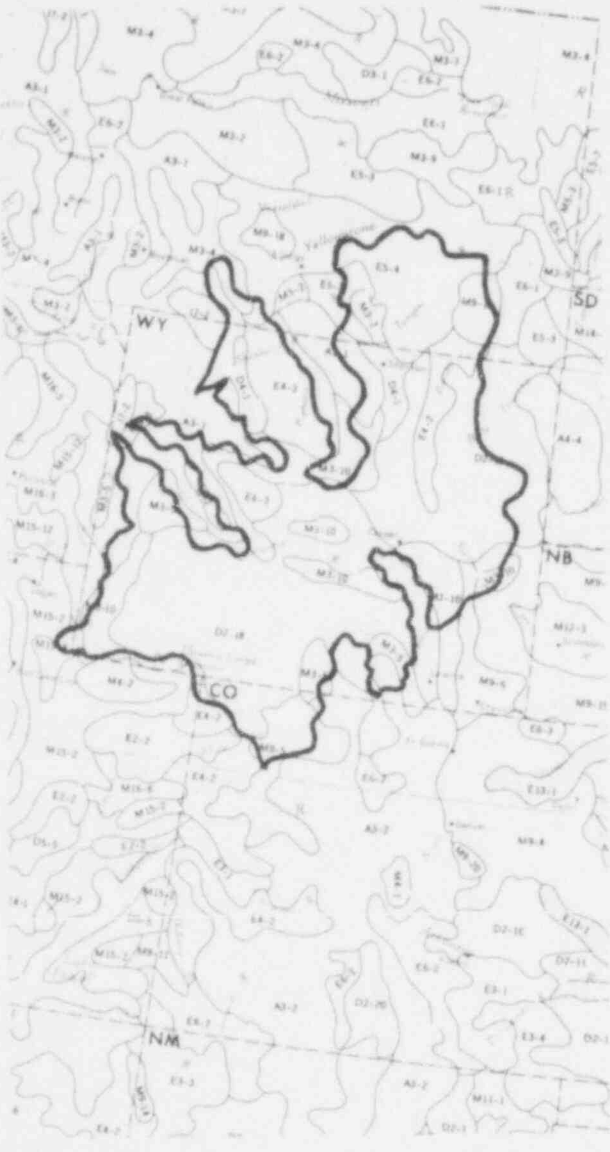
Series Name	Parent Material	Depth to Bedrock, cm	Dominant Texture: Surface	Dominant Texture: Subsurface	pH	Subsoil Permeability, cm/hr	Salinity, µm/hos/cm	Available Water Capacity	Topsoil Suitability
Loamy alluvial land	Alluvium	>152	SL to CL	LS to CL	6.1-8.4	1.6-51	0-4	Moderate to high	Fair to good; poor if wet
Sampson	Arkosic alluvium	>152	Cl, L, SiL	--	6.1-8.4	0.5-1.6	0-2	High	Fair to good
Fondis	Outwash, eolian	>152	C	SCL	6.1-7.8	0.5-1.6	0-2	High	Fair
Kutch	Clay shale	51-102	C or CL	--	6.1-8.4	0.1-0.5	2-4	High	Poor to fair
Bresser	Sandy loess, alluvium	>152	SL	SCL, SL	6.1-7.8	1.6-16	0-2	Low to high	Fair
Newlin	Mixed alluvium	>152	GSL	VGS	6.1-7.8	16-51	0-2	Low to high	Poor
Stapleton	Arkosic alluvium	>152	CsSL	--	6.1-7.8	5-16	0-2	Moderate to high	Poor
Razor	Pierre shale	51-102	C	--	7.3-9.0	0.1-0.5	4-8	Low to high	Poor
Denver	Clay shale	>102	C or CL	--	6.1-9.0	0.1-0.5	2-4	High	Poor
Peyton	Arkosic alluvium	>152	SL	SCL, SL	5.6-7.3	1.6-16	0-2	Low to high	Good to fair
Kettle	Sandy alluvium	>152	LS	SL, LCsS	5.1-6.5	5-51	0-[illegible]	Low	Poor
Crowfoot	Dawson arkose	>152	LS	SCL, CsS	5.6-7.3	1.6-51	0-2	Low	Poor to fair
Brussett	Eolian silts and sands	>152	CL	L	6.1-7.8	1.6-5	0-2	High	Good
Jarre	Sandy alluvium	>152	L to GCL	VGLS	6.1-7.8	16-51	0-2	Low	Poor
Garber	Alluvium	>152	VGSL	--	5.6-7.3	16-51	0-2	Moderate	Poor
Kassler	Arkosic alluvium	>152	VGLS	--	6.1-7.8	16-51	0-2	Low	Poor
Rockland	Materials too valuable to estimate			--	--	--	--	--	--
Juget	Granite	25-51	GLS	--	5.1-7.3	16-51	0-2	Low	Poor

[a]Modified from: L. S. Larsen et al., "Soil Survey of Castle Rock Area, Colorado," Soil Conservation Service, U.S. Dept. of Agriculture, in cooperation with Colorado Agriculture Experiment Station, 1974.

[b]Except for the loamy alluvial land where depth to the seasonal high water table is less than 1.5 meters, the water table in all these soils is at such a great depth that it is not "significant" for engineering purposes.

[c]Definitions of symbols used are given in Table 9.1.

SOILS



A3-1 Cryoboralfs + Cryorthods, steep
D4-1 Paleargids + Argiustolls, gently sloping

D2-18 Haplargids + Torriorthents and Salorthids, gently sloping, and Torriorthents, steep
D2-19 Haplargids + Torriorthents (shallow) and Paleargids, gently or moderately sloping
E4-2 Torriorthents (shallow to soft bedrock) + Haplargids, Camborthirds, and Rock land, moderately sloping to steep
E4-3 Torriorthents (shallow to soft bedrock) + Haplargids, Torrifluvents, and Natrargids, gently sloping to steep
E5-4 Ustorthents + Torriorthents, Camborthids, Argiustolls, and Haplargids, moderately sloping
M3-5 Argiborolls + Haploborolls, gently sloping to steep
M3-10 Argiborolls + Ustorthents (shallow and Boralfs, steep
M9-5 Argiustolls + Haploborolls and Argiborolls, moderately sloping
M9-18 Argiustolls + Ustorthents, gently sloping
M3-2 Argiborolls, gently sloping

WYOMING BASIN

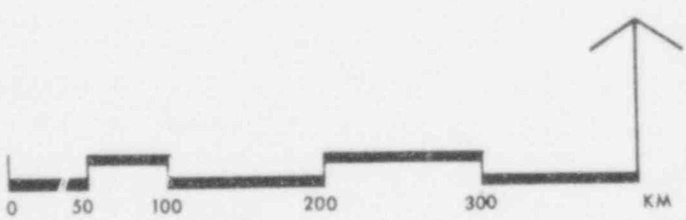


Fig. 9.3. Soils of the Wyoming Basin Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

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high salt content corresponding to 2 mmhos/cm* or greater,[9] and are classified as Entisols (map prefix E). Smaller areas of dark-colored soils containing more than 0.6% organic matter also occur in the region. These soils have a layer of clay accumulation close to the surface and a calcic horizon below the clay layer. They are classed as Mollisols (map prefix M).

The counties within this uranium resource region selected for further description are Fremont and Campbell in Wyoming. Soil survey reports for Natrona, Converse, and Carbon counties, in which most of the uranium-milling activity is expected, have not been published.

9.2.3.1 Riverton Area, Fremont County, Wyoming

The Riverton area occupies about 152,000 ha (about 375,000 acres) at elevations between 1500 to 1700 m (4800 to 5500 ft) in the central part of Fremont County. Most of the area is in the Wind River Basin. The area is characterized by flat-topped remnant terraces, gravel-capped buttes, and eroding uplands that have alluvial fans and recent alluvial deposits along the major drainages. The average annual precipitation is about 23 cm (9 inches).[10] Dominant species of vegetation are big sagebrush, Indian rice-grass, blue grama, and needle and thread, except in areas of high salinity and alkalinity, where salt-tolerant species such as greasewood, alkali sacaton, inland saltgrass, and western wheatgrass predominate.[10]

Soils of the Riverton area can be grouped as follows (names in parentheses refer to associations):[10]

1. Deep, nearly level to sloping sandy loams and sandy clay loams on alluvial fans (Apron-Lostwells).

2. Shallow, nearly level to moderately steep sandy clay loams and sandy loams on uplands (Persayo-Oceanet).

3. Deep, nearly level to sloping loams on terraces (Ethete-Griffy).

4. Deep, nearly level to moderately steep loamy sands and sandy loams on terraces and alluvial fans (Tipperary-Trook).

5. Deep, nearly level to moderately steep sandy loams on alluvial fans and terraces (Apron-Trook).

6. Deep, nearly level loams and fine sandy loams on floodplains (Crowheart-Bigwin).

7. Deep, nearly level to gently sloping silty clay loams on floodplains and low terraces (Fivemile-Binton).

8. Shallow to deep, nearly level to sloping alkali clay loams and sandy clay loams on alluvial fans and uplands (Birdsley-Effington-Boysen).

Details on these major series are listed in Table 9.6. The surface layers of the soils are generally light yellow to light brown and range in texture from sandy loam to clay loam. Depths of surface soils range from 15 to 25 cm (6 to 10 inches), underlain by subsoils of similar texture down to 150 cm (60 inches) or more. Occasionally, a compact clay layer is encountered on soils developed from shale. The profiles are generally alkaline to strongly alkaline, and most are calcareous throughout. Erosion hazards from wind and water range from slight to moderate on slopes of less than 6% to moderate to severe on steeper slopes. Permeabilities range from moderately slow to rapid.

9.2.3.2 Campbell County, Wyoming

Campbell County, located in northeastern Wyoming, covers a land area of about 1,232,000 ha (3,043,000 acres). The northern and western third of the county is a deeply dissected upland.

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*mmhos/cm is an electrical conductivity reading that is directly related to the salt content of a soil. 2 mmhos/cm corresponds (very roughly) to a salt content of 0.1%. At soil conductivities of less than 2 mmhos/cm, effects of salinity on plants are negligible; above 2 mmhos/cm, yields of very sensitive crops may be restricted, and above 4 mmhos/cm, yields of many crops are restricted. Most grasses and forage species can tolerate salinities of between 4 and 12 mmhos/cm. Species such as alkali sacaton, saltgrass, and Western wheatgrass can tolerate salinities of between 12 and 18 mmhos/cm.[9]

Table 9.6. Major Soils of the Riverton Area, Fremont County, Wyoming[a,b]

Series Name	Parent Material	Depth to Bedrock, cm	Depth to Seasonal High Water Table, m	Dominant Surface Texture	pH	Permeability, cm/hr	Salinity, mmhos/cm	Available Water Capacity	Topsoil Suitability
Apron	Alluvium	152	c/	SL	7.9-9.6	5-16	0-8	Moderate	Good, except with alkali, salts, high water table
Lostwells	Alluvium	152	c/	SCL	7.9-9.0	0.5-1.5	0-8	High	Good, except where strong alkali or saline.
Persayo	Clay shale	25-51	c/	SCL	7.9-9.0	1.5-5	0-4	Very low	Poor
Oceanet	Sandstone	25-51	c/	SL	7.9-8.4	5-16	0-4	Very low	Fair
Ethete	Sand and gravel	152	c/	CL	7.4-9.0	1.5-5	0-8	Moderate	Fair
Griffy	Mixed material	152	c/	SCL, FSL	7.4-9.0	1.5-16	0-4	High	Good
Tipperary	Loose sand	152	c/	LS, S	7.9-9.6	16-51	0-4	Low	Poor
Trook	Mixed material	152	c/	SL	7.9-9.0	5-16	0-8	Moderate	Good to fair
Crowheart	Sand and gravel	152	0.9-1.5	L	9.1-9.4	1.5-5	4-8	Moderate	Poor (soluble salts)
Bigwin	Sand and gravel	152	0.9-1.5	SL	7.9-8.4	5-16	0-4	Moderate	Good above gravel
Fivemile	Mixed alluvium	152	c/	SCL	7.9-9.0	0.5-1.5	0-8	High	Good (surface)
Binton	Mixed alluvium	152	c/	SCL	8.5-9.6	0.1-0.5	0-15	Low	Not suitable (salts and alkali)
Birdsley	Clay shale and sandstone	25-51	c/	CL	9.1-9.6	0.1	0-4	Very low	Not suitable (alkali)
Effington	Mixed material	152	c/	SCL, C	8.5-9.6	0.1-1.5	8-15	Low	Poor (alkali)
Boysen	Alluvium	152	c/	SCL	9.1-9.6	0.1	0-4	Low	Not suitable (alkali)

[a]Modified from: J. F. Young and C. F. Fowkes, "Soil Survey of Riverton Area, Wyoming (Fremont County)," Soil Conservation Service, U.S. Dept. of Agriculture, in cooperation with the Wyoming Agricultural Experiment Station, 1974.

[b]Definitions of symbols used are given in Table 9.1.

[c]Water table was observed to depth of profile, normally 1.5 m (5 ft), with some exceptions.

South and east of this upland is a rolling divide covering another third of the county and containing most of the cultivated land and population. East of this divide are the Rochelle Hills, which drop to a low eastward-sloping plain. Elevation in the county ranges from 1000 to 1800 m (3300 to 6000 ft). The average annual precipitation is about 20 cm (8 inches) in the central area of the county and decreases from the northeastern portion to the southwestern corner.[11*]

The natural vegetation on these soils consists mainly of short grasses. Blue grama, side-oats grama, western wheatgrass, rabbit brush and prickly pear cactus are common on the uplands and terraces, western wheatgrass is often dominant on stream bottoms and clayey soils, and saltgrass and geasewood are dominant on highly saline areas. In the northern and eastern areas of the county there are fairly dense stands of juniper and pine.[11]

The soils of Campbell County vary considerably and can be grouped on the basis of relief and parent material upon which they formed, as follows:[11]

1. Soils of the uplands and terraces derived from sandy and silty shales (the Ulm, Fort Collins, Goshen, and Bridgeport series).

2. Soils of the uplands and terraces derived from gray clayey shales (the Renohill, Arvada, Manuel, Moline, and McKenzie series).

3. Soils of the uplands and terraces derived from dark gray Pierre shale (the Pierre and Orman series).

4. Soils of the uplands derived from sandstone (Terry series).

5. Soils of the uplands and terraces derived from red, burned shale (Searing, Wibaux, and Dillinger series).

6. Soils of the bottomlands (Banks, Laurel, and Sarpy series).

The soils derived from sandstone and sandy shale are sandy and medium textured, while those derived from clayey shale are fine textured, often with a very dense, compact clay subsoil. In general, the soils are shallow, have low to moderate amounts of organic matter, and often have a calcium carbonate layer close to the surface. Throughout the county, there are small, localized areas of high salt content, commonly occurring on the clay soils derived from heavy gray shale.[11]

9.2.4 Southern Rocky Mountains

The largest single order of soils in this region is the Alfisols (map prefix A in Fig. 9.4) found primarily under coniferous vegetation on slopes of the Rocky Mountains and the Sangre de Cristo Range. Alfisols are moist soils that have medium to high base content and contain a layer in which silicate clays have accumulated (argillic horizon). In this region, the Alfisols have formed under mean annual temperatures higher than 0°C (32°F) but lower than 8°C (46°F) (cryic temperatures). These soils commonly have a layer of organic material on the surface (O horizon) overlying a layer from which clay and iron oxides have been removed (albic horizon). Under the albic horizon is the argillic horizon.

Extending into Wyoming (the northern extremity of the region) and into New Mexico (the southern extremity) are a group of Aridisols (map prefix D). These soils form in dry climates and have less than 0.6% organic matter. In this region, these soils have an argillic horizon, are generally noncalcareous above the argillic horizon, but have a layer below it in which calcium carbonate or calcium and magnesium carbonates have accumulated (calcic horizon). These areas also include soils whose argillic horizons have high exchangeable sodium and soils that have horizons of salt accumulation.

Isolated pockets of Entisols and Mollisols also occur. Entisols are young soils with poor horizon development. In this region, the Entisols (map prefix E) are found on recent erosional surfaces, are neutral to calcareous, and are often salty. The Mollisols (map prefix M) are mainly dark-colored soils rich in calcium and magnesium. In this region they are moist soils formed in cool areas and occur on moderately sloping topography. They may have an argillic horizon underlain by a calcic horizon.

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*Reference 11 is an older, reconnaissance soil survey report, and a number of details are not known. This presentation of the major soil series thus deviates from descriptions of other counties.

SOILS

A3-2 Cryoborals + Cryorthods, Cryoborolls, Cryoquolls, and Rock land, steep

D2-17 Haplargids and other Aridisols + Torriorthents and Rock land, gently or moderately sloping

D2-18 Haplargids + Torriorthents and Salorthids, gently sloping, also Torriorthents (shallow), steep

D2-20 Haplargids + Torripsamments, Natrargids, and Salorthids, gently sloping

E4-2 Torriorthents (shallow to soft bedrock) + Haplargids, Camborthids and Rock land, moderately sloping or steep

E6-2 Ustorthents (shallow) + Haploborolls and Argiborolls, steep

M3-5 Argiborolls + Haploborolls, gently sloping to steep

M4-1 Cryoborolls + Cryorthents and Haplargids, moderately sloping

M9-5 Argiustolls + Haploborolls and Argiborolls, moderately sloping

SOUTHERN ROCKY MOUNTAINS

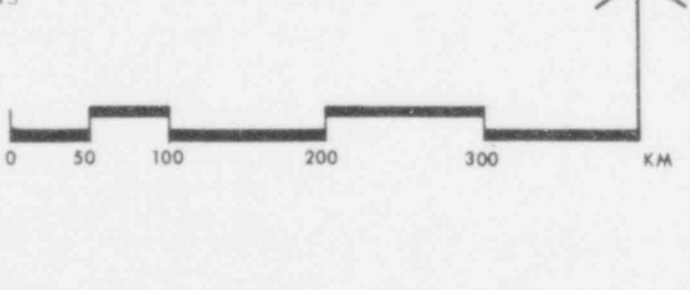

Fig. 9.4. Soils of the Southern Rocky Mountair ; Region. (Modified from: "The National Atlas of the United St tes of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

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The uranium-resource counties selected for further description are Taos in New Mexico and Alamosa in Colorado, and the Gunnison and Lake-Chaffee areas, also in Colorado.

9.2.4.1. Taos County, New Mexico

The area of Taos County, in north-central New Mexico, is about 585,000 ha (1,445,000 acres). The eastern part of the county is mountainous and wooded, with elevations ranging from about 2100 m (7000 ft) near the base of the mountains to 4010 m (13,160 ft) on Wheeler Peak. The remainder of the county is divided into alluvial fans or valley-filling slopes at the base of the Sangre de Cristo Mountains and the extensive valley or plains area west of the Rio Grande. Because of the extremes in elevation, the average annual precipitation ranges widely, from 23 to 36 cm (9 to 14 inches) along the Rio Grande Valley, to 41 cm (16 inches) in the foothills and along the western border, and to more than 76 cm (30 inches) in the higher mountain areas.[12] Vegetation of the eastern portion of the county is mainly forest, including pinyon pine, ponderosa pine, juniper, and Douglas fir. The western portion consists predominantly of grasslands and shrubs.

The major soils of the county can be grouped as follows (names in parentheses refer to associations):[12]

1. Soils on gently sloping and undulating alluvial fans and valley-filling slopes between the base of the Sangre de Cristo Mountains and the Rio Grande Gorge (Hondo-Fernando-Tenorio).

2. Soils in the northwestern part of the county formed mainly from materials of volcanic or basic igneous origin on old lava flows (Dormilon-Stoneham-Harvey).

3. Soils formed predominantly in eolian and alluvial sediments on gently to strongly sloping landscapes (Fernando-Dean).

4. Soils formed in materials weathered from a variety of sedimentary and igneous rocks on mountainous terrain (Gambler-Etown).

5. Soils on old alluvial fans and terraces in narrow valley areas and on steep mountainous topography, formed from a wide variety of parent materials, including tuff, granite, shale, limestone, sandstone, and old alluvium (Eutroboralf-Chryochrept).

These associations account for about 72% of the county's soils. The remainder consist of seven minor associations.

Some properties of the major series are listed in Table 9.7. These soils have disparate characteristics. They range from shallow to very deep, from very strongly acidic to calcareous, from slow to very rapid in subsoil permeabilities, and from very low to high in water-holding capacities. Topsoil suitabilities are fair to good in five of these series but are poor in the remainder, principally because of the presence of stones and cobbles.[12]

9.2.4.2 Alamosa Area, Colorado

The Alamosa area consists of about 176,000 ha (434,000 acres) in the San Luis Valley, a broad, high mountain valley in south-central Colorado. A large part of the area lies within a closed basin that has a high water table, is very strongly alkaline, and has no external drainage. It has many lake basins, most of which are dry nearly all the time. The average annual precipitation is 17 cm (6.7 inches), most of which falls in July and August. Vegetation consists primarily of salt-tolerant species, such as greasewood, rabbitbrush, alkali sacaton, and inland saltgrass, except on mountain slopes, where spruce, ponderosa, pinyon, Douglas fir, and juniper occur.

The soils of the area can be grouped as follows (names in parentheses refer to associations):[13]

1. Deep, nearly level, well-drained to poorly drained soils in the northwestern part of the area, formed in alluvial material (Gunbarrel-Mosca-San Luis).

2. Deep, nearly level, well-drained and somewhat poorly drained soils in the northern part of the area on flood plains on the valley floor (McGinty-Gunbarrel).

3. Dark-colored alluvial soils on low flood plains (Alamosa-Vastine-Alluvial land).

4. Intensely farmed, nearly level to gently sloping soils in the southwestern part of the area (San Arcacio-Acacio-Zinzer).

Table 9.7. Major Soils of Taos County, New Mexico[a,b]

Series Name	Soil Depth, cm	Surface Texture	Reaction	Subsoil Permeability, cm/hr	Available Water Capacity	Substratum	Topsoil Suitability
Hondo	51-102	L, CL	Noncalcareous	0.1-0.5	Moderate	Limy alluvium or soft caliche	Fair to 3-5"
Fernando	152 or more	L, CL	Noncalcareous	0.1-0.5	High	Loamy alluvial sediments	Good to 5-8"
Tenorio	61-122	L, SL	Noncalcareous	15-51	Low	Very gravelly alluvium	Fair to 4-5"
Dormilon	25-50	StL, StCL	Calcareous	1.5-5	Very low to low	Basalt bedrock	Poor
Stoneham	152	CoL, StL	Calcareous	1.5-5	Moderate	Gravelly and cobbly loam	Poor
Harvey	38-51	L, FSL	Calcareous	1.5-5	Low	Very limy loam or soft caliche	Fair to 5-6"
Fernando	152 or more	L, VFSL	Noncalcareous	0.1-0.5	High	Loamy sediments	Good to 5-8"
Dean	15-38	L	Calcareous	1.5-5	Very low to low	Soft caliche	Poor
Gambler	152 or more	CoSL, CoL	Medium acid	1.5-5	Moderate	Cobbly sandy loam	Poor
Etown	152 or more	CoFSL	Medium acid	0.1-5	Moderate	Very cobbly sandy clay	Poor
Etown	152 or more	CoSL, CoL	Neutral to slightly acid	0.1-0.5	Moderate	Very cobbly sandy clay loam	Poor
Eutroboralf-Chryochrept	152 or more	GL, CoL	Very strongly acid	51	Moderate	Gravelly and stony sandy loam	Poor

[a]Modified from: H. J. Maker et al., "Soil Associations and Land Classifications for Irrigation, Taos County," Agriculture Experimental Station Research Report No. 268, New Mexico State University, 1974.

[b]Definitions of symbols used are given in Table 9.1.

5. Deep, nearly level to hummocky soils, strongly affected by alkali, on alluvial material and dune sand (Hooper-Corlett).

6. Deep, nearly level to gently sloping soils on a narrow strip in the eastern part of the area (Costilla-Space City).

7. Deep to very shallow, sloping to very steep, cobbly and stony soils along the eastern edge of the area (Uracca-Mount Home-Commodore).

8. Deep, nearly level to hilly alkali soils in the central part of the area (Hapney-Hooper-Corlett).

9. Deep, rolling to hilly dunelike soils in the northeastern corner of the area (Cotopaxi-Dune land).

Some properties of these major series are listed in Table 9.8.

With one exception, all the soils are deep, with medium to coarse-textured surface layers. Permeabilities range from very low to very rapid. Most of these soils have poor topsoil suitability, primarily because of salinity or the presence of stones and cobbles.[13]

9.2.4.3 Gunnison Area, Colorado

The Gunnison area consists of 325,000 ha (803,000 acres) in Gunnison, Hinsdale, and Saguache counties. Nearly level floodplains, low terraces, and alluvial fans are adjacent to major streams; the interstream areas consist of moderately rolling to steeply rolling uplands, dissected mesas, and long, narrow ridges paralleled by drainageways that slope toward the Gunnison River Valley. The average annual precipitation at Gunnison is 28 cm (11 inches). Vegetation is mixed grass and timber, with grasses occupying the lower elevations and timber becoming more dense with elevation.[14]

The soils of the area can be grouped as follows (names in parentheses refer to associations):[14]

1. Deep, nearly level to strongly sloping soils on floodplains, terraces, and alluvial fans, formed in alluvium derived from mixed rock sources (Evanston-Gas Creek-Irim).

2. Deep to moderately deep, moderately sloping to steep soils on hills, mountains, ridges, and benches, formed in material weathered from rhyolite, tuff, gneiss, and schist (Parlin-Lucky-Hopkins).

3. Deep to moderately deep, moderately sloping to steep soils on mountains, ridges, and mesas, mostly in the southern part of the area, formed in material derived from igneous rock (Vulcan-Wetterhorn-Ruby).

4. Shallow to moderately deep, moderately sloping to very steep soils on mountains, hills, and ridges in the southern part of the area, formed in materials derived mainly from fine-grained igneous rock (Posant-Woodhall-Stony Rock land).

5. Deep to moderately deep, strongly sloping to steep soils on alluvial fans, hills, ridges, and mountains in the western part of the area, formed in material derived from rhyolite and tuff (Shule-Youman-Pasar).

6. Deep, stony, strongly sloping to very steep soils and rockslides on mountain and alpine rimland in the extreme south-central part of the area, formed in stony colluvium derived from latite-basalt (Meredith-Rockslides).

Some properties of these major series are listed in Table 9.9. In general, the soils are medium textured and range from strongly acid to moderately alkaline. Subsoil permeabilities range from very slow to very rapid and are generally different from surface soil permeabilities. Water-holding capacities range from low to high. Most series have poor topsoil suitability because of poor drainage or the presence of stones, cobbles, and rocks.[14]

9.2.4.4 Chaffee-Lake Area, Colorado

The Chaffee-Lake area covers about 92,000 ha (227,000 acres) of Chaffee and Lake counties in central Colorado. It consists of narrow, high-mountain valleys of the Arkansas River, which flows from north to south through the central part of the area. A variety of soil parent material occurs in the area, including recent floodplain alluvium, recent deposits of fans and foot slopes, glacial till, and residuum from cystalline bedrock.[15]

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Table 9.8. Major Soils of the Alamosa County Area, Colorado[a,b]

Series Name	Parent Material	Depth to Seasonal High Water Table, m	Soil Depth, cm	Dominant Texture		Reaction, pH		Permeability, cm/hr		Salinity, mmhos/cm		Available Water Holding Capacity	Topsoil Suitability
				Surface	Sub-surface	Surface	Sub-surface	Surface	Sub-surface	Surface	Sub-surface		
Gunbarrel	Sandy alluvium	0.3-1.2	152	LCsC	S&C	7.9-10	7.9-10	15-51	>25	0-30	0-2	Very low to low	Poor
Mosca	Alluvium	0.6-c/	152	LS	SL,S&G	8.5-10	7.9-10	15-51	5->25	0-15	0-15	Low	Poor
San Luis	Alluvium	0.9-1.2	152	SL	CL,C, SCL,S	7.9-10	8.5-10	5-15	0.5->13	0-30	0-30	Low to high	Poor to fair
McGinty	Alluvium	0.6-c/	152	SL	--	7.4-8.4	--	5-15	--	0-4	--	Moderate	Poor to good
Alamosa	Alluvium	0.3-0.7	165	L	CL,L,S	7.9-9.0	7.4-9.0	1.5-5	0.5->25	0-15	0-15	Moderate to high	Poor to good
Vastine	Alluvium	0.3-0.7	152	CL,L,SCL	S&LS	7.4-8.4	7.4-8.4	0.5-5	15-51	0-4	0-4	Moderate	Fair
Alluvial land (loamy)	Loamy alluvium	0.4-0.9	152	L,CL	S	7.9-8.4	7.9-8.4	0.5-5	>25	0-8	0-2	Moderate to high	Fair to poor
San Arcacio	Alluvium	0.3-1.2	152	SL	SCL,S&G	7.9-8.4	7.4-9.0	5-15	1.5->25	0-30	0-30	Low	Poor to good
Acacio	Alluvium	0.7-c/	152	SL	CL,L	8.5-9.0	7.4-8.4	5-15	0.5-5	0-30	0-15	Moderate to high	Good to poor
Zinzer	Alluvium	0.6-c/	152	L,SL,SCL	--	7.9-8.4	--	1.5-5	--	0-30	--	High	Good to poor
Hooper	Sand	0.6-c/	152	LS,CL,C	CL,SL,S	9.0-10.5	9.0-10.5	5-15	<0.1->25	0-30	0-30	Low	Poor to unsuitable
Corlett	Dune sand	1.1-c/	152	S	--	9.1-10.5	--	>13	--	0-4	--	Low	Poor
Costilla	Alluvium	c/	152	LS,GLS	GS	7.9-9.0	7.9-9.5	15-51	15-51	0-2	0-2	Very low	Poor
Space City	Sand (igneous origin)	c/	152	LFS	LFS	7.9-8.4	8.5-10	15-51	15-51	0-2	4-8	Low	Poor
Uraca	Alluvium	c/	152	VCoL, VCoCL	VCoSL,CO, C,B	7.9-8.4	7.9-8.4	1.5-5	15->51	0-2	0-2	Very low	Poor
Mount Home	Alluvium	c/	152			7.4-8.4	--	5-15	--	0-2	--	Very low	Poor
Commodore	Acid ign. & met. rock	c/	38	VStL	Granite	6.1-6.5	--	1.5-5	--	0-1	--	Very low	Poor
Hapney	Alluvium	c/	152	CL,L	S	7.9-9.6	8.5-9.0	0.1-0.5	>25	0-4	0-2	Moderate	Poor
Cotopaxi	Eolia sand	c/	152	S	--	7.4-7.8	--	>13	--	0-2	--	Very low to low	Poor
Dune land	Eolian sand	c/	152	S	--	7.4-7.8	--	>25	--	0-2	--	Low	Poor
Alluvial land (sandy)	Sand	0.6-0.9	152	GSL	G&S	7.4-8.4	7.4-8.4	5-15	>25	0-2	0-2	Very low to low	Poor

[a]Modified from: J. P. Pannell et al., "Soil Survey of the Alamosa Area, Colorado," Soil Conservation Service, U.S. Dept. of Agriculture, in cooperation with the Colorado Agriculture Experiment Station, 1973.

[b]Definitions of symbols used are given in Table 9.1.

[c]No water table encountered to a depth of at least 1.5 m (5 ft).

Table 9.9. Major Soils of the Gunnison Area, Colorado[a,b]

Series Name	Parent Material	Depth to Bedrock, m	Texture Surface	Texture Subsurface	Reaction, pH Surface	Reaction, pH Subsurface	Permeability, cm/hr Surface	Permeability, cm/hr Subsurface	Available Water Holding Capacity	Topsoil Suitability
Evanston	Alluvium derived from sandstone, rhyolite, and tuff.	>1.5	L	CL, L	6.1-7.3	6.6-8.4	1.5-5	0.1-5	High	Fair (clay loam at 9").
Gas Creek	Cobbly alluvium from mixed sources.	>1.5	SL	VCoSL, VCoS	6.6-7.3	6.6-7.3	5-15	15-51	Low to moderate	Poor (poorly drained, cobblestones).
Irim	Recent alluvium of mixed origin.	>1.5	L	VGL	6.5-7.5	6.5-7.5	1.5-5	5-15	Low	Poor (poorly drained).
Parlin	Channery and gravelly sediment weathered from rhyolite and similar rocks.	1-1.5	ChL	ChCL, VStL	6.6-7.3	7.4-8.4	1.5-5	0.5-15	Moderate	Poor (30% stone fragments).
Lucky	Gravelly sediment derived from gneiss and schist.	0.4-1	GSL	GSCL	6.6-7.3	6.6-7.3	5-15	1.5-5	Low	Poor (15-20% gravel).
Hopkins	Channery material weathered from rhyolite and tuff.	>1.5	ChL	Rhyolitic flagstone	7.4-8.4	7.4-8.4	1.5-5	>51	Low	Poor (cobblestones).
Vulcan	Gravelly material weathered from rhyolite and rhyolitic tuff.	>1.5	GSL	VStGCL	6.1-6.5	5.6-6.5	15-51	0.1-5	Low	Poor (gravelly and stony).
Wetterhorn	Alluvium and colluvium derived from quartz latite or breccia.	0.4-1	StL	StCL	5.5-6.6	5.6-6.6	1.5-5	0.1-0.5	Low	Poor (stony).
Ruby	Gravelly material derived from rhyolite and rhyolitic tuff.	>1.5	GSL	GCL	6.1-7.0	6.1-7.0	5-15	0.5-1.5	Low	Poor (gravelly).
Posant	Quartz latite and breccia.	0.3-0.6	GL	VGCL	6.1-7.0	6.0-7.0	1.5-5	1.5-5	Low	Poor (very gravelly).
Woodhall	Stony and gravelly material weathered from rhyolitic tuff.	>1.5	GL	VStCL	6.1-7.3	6.1-7.3	1.5-5	0.1-0.5	Low	Poor (gravelly).
Stony rockland	Rhyolite, tuff, quartz latite, sandstone, granite, breccia, gneiss, and schist.	---	Too variable to estimate		Too variable to estimate		---	---	---	Poor (stony).
Shule	Material derived from rhyolite or rhyolitic tuff.	0.4-1	L	CL	6.1-7.3	6.1-7.0	1.5-5	0.1-0.5	Low	Good to 16".
Youcan	Alluvial sediment derived from rhyolite and rhyolitic tuff.	>1.5	L	HCL	6.1-7.3	6.1-7.3	1.5-5	0.1-0.5	High	Fair (clay loam at 12").
Passar	Stony alluvium derived from and tuff.	>1.5	L, CL	StC and CL	6.1-6.5	6.1-6.5	0.5-1.5	0.1-0.5	Moderate	Poor (extremely stony).
Meredith	Stony material derived from latite basalt.	>1.5	VStL	VStSiL	5.1-5.5	5.6-6.0	1.5-5	1.5-5	Low	Poor (very stony and gravelly, highly acid).
Rockslides	----------	---	Too variable to estimate		Too variable to estimate		---	---	---	Poor (stones and boulders).

[a]Modified from: W. R. Hunter and C. F. Spears, "Soil Survey of the Gunnison Area, Colorado," Soil Conservation Service, U.S. Dept. of Agriculture, in cooperation with the Colorado Agriculture Experiment Station, 1975.

[b]Definitions of symbols used are given in Table 9.1.

Temperature and precipitation vary widely with elevation, which ranges from about 2200 m (7100 ft) in the valley areas to more than 3600 m (12,000 ft) on some mountain peaks. At 3000 m (10,000 ft) the average annual precipitation is about 47 cm (18.5 inches). Vegetation is predominantly grasses at lower elevations and conifer forests at higher elevations; the transition is gradual, and intermediate areas contain both grass and timber.[15]

The soils of the Chaffee-Lake area can be grouped as follows (names in parentheses refer to associations):[15]

Soils of the mountains

1. Rock outcrops and sloping to steep, deep soils at elevations of 3000 to 4000 m (10,000 to 14,000 ft) formed in mixed outwash materials (Rock outcrop-Bross).

2. Gently sloping to steep, deep, gravelly soils at elevations of 2400 to 3000 m (8200 to 10,000 ft) formed in glacial outwash and glacial till (Troutwille-Leadville).

3. Rock outcrops and steep to very steep, very shallow soils at elevations of 2000 to 2500 m (7000 to 8500 ft) formed in material weathered from granite (Rock land-Rock outcrop).

Soils of the high terraces

1. Nearly level to steep, deep, well-drained, limy soils formed in gravelly alluvium and outwash material (St. Elmo-Manhattan).

2. Nearly level to steep, deep soils formed in gravelly outwash material (Dominson-San Isabel).

3. Nearly level to sloping, deep, well-drained soils formed in alluvium and windblown material (Cotopaxi-Ouray).

4. Nearly level to steep, deep, well-drained soils formed in glacial outwash and alluvium (Pierian-Poncha).

5. Moderately steep to steep, severely eroded sediments (Rough broken land-Badland).

Soils of the terraces and bottomlands

1. Nearly level and gently sloping, deep, poorly drained soils formed in gravelly alluvium (Wet alluvial land-Gas Creek).

2. Nearly level and gently sloping, deep, poorly drained soils subject to floods, and marshes (Newfork-Marsh-Rosane).

Some properties of these major series are listed in Table 9.10. Most of these soils are of coarse texture, and subsurface permeabilities are very rapid. Water-holding capacities are generally low, and although most of the soils are deep, they have poor topsoil suitability either because of poor drainage or the presence of rocks, stones, and cobbles.[15]

9.2.5 Colorado Plateau

Most of the soils of the Colorado Plateau are Entisols, Aridisols, and Mollisols. In this region, most of the Entisols have formed under cool to arid climates on recent erosional surfaces (map prefix E in Fig. 9.5). Most of the soils are neutral or calcareous, and a number may be salty, with conductivities of 2 mmhos/cm or greater. The sparse vegetation on these soils consists mainly of xerophytic shrubs and ephemeral grasses and forbs, occasionally including saltgrass. A suborder of Entisols (map symbol E6-2 in Fig. 9.5) occurs in the east-central area of the region under a wetter regime in which moisture is limited but is present when conditions are suitable for plant growth. These soils occur on steep slopes associated with badlands and have salinities less than 2 mmhos/cm.

Aridisols are light-colored soils that do not have water available to mesophytic plants for periods of three months or longer. Some Aridisols have one or more horizons formed as a result of movement and accumulation of salts, carbonates, or silicate clays; others show alteration of the parent material without noticeable accumulations. The Aridisols of this region (map prefix D) include soils that have a layer in which silicate clays, predominantly the 2:1 lattice type (e.g., montmorillonite), have accumulated. Large areas of Aridisols that have accumulations of soluble salts and carbonates instead of clay accumulations are found in the central and southern parts of the region (map symbols D5 and D6).

Table 9.10. Major Soils of the Chaffee-Lake Area, Colorado[a,b]

Series Name	Parent Material	Depth to Seasonal High Water Table, m	Soil Depth, cm	Texture: Surface	Texture: Subsurface	Reaction, pH: Surface	Reaction, pH: Subsurface	Permeability, cm/hr: Surface	Permeability, cm/hr: Subsurface	Available Water Holding Capacity	Topsoil Suitability
Rock outcrop	Granite, gneiss, schist	Too variable to estimate	---	---	---	---	---	---	---	---	Poor (exposed bedrock)
Bross	Mixed outwash	c	152	VCoSL	---	4.5-5.5	---	5-15	---	Moderate	Poor (cobblestones)
Troutville	Gravelly glacial till	c	152	GSL	SL, Co and G	6.1-7.3	6.1-7.3	5-15	5->51	Low	Poor (gravel and cobblestones)
Leadville	Glacial outwash	c	152	SL	SCL, CL	5.6-6.5	6.1-7.3	1.5-5	0.5-5	Moderate	Fair (high content of stones)
Rockland	Granite, gneiss, schist	Too variable to estimate	---	---	---	---	---	---	---	Low	Limited material
St. Elma	Calcareous outwash	c	152	GSL	GCOLS, G, Co, S	7.9-8.4	7.9-8.4	5-15	15->51	Low	Fair (high content of gravel)
Manhattan	Calcareous alluvium	c	152	SL	GSL, Co, G, S	6.6-7.8	7.9-8.4	5-15	5->51	Low	Fair (high content of gravel)
Dominion	Gravelly outwash	c	152	GSL	Co, G, S	6.6-7.8	6.6-7.8	5-15	>51	Low	Poor (high content of gravel)
San Isabel	Gravelly outwash	c	152	GSL	Co, G, S	6.6-7.3	---	5-20	>51	Low	Poor (stones, gravel and cobblestones)
Cotopaxi	Eolian sands	c	152	LFS	FS	6.8-8.4	7.9-9.0	5-15	15-51	Low	Poor (sandy)
Catay	Noncalcareous alluvium	c	152	SL	S	6.6-7.8	6.6-7.8	5-15	15-51	Low	Good
Plorian	Stony and cobbly outwash	c	152	GSL	B, Co, G, S	6.1-7.3	---	5-15	>51	Low	Poor (high content of gravel)
Poncha	Calcareous alluvium	1.5	152	GSL	Co, G, S	6.6-9.0	7.4-9.0	5-15	>51	Low	Poor (high content of gravel)
Rough broken land	Calcareous silt, clay, sand	Too variable to estimate	---	High erosion hazard -		---	---	---	---	---	---
Wet alluvial land	Mixed materials	Too variable to estimate	---	---	---	---	---	---	---	---	Poor (poorly drained)
Gas Creek	Gravelly material	0-0.3	152	GSL	Co, G, S	6.3-7.3	6.3-7.3	5-15	>51	Low	Poor (poorly drained & high content of gravel
Newfork	Gravelly alluvium	0-0.3	152	GSL	Co, G, S	6.3-7.3	---	15-51	>51	Low	Poor (poorly drained)
Marsh	Mixed material	0-0.1	Too variable to estimate			---	---	---	---	---	Poor (very poorly drained)
Rosane	Mixed alluvium	0-0.3	152	L, SL	G, Co, S	6.3-7.3	---	5-15	>51	Low	Poor (poorly drained)

[a]Modified from: L. A. Fletcher, "Soil Survey of the Chaffee Lake Area," Colorado Soil Conservation Service, U.S. Dept. of Agriculture, in cooperation with the Colorado Agriculture Experiment Station, 1975.

[b]Definitions of symbols used are given in Table 9.1.

[c]No water table was encountered to bedrock or to a depth of at least 1.5 meters (5 feet).

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SOILS

A3-2 Cryoboralf + Cryothods, Cryoborolls, Cryaquolls, and Rock land, steep

D2-1 Haplargids + Argiustolls, Ustorthents, and Calciustolls, gently sloping

E3-1 Torriorthents + Haplargids and Torrifluvents, gently or moderately sloping

E7-1 Xerorthents + Calciorthids, Haploxerolls, Argixerells, and Palexerolls, gently sloping to steep

D2-17 Haplargids and other Aridisols + Torriorthents and Rock land, gently or moderately sloping

D5-5 Calciorthids + Torriorthents (shallow), Camborthids and Rock land, gently or moderately sloping

D6-6 Camborthids + Torriorthents, Toripsamments, Calciorthids, and Badlands, gently or moderately sloping

E2-2 Torrifluvents + Torriorthents, Calciorthids, Haplargids, and Salorthids, gently or moderately sloping

E3-3 Torriorthents + Torriorthents (shallow), Camborthids and Badlands, gently or moderately sloping

E4-1 Torriorthents (shallow) + Haplargids and Badlands, moderately sloping or steep

E4-2 Torriorthents (shallow to soft bedrock) + Haplargids, Camborthids, and Rock land, moderately sloping or steep

E6-2 Ustorthents (shallow to soft bedrock) + Badlands, steep

M9-3 Argiustolls + Chromusterts, Rhodustalfs, Argiborolls and Torriorthents (shallow), gently sloping to steep

M9-5 Argiustolls + Haploborolls and Argiborolls, gently sloping to steep

M9-7 Argiustolls and Haplustolls, gently sloping to steep

M9-8 Argiustolls + Haplustolls, Chromusterts, Ustorthents, and Ustipsamments, gently or moderately sloping

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M9-14 Argiustolls + Paleustolls and Haploborolls, gently sloping to steep

M15-2 Argixerolls + Argiborolls and Haploxerolls, steep

M16-6 Haploxerolls + Camborthids and Calciorthids (shallow), moderately sloping or steep

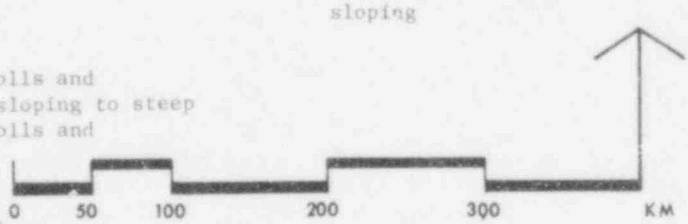

Fig. 9.5. Soils of the Colorado Plateau Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

A third major order of soils in this region, the Mollisols (map prefix M), usually have dark-colored surface layers that are relatively high in organic matter (greater than 0.6%) and contain a high portion of exchangeable calcium and magnesium. The Mollisols include soils that have a clay (argillic) horizon below a sandy or loamy surface layer. These are sometimes associated with clay soils of high bulk densities that develop deep wide cracks part of the year (Vertisols). Such associations (map symbol M9-8) occur along the southwestern portion of the region in Arizona.

Uranium resource counties selected for further discussion are Navajo in Arizona, Valencia in New Mexico, portions of Carbon, Emery, and San Juan in Utah, and portions of Mesa, Delta, and Montrose in Colorado.

9.2.5.1 Navajo County, Arizona

Navajo County occupies about 2,567,000 ha (6,343,000 acres) in the northeastern part of Arizona. Elevation ranges from about 1500 m (4800 ft) north of Winslow, to about 2500 m (8300 ft) on the Black Mesa. The county consists of slightly to strongly dissected high plains underlain predominantly by sandstone and shale. Annual precipitation ranges from about 20 cm (8 inches) near Winslow to 76 cm (30 inches) or more along the Mogollon Rim in the southern part of the county. Vegetation of the Black Mesa is generally pinyon pine and juniper, with an understory of brush and grasses. In the lower, drier sites the vegetation consists of sparse stands of brush and short grasses. Southward toward the Mogollon Rim, the vegetation consists of pinyon, juniper, brush, and grass. Ponderosa pine predominates at higher elevations. South of the rim on the Fort Apache Indian Reservation, the dominant vegetation consists of pinyon, juniper, shrubs, and grasses.[16]

The soils of Navajo County can be grouped into the following associations:[16]

1. Deep soils on floodplains (Tours-Navajo-Trail).
2. Shallow to very shallow soils and sandstones and shale rock outcrops on uplands (Moenkopie-Rock outcrop).
3. Deep soils and sandstone rock outcrop on uplands (Sheppard-Rock outcrop).
4. Sedimentary rock outcrop in the canyons and on the mesas (Rock outcrop).
5. Nearly barren shale uplands (Badland).
6. Deep soils on old alluvium on uplands (Palma-Clovis).
7. Very steep stony land and sedimentary rock outcrop on uplands (Rough broken and stony land-Rock outcrop).
8. Shallow soils on calcareous sedimentary rocks and rock outcrop on uplands (Winona-Rock outcrop).
9. Shallow soils on basalt and cinder uplands (Rudd-Bandera).
10. Moderately deep to deep soils on basalt uplands (Thunderbird-Springerville).
11. Very steep stony land and deep to shallow soils on sandstone uplands (Rough broken and stony land-Jacks-Dye).
12. Deep soils on old alluvium on uplands (Showlow).
13. Very shallow to moderately deep soils on sandstone uplands (Telephone-Elledge).
14. Deep to moderately deep soils on old alluvium and sandstone uplands (Overgaard-Elledge).
15. Moderately deep to deep soils and very steep stony land on basalt, ash, and cinder uplands (Sponseller-Ess-Rough broken and stony land).

Some details of these series are listed in Table 9.11.

In general, the soils of Navajo County are quite variable; they range widely in depth and are strongly acidic to moderately alkaline. Permeabilities range from very slow to rapid. Most are nonsaline, but many localized areas of saline soils occur. With few exceptions, however, the

Table 9.11. Major Soils of Navajo County, Arizona[a,b]

Series Name	Parent Material	Depth to Bedrock, cm	Dominant Surface Texture	Permeability, cm/hr	pH	Salinity	Topsoil Suitability
Tours	Alluvium	>152	SiL, SiCL	0.5-2	7.9-8.4	Some saline local areas	Fair; poor if saline
Navajo	Alluvium	>152	C, SiC	<0.1-0.5	7.9-8.4	Some saline local areas	Poor (clayey, may be saline)
Trail	Alluvium	>152	FSL, LFS	6-25	7.9-8.4	Non-saline	Fair (FSL); poor (LFS)
Moenkopie	Sandstone, shale	10-51	SL	6-13	7.9-8.4	Shaly areas may be saline	Poor (thin)
Sheppard	Sandstone	>152	LS, S	13-25	7.9-8.4	Non-saline	Poor
Rock outcrop	Sandstone, shale, limestone	0	---	---	---	---	---
Badland	Shales and siltstone	<25	---	---	---	Many areas saline	Poor (thin, shaly)
Palma	Loess, alluvium	>152	LFS, SL	6-13	7.9-8.4	Usually non-saline	Good
Clovis	Loess, alluvium	>152	SL, L	0.5-2	7.9-8.4	Non-saline	Good
Rough broken stony land	Properties too variable to estimate	0->152	---	---	---	Usually non-saline	Poor (steep, thin)
Winona	Limestone, sandstone	25-46	GL, CoL	2-6	7.9-8.4	Non-saline	Poor (Rock fragments)
Rudd	Basalt flows	15-51	GL, VGL	2-6	7.9-8.4	"	Poor (gravelly)
Bandera	Cinder cones	30-66	G(Ci)L	2-25	6.6-7.3	"	Poor (cindery)
Thunderbird	Basalt	51-101	GCL, CoCL	0.1-5	6.5-8.4	"	Poor (gravelly, cobbly)
Springerville	Basalt	76-178	CoCL, C	0.1-5	7.4-7.8	"	Poor (clayey, cobbly)
Jacks	Mainly sandstone	51-127	FSL, StFSL	0.1-5	6.6-8.4	"	Poor (rocks)
Dye	Mainly sandstone	25-51	FSL, StFSL	0.1-5	6.6-8.4	"	Poor (clayey, stony)
Showlow	Alluvium	>152	CL	1-5	6.6-8.4	"	Poor (gravelly)
Telephone	Sandstone	20-51	VCoSL	6-13	5.1-6.5	"	Poor (rock fragments)
Elledge	Sandstone	51-102	CoSL	0.1-5	5.6-7.3	"	Poor (gravelly, cobbly)
Overgaard	Alluvium, sandstone	>152	GL, CoL	0.1-5	5.6-7.3	"	Poor (gravelly, cobbly)
Sponseller	Basalt	76-152	GSiL, CoSiL	0.5-6	6.6-7.3	"	Poor (rock fragments)
Ess	Basalt	>152	VGSiL, CoSiL	2-6	6.1-7.3	"	Poor (rock fragments)

[a]Modified from: M. L. Richardson and M. L. Miller, "Report and Interpretations for the General Soil Map, Navajo County, Arizona," Soil Conservation Service, U.S. Dept. of Agriculture, in cooperation with the Navajo County Planning Commission and the Little Colorado Plateau Resource Conservation and Development Project, 1972.

[b]Definitions of symbols used are given in Table 9.1.

soils have poor topsoil suitability because of excessive amounts of gravel, cobbles, rock fragments, or cinders.[16]

9.2.5.2 Valencia County, New Mexico

Valencia County occupies a land area of about 1,465,000 ha (3,621,000 acres) in west-central New Mexico, extending from the Arizona state line on the west to the foothills of the Manzano Mountains on the east. Valleys range from nearly level to strongly sloping, but most are gently sloping. Interspersed throughout the area are moderately steep and rolling upland ridges and low hills. In the central part of the county south of Grants is a large lava flow area, consisting of basalt rock and stones, which is essentially barren of soils. The eastern part of the county includes the floodplain of the Rio Grande and extensive areas of gently to strongly sloping alluvial fans, piedmont slopes, and terraces. The average annual precipitation in Valencia County ranges from 18 to 25 cm (7 to 10 inches) below about 2100 m (7000 ft), and from 25 to 36 cm (10 to 14 inches) at higher elevations. Mountain peaks receive up to 64 cm (25 inches) or more. Most of the rainfall occurs in the summer.[17] Vegetation is mostly short and mid-grasses, with forests (including ponderosa pine, pinyon pine and spruce) at higher elevations.

The soils of the county can be grouped into 25 associations, eight of which account for about 66% of the soils, as follows:[17]

1. Soils on rough, broken topography with considerable variation in local relief. Outcrops of sandstone bedrock and some shale are common on the steep canyon walls and escarpments. Thin deposits of gravelly alluvium occur occasionally on the breaks adjacent to some of the larger drainages. Also soils on gently sloping to moderately steep and rolling upland areas and mesa tops, underlain by sandstone at shallow depths. Included are small areas of unclassified alluvial soils, deep, on nearly level to gently sloping topography (Rock land-Travessilla).

2. Soils formed dominantly in materials of volcanic or basic igneous origin on old lava flows, characteristically stony and cobbly. Soils are dominantly shallow to moderately deep (Prieta-Rock land-Thunderbird).

3. Shallow and moderately deep soils on upland ridges and mesa tops formed mainly in weathered sandstone, and deep soils in valley areas formed principally in alluvial and eolian sediments of mixed origin (Penistaja-Travessilla-Rock land).

4. Nearly level to strongly sloping and undulating soils formed mainly on alluvial sediments of mixed origin; generally deep, well drained, and moderately coarse to moderately fine-textured (Penistaja-Prewitt-Moriarty).

5. Soils on nearly level to strongly sloping [illegible] rolling topography, formed from weathered sandstone and shale, or alluvial [illegible] diments of similar origin (Little-Clovis-Travesilla).

6. Shallow to moderately deep soils on gently to strongly sloping and undulating on ridge crests and mesa tops to steep and very steep on mesa sides, escarpments, and breaks. Formed mainly in materials weathered from basic volcanic rocks, principally basalt, also ash, cinders, and eolian sediments of mixed origin. Outcrops of basalt rock are common (Rock land-Thunderbird).

7. Soils nearly level to strongly sloping in the valley areas to steep and very steep on mountain slopes, upland ridges and escarpments or breaks, formed mainly in material weathered from sedimentary rocks, including sandstone, shale, and siltstone. Soils are usually deep in the valley areas and moderately deep to deep on gentle slopes. Shallow to moderately deep soils and rock outcrops occur on strongly sloping to steep uplands (Osoridge-Jerkley-Rockland).

8. Soils on ger[illegible] ing to steep limestone ridges, hills, and mountain footslopes. Soils are u[illegible] llow, formed in materials weathered mainly from limestone (Laporte-Rock[illegible]

Some properties of individual series are listed in Table 9.12.

In general, these soils are medium textured, and can range from shallow to deep. Permeabilities are slow to moderate, and most of the soils have some limitation in terms of topsoil suitability, such as steep slope, poor drainage, saline and alkali spots, or stony surface layers.[17]

Table 9.12. Major Soils of Valencia County, New Mexico[a,b]

Series Name	Soil Depth, cm	Dominant Texture		Reaction	Permeability, cm/hr	Available Water Capacity	Topsoil Suitability
		Surface	Subsurface				
Rockland	Properties too variable to estimate						Poor
Travesilla	20-51	StSL, SL	St,SL, SL	Slightly calcareous	5-15	Very low	Poor (sandstone fragments)
Prieta	25-51	StL, StCL	CoC, StC	Noncalcareous	<0.5- 5	Low	Poor (stony)
Thunderbird	51-102	StCL, StL	CoC, StC	Noncalcareous	<0.5- 5	High	Poor (stony, clayey at 5-8")
Penistaja	152 or more	FSL, VFSL	SCL, CL	Noncalcareous	1.5-15	Moderate	Fair (sandy and erodible)
Prewitt	152 or more	L, SCL	SCL, CL	Calcareous	0.5- 5	High	Fair to good (8-10")
Moriarty	152 or more	C, SiC	C, SiC	Calcareous	<0.5	High	Poor (high clay)
Litle	51-102	SiCl, CL	SiC, C	Calcareous	<0.5-1.5	Moderate	Poor (clayey)
Clovis	51-102	FSL, L	SCL, C	Noncalcareous	1.5-15	Moderate	Fair (6-8")
Osoridge	51-91	StFSL, StL	C	Neutral	<0.5-15	Low to moderate	Poor (stony)
Jackley	51-76	SiL, StSiL, StL	SiL, SiCL	Neutral	0.5- 5	Low to moderate	Poor to fair (erodible, coarse fragments)
Laporte	20-51	StL, CoL, L	StL, StSCL	Weakly calcareous	1.5-15	Very low	Poor (cobbles and stones)

[a]Modified from: H. J. Maker, L. W. Hacker, and J. U. Anderson "Soil Associations and Land Classifications for Irrigation, Valencia County," New Mexico State University Agriculture Experiment Station in Cooperation with the Water Resources Research Institute and the Soil Conservation Service, Research Report no. 267, 1974.

[b]Definitions of symbols used are given in Table 9.1.

Other soils that occupy minor acreages in the county include soils contiguous to the Rio Grande, which are deep and well drained but have saline-alkali spots, soils on piedmont and valley slopes underlain at shallow depths by gravelly caliche, soils on valley bottoms and floodplains that are deep and have saline and alkali-affected areas because of inadequate drainage.[17]

9.2.5.3 Carbon-Emery Area, Utah

The Carbon-Emery area (Castle Valley) occupies about 193,000 ha (478,000 acres) in east-central Utah in the canyonland part of the Colorado Plateau. Elevation of the area ranges from about 1200 to 2000 m (4000 to 6500 ft). Most of the area consists of rolling hills, narrow valleys, mesalike remnants of old outwash plains, and steep, rough, broken land. The average annual precipitation is between 15 and 25 cm (6 and 10 inches), with the largest amount falling during August.[18] The natural vegetation of the area consists mainly of desert shrubs and some bunch grasses.

The soils of the area can be grouped into the following associations:[18]

1. Gently rolling and gently sloping to moderately steep, well-drained soils that are shallow and moderately deep over shale, on uplands (Chipeta-Killpack).

2. Nearly level to gently sloping, deep, well-drained to moderately well-drained soils on alluvial fans and floodplains and in alluvial valleys (Ravola-Billings-Penoyer).

3. Nearly level to gently sloping, deep to moderately deep, salty soils on bottomlands and foothills (Saltair-Libbings).

4. Gently sloping, deep, well-drained soils over gravel, on mesas, benches, and old alluvial fans (Sanpete-Minchey).

5. Gently sloping and gently rolling to steep, well-drained soils that are shallow over shale and eroding shale outcrops, on uplands (Chipeta-Persayo-Badland).

6. Gently sloping to very steep, shallow to deep gravelly and stony soils, and rockland, on benches and hills (Rock land-Shaly colluvial land-Castle Valley-Kenilworth).

Some properties of these major series are listed in Table 9.13.

Most of these soils have medium- to heavy-textured surface layers and permeabilities that range from slow to moderate. Salinities range from none to over 2% salt, which renders most of them poor in terms of topsoil suitability. Depth to water table varies from 0.1 m to over 2 m (0.3 to 6.5 ft).[18]

9.2.5.4 San Juan Area, San Juan County, Utah

The San Juan area occupies 142,000 ha (351,000 acres) north of the San Juan River in the east-central portion of San Juan County, which is in the southeastern corner of Utah. The area, deeply dissected by canyons, is on the Sage Plain, an extensive tableland. Elevations range from about 1800 to 2100 m (6000 to 7000 ft). Average annual precipitation ranges from about 33 cm (13 inches) at Blanding in the south to about 41 cm (16 inches) further north.[19] The vegetation in the southern part of the county consists of stands of juniper or pinyon and a sparse understory of grasses, forbs, and shrubs. Where moisture is more favorable to the north and east, vegetation is mainly grasses and forbs.

The soils of the area can be grouped as follows (names in parentheses refer to associations):[19]

Upland soils of dry subhumid regions

1. Deep and moderately deep soils in wind-deposited materials (Monticello-Northdale-Abajo-Hovenweep).

2. Deep and moderately deep soils in wind-deposited materials in areas that have low rainfall and are subject to damage by frost (Sorup-Hovenweep-Northdale-Monticello).

3. Deep to shallow soils on shale (Hovenweep-Lockerby-Ucolo-Menefee).

4. Cobbly soils (Abajo-Memefee-Pack-Scorup).

5. Shallow, very rocky soils (Montvale).

Table 9.13. Major Soils of the Carbon-Emery Area, Utah[a,b]

Series Name	Parent Material	Depth to Seasonal High Water Table, m	Depth to Bedrock, cm	Dominant Texture	Reaction, pH	Permeability cm/hr	Salinity, mmhos/cm[c]	Topsoil Suitability
Chipeta	Residuum from gypsum-bearing marine shale	1.8 or more	25 - 51	SiCl	7.4 - 8.0	<0.1 - 5	4 - >16	Poor
Killpack	Residuum from clayey marine shale	0.5 - >1.8	51 - 102	CL, L	7.7 - 8.0	0.5 - 2	4 - 16	Fair
Ravola	Alluvium from shale and sandstone	1.8 or more	152 or more	L	7.7 - 8.0	2 - 6	0 - 8	Fair
Billings	Alluvium from gypsum-bearing marine shale	0.5 - >1.8	152 or more	SiCL	7.6 - 8.6	0.1 - 5	4 - 8	Fair in surface layer
Penoyer	Alluvium from sandstone, limestone, and basic igneous rocks	1.8 or more	152 or more	L, SiCl	7.7 - 8.2	2 - 6	<2	Good
Saltair	Alluvium from marine shale and sandstone	0.1 - 1.5	152 or more	SiCL, SiL	8.3 - 8.9	0.1 - 0.5	2% salt	Not suitable
Libbings	Alluvium derived from shale	0.3 - 0.8	51 - 102	SiCl, C, SiC	8.2 - 8.9	0.1 - 0.5	2% salt	Not suitable
Sunpeta	Glacial outwash	1.8 or more	152 or more	GSCL	7.9 - 8.5	6 - 13	<2	Poor (gravel and cobbles)
Minchey	Glacial outwash	1.8 or more	152 or more	CL	7.9 - 8.3	2 - 6	<2	Fair to good
Persayo	Residuum weathered from shale	1.8 or more	15 - 51	L, SiCL	7.5 - 8.0	2 - 6	4 - >16	Poor
Castle Valley	Material from sandstone and interbedded shale	1.8 or more	25 - 51	VFSL	7.5 - 8.0	6 - 13	<2	Fair
Kenilworth	Calcareous stony alluvium	1.8 or more	152 or more	StSL	7.7 - 8.5	2 - 6	<2	Good
Badland	Shale and sandstone	Properties too variable to estimate			---	---	---	Not suitable
Rockland	Shale and sandstone	Properties too variable to estimate			---	---	---	Poor
Shaly Colluvial Land	Colluvium from shale	Properties too variable to estimate			---	---	---	Poor

[a]Modified from: J. L. Swenson et al., "Soil Survey of the Carbon-Emery Area, Utah," Soil Conservation Service, U.S. Dept. of Agriculture, in Cooperation with Utah Agriculture Experiment Station, 1970.

[b]Definitions of symbols used are given in Table 9.1.

[c]Unless otherwise indicated as percentage of salt.

Upland soils of semiarid regions

1. Deep soils in wind-deposited materials (Blanding).

2. Shallow, very rocky soils (Mellenthin).

3. Sandstone rockland.

Soils of drainageways in semiarid and dry subhumid regions

1. Deep soils of drainageways (Ackmen-Pack-Shay-Vega).

Some details of these major series are listed in Table 9.14. In general, these soils have medium surface textures, slow to moderate permeabilities, and are moderately susceptible to erosion by wind and water. They range from neutral to strongly alkaline and are generally nonsaline except for a few of substrata that can be strongly saline.[19]

9.2.5.5 Grand Junction Area, Colorado

The Grand Junction area includes approximately 49,000 ha (122,000 acres) near the western edge of Mesa County. In the southwest are deep canyons, a sharp escarpment (Book Cliffs) rises to the north and northeast, foot slopes of the Grand Mesa lie to the east, and rough, broken and steep hilly land lies to the south. Three general types of relief occurring in the area are (1) a recent alluvial plain, (2) older and higher-lying alluvial fans, terraces or mesas, and (3) rolling to steep land on terrace escarpments, high knobs, or remnants of former mesas. The climate of the area is classified as semidesert. The annual average precipitation is about 23 cm (9 inches), well distributed throughout the year but inadequate to support more than a scant growth of native grasses and shrubs.[20]

The soils of the area can be grouped as follows (series names are given in parentheses):[20]

1. Soils of the river floodplains (Green River).

2. Soils of recent alluvial fans and local stream floodplains (Genola, Naples, Ravola, Thoroughfare, Mayfield, Naples, Billings, Navajo).

3. Soils of the mesas (Fruita, Ravola, Redlands, Mack, Mesa, Hinman).

4. Soils of the shale uplands (Chipeta, Persayo).

5. Miscellaneous soils and land types (Chipeta, Persayo, Fruita, Ravola, Redlands, Thoroughfare, Riverwash, Rough broken land, Rough gullied land).

Some details of these series are listed in Table 9.15. With the exception of the Persayo and Chipeta series, derived from Mancos shale, all the soils have developed from alluvium. Most of the soils are deep and are mildly to strongly alkaline, with permeabilities ranging from very slow to rapid. About one-third of the Grand Junction area is occupied by soils affected by accumulations of salts, alkali, or both. These are mainly soils that have developed on the Mancos shale or on parent material that came mainly from the Mancos formation. Poor drainage is primarily responsible for most of the saline areas. The predominant salt in these soils is sodium sulfate, but calcium and magnesium are high in many of them.[20]

9.2.5.6 Delta-Montrose Area, Colorado

The Delta-Montrose area includes about 103,000 ha (255,000 acres) and extends from the south-central part of Delta County southward through Montrose County and into Ouray County in west-central Colorado. It is an intermountain valley [elevation 1500 to 2400 m (5000 to 8000 ft)] drained by the Uncompahgre and Gunnison rivers and their tributaries. The annual average precipitation is about 23 cm (9 inches).[21] The vegetation of the area is desert brush, primarily greasewood, rabbitbrush, and salt grass, with scattered cottonwoods bordering intermittent streams and washes.

The soils of the area can be grouped as follows (names in parentheses refer to associations):[21]

1. Deep, nearly level and gently sloping soils on mesas, high terraces, and old alluvial fans (Mesa-Orchard).

2. Moderately deep, nearly level soils derived from shale on uplands (Chacra-Menoken).

Table 9.14. Major Soils of the San Juan Area, Utah[a,b]

Series Name	Parent Material	Dominant Texture	Reaction, pH	Permeability, cm/hr	Salinity, mmhos/cm	Available Water Holding Capacity
Monticello	Sandstone loess	VFSL	6.7-8.1	1.5-5	0.3-0.5	High
Northdale	Loess, sandstone, shale	L	7.5-8.3	1.5-5	0.3-0.5	Moderate
Abajo	Loess	L, CoL, CoCL	7.1-8.2	0.1-0.5	0.3-0.6	High
Hovenweep	Loess	L	7.7-8.3	0.1-0.5	0.3-0.7	Moderate
Scorup	Alluvium	VFSL	7.9-8.8	1.5-5	0.7-12	Moderate
Lockerby	Mancos shale	SiCL	8.0-8.4	<0.1-0.5	0.6-15	Moderate
Ucolo	Alluvium	SiCL	8.2-8.4	<0.1-0.5	0.4-19	High
Menefee	Shale	--	7.7-7.8	0.1-0.5	0.5-7	Low
Pack	Alluvium	SiL, CoSiL	7.6	1.5-5	0.7-0.8	High
Montvale	Sandstone	VFSL	7.6-7.8	1.5-5	0.4-0.6	Low
Blanding	Loess	VFSL	7.7-8.3	1.5-5	0.4-1	High
Mellenthin	Sandstone	VRFSL	8.0-8.3	1.5-5	0.5-0.6	Low
Ackmen	Alluvium	SiL, L, SiCL	7.4-7.8	1.5-5	0.7-1.4	High
Shay	Alluvium	CL	7.6-7.9	<0.1	0.8-4	High
Vega	Alluvium	CL	7.5-7.9	0.1-0.5	1.6-12	High
Sandstone rockland	Sandstone	Properties not estimated			--	--

[a]Modified from: M. E. Olson, et al., "Soil Survey of the San Juan Area, Utah," Soil Conservation Service, U.S. Dept. of Agriculture, in cooperation with Utah Agriculture Experiment Station, Series 1945, No 3, 1962.

[b]Definitions of symbols used are given in Table 9.1.

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Table 9.15. Major Soils of the Grand Junction Area, Colorado[a,b]

Series Name	Parent Material	Soil Depth, cm	Permeability, cm/hr	Occurrence of Salt or Alkali
Green River	Alluvium, shale, sandstone	76-152	1.5-51	Occasional to considerable
Genola	Recent alluvium	51-152	1.5-5	None
Naples	Alluvium derived form sandstone and shale	76-152	1.5-51	None to occasional
Ravola	Mancos shale and sandy alluvium	76-152	1.5-5	Slight to strong
Thoroughfare	Alluvium from sandstone and ign. rocks	76-152	15-51	Occasional
Mayfield	Shale	51-152	1.5-5	None
Billings	Alluvium from Mancos shale	76-152	<0.1-0.5	Slightly to strongly saline
Navajo	Alluvium from shale, sandstone, granite	76-152	<0.1	Frequently strongly saline
Fruita	Alluvium from sandstone	51-152	1.5-5	None to occasional
Redlands	Alluvium form sandstone, shale, granite	76-152	1.5-5	With high water table
Mack	Old alluvial sediments	76-172	1.5-5	None
Mesa	Acid igneous alluvium	51-152	1.5-5	None to occasional
Hinman	Acid igneous alluvium	51-152	<0.1-0.5	Occasional
Chipeta	Mancos shale	0-51	---	Slightly to strongly saline
Persayo	Mancos shale	0-51	---	Small saline spots
Riverwash	Sand, gravel, cobblestones	Variable	---	None
Rough, broken land	Shale	0-25	---	Salts in Mancos shale
Rough, gullied land	Alluvium from Mancos shale	Variable	---	Generally saline

[a]Modified from: E. W. Knobel et al., "Soil Survey of the Grand Junction Area, Colorado," Soil Conservation Service, U.S. Dept. of Agriculture, in cooperation with the Colorado Agriculture Experiment Station, Series 1940, No. 19, 1955.

[b]Definitions of symbols used are given in Table 9.1.

3. Deep, gently sloping soils on alluvial fans and valley side slopes (Bostwick-Cerro).

4. Deep, nearly level and gently sloping, moderately well drained to poorly drained soils on floodplains (Colona-Salt Lake).

5. Deep, nearly level and very gently sloping soils on alluvial fans (Genola-Fruitland).

6. Deep, nearly level, somewhat poorly drained soils on floodplains and low terraces (Uncompahgre).

7. Deep, nearly level and gently sloping soils on alluvial fans, floodplains and terraces (Billings-Christianburg).

8. Shallow, nearly level, gently sloping and hilly soils derived from shale (Chipeta-Persayo).

9. Bare rock outcrop and shallow, rolling to steep soils on hills, ridges, and sides of mesas (Rock outcrop-Travessilla).

Some details of these major soil series are listed in Table 9.16.

In general, these soils have fine to medium surface textures, are mildly to moderately alkaline, and have slow to moderately rapid permeabilities. Salinities range from slight to severe, and most of the soils are highly susceptible to erosion. Most soils are relatively deep, but their suitability as topsoil is limited by salinity or other unfavorable properties.[21]

9.2.6 Texas Coastal Plains

The Texas Coastal Plains region does not have the soil variety characteristic of the other regions discussed here, in part because of the relatively uniform topography of the region. Also unlike most of the other regions, the Texas Coastal Plains region consists primarily of Alfisols and Vertisols in most areas.

Alfisols are moist soils formed usually in humid regions. They have grey- to brown-colored surface horizons, medium to high base status, and contain a horizon in which silicate clays have accumulated (argillic horizon). In this region, some of the Alfisols occur on relatively recent erosional surfaces and have relatively thin reddish to brownish surface soils that are sandy or loamy (map symbol A9 in Fig. 9.6). Others are found on older surfaces and typically may have a layer of calcium carbonate accumulation below the argillic horizon (map symbol A10).

Vertisols are characterized by clayey soils that have deep, wide cracks during part of the year and high bulk densities between the cracks. In the United States, the Vertisols consist mainly of montmorillonitic clays, but a few have mixed or kaolinitic clays. The Vertisols in the Texas Coastal Plains region are mapped as V3 and V4 in Figure 9.6. These soils are characterized by cracks that remain open for 90 cumulative days or more in most years, and open and close more than once each year. Some of them have a horizon of calcium carbonate accumulation and occur on gentle slopes. Others are predominantly grey or black in all subsurface layers and are mostly on level relief or in depressions.

A third major soil order, Entisol, occurs at the southeastern extreme of the region. These soils have poorly developed horizons and consist of well-sorted sands on sand dunes or sandy material. They have limited moisture, but moisture is present when conditions are suitable for plant growth (map symbol E13).

Jim Hogg County,* in the southern extreme of the uranium-resource region, was selected for further discussion. A number of other counties for which soil maps were available will be briefly reviewed.

9.2.6.1 Jim Hogg County, Texas

Jim Hogg County occupies about 297,000 ha (733,000 acres) in southern Texas. The topography in general is nearly level to gently sloping and gently undulating. The average annual precipitation is about 47 cm (18.5 inches), and long dry periods occur. The soils are seldom wet below the root zone and as a result, most of the soils have a horizon of calcium accumulation, except for sandy soils that have been leached. Grasses are the predominant vegetation.[22]

*This was the only county in the region for which a soil survey report was available.

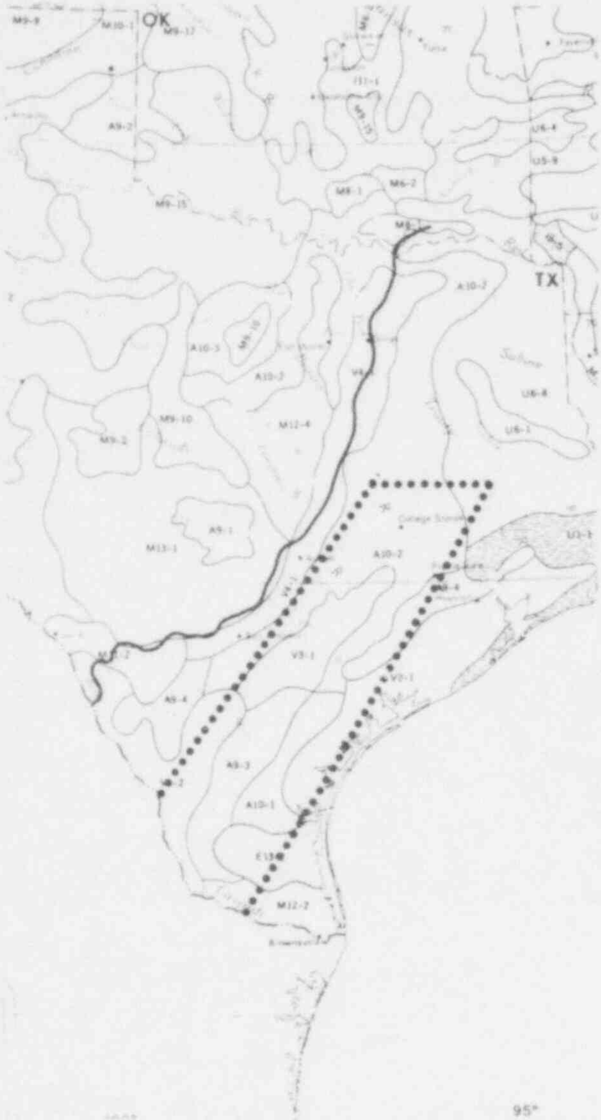
Table 9.16. Major Soils of the Delta-Montrose Area, Colorado[a,b]

Series Name	Parent Material	Soil Depth, cm	Dominant Texture Surface	Dominant Texture Subsurface	Reaction, pH	Permeability, cm/hr	Salinity, mmhos/cm	Available Water Holding Capacity	Topsoil Suitability
Mesa	Mixed alluvium	60	CL	GCL	7.4-7.8	2.5-10	2-4	Low	Fair to good
Orchard	Alluvium	60	CL	GCL	7.4-7.8	6-8	2-4	High	Fair
Chacra	Shale and siltstone	30	L	CL, L	7.4-7.8	2.5-5	2-4	High	Fair
Menoken	Shale and siltstone	26	C	--	7.9-8.4	1-2.5	2-4	High	Fair
Bostwick	Alluvium	60	GL, FSL	CL, L	7.4-7.8	0.8-2.5	2-4	High	Good to fair
Cerro	Glacial till	60	CL	StCL	7.4-7.8	1-4	2-4	High	Fair
Colona	Alluvium	60	C	SiC	7.4-7.8	0.2-1	8-16	High	Poor
Salt Lake	Alluvium	60	C	--	7.4-7.8	0.2-0.8	8-16	High	Poor
Cenola	Alluvium	60	CL	L	7.9-8.4	2.5-4	2-16	High	Fair to good
Fruitland	Alluvium	60	SL, SCL	FSL	7.4-7.8	6-8	2-4	Moderate	Good
Uncompahgre	Alluvium	60	CL, FSL, GL	L	7.9-8.4	5-8	4-8	Moderate	Fair
Billings	Alluvium	36-60	GCL, SiC, SiCL	SiCL, L	7.9-9.0	0.8-2.5	8-16	High	Poor to fair
Christianburg	Alluvium	60	SiC, SiCL	SiC	7.9-8.4	0.2-0.8	8-16	High	Poor
Chipeta	Shale	10	SiC	--	7.9-8.4	0.2-0.8	4-8	High	Poor
Persayo	Shale and siltstone	12	SiCL	--	7.9-8.4	0.8-1	4-8	High	Poor
Travesilla	Sandstone	8	FSL	--	7.9-8.4	8-11	2-4	Moderate	Poor
Rock outcrop	No estimates made	--	--	--	--	--	--	--	Unsuitable

[a]Modified from: A. J. Cline et al., "Soil Survey of the Delta-Montrose Area, Colorado," Soil Conservation Service, U.S. Dept. of Agriculture, in cooperation with the Colorado Agriculture Experiment Station, 1967.

[b]Definitions of symbols used are given in Table 9.i.

SOILS



A9-4 Haplustalfs + Palenstalfs, gently sloping
A9-3 Haplustalfs + Haplustolls and Calciustolls (shallow), gently sloping
A10-1 Paleustalfs + Argiustolls, gently sloping
A10-2 Paleustalfs + Haplustalfs, gently sloping
E13-2 Ustipsamments + Paleustalfs (sandy) gently or moderately sloping
M12-2 Haplustolls + Argiustolls and Haplustalfs, gently sloping
V3-1 Chromusterts + Paleustalfs, gently sloping
V4-2 Pellusterts + Camborthids and Torrerts, gently sloping
V2-1 Pelluderts + Pellusterts and Rendolls, gently sloping

TEXAS COASTAL PLAINS

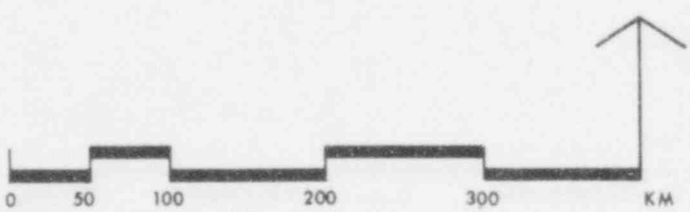


Fig. 9.6. Soils of the Texas Coastal Plains Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

The soils of the county can be grouped as follows (names in parentheses refer to associations):[22]

1. Nearly level to gently sloping and gently undulating moderately deep soils (Delmita).
2. Nearly level and gently undulating deep soils (Nueces-Sarita).
3. Nearly level to gently sloping and gently undulating deep soils (Falfurrias-Sarita).
4. Nearly level to gently sloping and gently undulating deep soils (Brennan-Hebbronville).
5. Nearly level to gently sloping deep soils (Copita-Brennan).
6. Nearly level to gently sloping and gently undulating, very shallow to shallow soils (Cuevitas-Randado-Zapata).
7. Nearly level to gently sloping and gently undulating deep soils (Comitas).

Some details of these major soils are listed in Table 9.17. Most of the soils have developed from calcareous, loamy sediments or sandy material. Surface textures are predominantly sandy, with moderate to rapid permeabilities, but the subsoils are often sandy clay loams which are less permeable. Extensive areas of some of these soils are underlain by an indurated or cemented layer of calcium carbonate (caliche). The soils are slightly acidic to moderately alkaline and with a few exceptions, have low available-water capacity. Most have poor to fair topsoil suitability.[22]

9.2.6.2 Other Texas Coastal Plains Counties

Northeastward from Jim Hogg County are, among other counties, Duval, Live Oak, Bee, Karnes, Fayette, Washington, and Burleson, in that order. (The uranium resource belt is centered in Karnes, Live Oak, Duval, and Webb Counties.[23]) In general, the soils of Duval, Live Oak, and Karnes are predominantly Alfisols. They are usually deep, well drained, and moderately permeable, with sandy to loamy surface textures and loamy to clayey subsoils. A number of them are underlain by a cemented caliche layer. In Karnes County, permeabilities are mostly very slow, surface soils are loamy, and subsoils are loamy or clayey. In Fayette and Washington counties, soils are deep, clays predominate, and in general the soils are very slowly permeable, with high shrink-swell potential typical of Vertisols. In Burleson County, the soils have more variable properties, and permeabilities range from very slow to very rapid. Brief descriptions of specific soil series in these counties can be found on county soils maps.[24]

9.3 REGIONAL OCCURRENCE OF SELENIUM, MOLYBDENUM, ARSENIC, AND VANADIUM

Selenium, molybdenum, arsenic, and vanadium can occur with uranium in the ore and overburden, and could be introduced in abnormal quantities into the biosphere during and after mining and milling. These elements can be toxic to plants and animals and can interfere with the successful reclamation of tailings disposal sites. The occurrence of these elements within uranium-resource regions is briefly discussed.

9.3.1 Selenium

Among the four elements of interest, selenium poses the greatest potential hazard. Selenium concentrations in basic and acidic igneous rocks in the earth's crust are on the order of 0.1 ppm, as indicated in Table 9.18.[25] Soils derived from these rocks generally contain about 0.01 ppm or less and normally do not support vegetation that is toxic to herbivores. Sedimentary rocks, on the other hand, contain more variable amounts of selenium, with shale usually containing the highest concentrations.[26] The selenium content of a number of sedimentary formations in the uranium resource regions is listed in Table 9.19.[27] Although not all selenium-bearing rocks give rise to seleniferous soils,* physical, chemical, climatic, and biological factors acting on such rocks can result in seleniferous soils. In the arid and semiarid seleniferous areas of the western United States, there is little soil transport or leaching of selenium; high evaporation rates and low percolation tend to redeposit water-soluble selenium on or near the surface. Seleniferous soils usually are alkaline and contain free calcium carbonate. Nonseleniferous soils are usually acidic (pH 4.5-6.5) and have a zone of accumulated iron and aluminum compounds.

The selenium content of some seleniferous soils in parts of the western United States are listed in Table 9.20. Considerable variation in selenium concentration can occur within a given soil profile, as indicated in Table 9.21. Similarly, uptake by vegetation is variable, as illustrated

*Soils that support vegetation containing selenium concentrations toxic to grazers.

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Table 9.17. Major Soils of Jim Hogg County, Texas[a,b]

Series Name	Parent Material	Depth to Bedrock, cm	Dominant Texture	Reaction, pH	Permeability, cm/hr[c]	Available Water Holding Capacity	Topsoil Suitability
Delmita	Loamy material	0.5-1	FSL[d]	6.6-7.3	5-16	Low	Poor
Nueces	Loess	>1.5	FS	6.1-7.3	16-51	Low	Poor
Sarita	Loess and alluvium	>1.5	FS	6.1-7.3	16-51	Low	Poor
Falfurrias	Eolian sands	>1.5	FS	6.6-7.3	16-51	Low	Poor
Brennan	Loamy, calcareous material	>1.5	FSL	6.6-7.3	5-16	High	Fair
Hebbronville	Loamy materials	>1.5	LFS	6.6-7.8	5-6	High	Poor
Copita	Loamy, calcareous material	>1.5	FSL	7.9-8.4	5-16	High	Fair
Cuevitas	Loamy material	0.2-0.4	FSL[d]	6.6-7.8	1.5-5	Low	Fair
Randado	Loamy material	0.2-0.5	FSL[e]	6.1-7.8	1.5-5	Low	Fair
Zapata	Loamy material	0.05-0.25	FSL, SCL[d]	7.9-8.4	1.5-5	Low	Poor
Comitas	Loamy and sandy materials	>1.5	LFS	6.1-7.3	5-16	Low	Poor

[a]Modified from: R. R. Sanders et al., "Soil Survey of Jim Hogg County, Texas," Soil Conservation Service, U.S. Dept. of Agriculture, in cooperation with the Texas Agriculture Experiment Station, 1974.

[b]Definitions of symbols used are given in Table 9.1.

[c]Values are for surface soils. Subsoils have somewhat lower permeabilities.

[d]Soil is underlain by indurated caliche.

[e]Soil is underlain by cemented caliche.

Table 9.18. Trace Element Concentrations (ppm) in Rocks and Soils[a]

Element	Earth's Crust	Basic Rocks	Acid Rocks	Sedimentary Rocks	Soils
B	3	1-2	3	100	10-20
F	700	100	1000	100-1000	20-1000
V	110	200	50	100	100
Cr	200	2000	2	100-500	200
Mn	1000	2000	1000	1000	1000
Fe	50,000	100,000	25,000	35,000	30,000
Co	23	50	8	20	3
Ni	80	200-1000	10	-	40
Cu	45	150	10	10-100	2-50
Zn	65	100	60	-	60
As	2	1.5	1.5	12	1.10
Se	0.09	0.1	0.1	-	0.01
Br	3	2.5	2.5	-	6
Mo	1	2	2.5	2	2.5
I	0.3	0.3	0.3	0.3	5
Ba	400	300	800	-	500
Pb	16	-	-	-	12

[a]Source: K. Norrish, "Geochemistry and Minerology of Trace Elements," in: Trace Elements in Soil-Plant-Animal Systems, D. J. D. Nicholas and A. R. Egan, editors, Academic Press, New York, 1975.

Table 9.19. Selenium Content of Some Sedimentary Formations in the Uranium Resource Regions[a]

Formation	Concentration, ppm	Location
Niobrara Shale	2.3-52.0	Wyoming, South Dakota
Dakota Sandstone	8-21	Albany County, Wyoming
Manning Canyon Shale	96.3	Utah
Carbonaceous shale	150	Albany County, Wyoming
Pierre Shale	≥2	Wyoming
Carbonaceous marine shales	<1-675	Western U.S.
Bear River Lignite	2-7	Western Wyoming
Fort Union Lignite	3	Northeastern Wyoming
Tuffaceous sedimentary rocks	12.5-187	Fremont County, Wyoming
Impure bentonite in:		
Bear River Formation	5	Wyoming
Pierre Shale	22	Nebraska
Phosphate rock in the Phosphoria Formation	1-212	Western Wyoming
Sandstones in Medicine Bow Formation	14-112	(not specified)
Browns Park Formation	112	Carbon County, Wyoming
Sandstones	0.2-46	New Mexico
Limy sandstone in Chugwater Formation	2-10	Albany County, Wyoming
Limestones in Phosphoria and Frontier Formations	0.1-12	Wyoming, Utah
Vanadium-uranium ores in		
Phosphoria Formation	580	Wyoming
Morrison Formation	≤2630	
(not specified)	526-1995	Near Thompson, Utah
Carbonaceous ore	2630	(not specified)
Carnotite	810	(not specified)
Limonitic concretions in		
Niobrara Formation	23-548	(not specified)
Medicine Bow	57	(not specified)
Jarosite in		
Thermopolis Shale	3	Big Horn Basin
Pierre Shale	10	Wyoming
Phosphoria Formation	18	Western Wyoming
Pyritic concretions in		
Niobrara Formation	≤548	(not specified)

[a]Compiled from I. Rosenfeld and O. A. Beth, "Selenium," Academic Press, New York, 1964.

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Table 9.20. Selenium Concentration in Some Seleniferous Soils[a]

Soils	Concentration, ppm	Location
Soils derived from Niobrara Shale	22	Eastern Wyoming
600 soil samples	0-44	South Dakota
Soils from the Mobridge member of Pierre Shale	(not specified) Toxic vegetation	South Dakota
500 soil samples	1-80	Western U.S.
10 soil samples	Trace - 6.4	Albany, Carbon, Campbell, and Natrona in Wyoming

[a]Compiled from I. Rosenfeld and O. A. Beath, "Selenium," Academic Press, New York, 1969.

Table 9.21. Selenium in Soil Profiles[a]

Location	Soil Source	Soil Depth, cm	Total Se, ppm	Water-Soluble Se ppm	Water-Soluble Se %
Wyoming					
Shirley Basin	Niobrara Shale	0-30	9.5	0.4	4.2
		30-60	26.0	1.0	3.8
		60-90	37.0	1.8	4.9
Laramie	Niobrara Shale	0-30	3.7	0.5	13.5
		30-60	4.0	0.3	7.5
		60-90	3.8	0.5	13.2
Laramie	Alluvium (on Niobrara Shale)	0-15	6.0	0.8	13.3
		15-45	14.0	2.2	15.7
		45-60	28.0	11.0	39.3
		60-100	21.0	6.4	40.0
Utah					
Cisco	Mancos Shale	0-30	5.6	0.7	12.5
		30-60	4.4	0.5	11.4
		60-90	4.0	0.2	5.0
Thompson	Alluvium (on Morrison Fm.)	0-30	35.0	9.1	26.0
		30-60	82.0	41.4	50.5
		60-90	40.0	25.0	62.5
		90-120	90.0	14.8	16.4

[a]Modified from I. Rosenfeld and O. A. Beath, "Selenium," Academic Press, New York, 1964.

in Table 9.22, and depends in large part on the chemical form of selenium in the soil. Seleniferous areas often can be identified by the occurrence of the so-called selenium "indicator" plants,* e.g., some species of *Astragalus, Stanleya, Oonopsis,* and *Xylorhiza*. The selenium content of these plants, as found on several formations within the subject regions,[27] are indicated in Table 9.23.

Table 9.22. Uptake of Selenium by *Astragalus bisulcatus* from Alluvium[a,b]

Location	Concentration, ppm Plants	Concentration, ppm Soils	Depth, cm
Wyoming			
Albany County			
Sec. 5, T. 16 N., R. 74 W.	57	3.2	30
		6.4	60
Sec. 26, T. 22 N., R. 77 W.	560	0.5	30
		Trace	60
Sec. 15, T. 19 N., R. 75 W.	187	-	-
Sec. 11, T. 17 N., R. 76 W.	1364	-	-
Sec. 15, T. 15 N., R. 74 W.	2640	5.1	30
		5.0	60
Carbon County			
Sec. 2, T. 22 N., R. 79 W.	37	1.4	30
		1.6	60
Campbell County			
Rozet-Gillette area	94	1.5	30
		1.7	60
Natrona County			
Casper-Bishop area	180	-	-

[a]The alluvium was derived by transport from all available rock sources. *Astragalus bisulcatus* is a selenium accumulator plant species.

[b]Modified from I. Rosenfeld and O. A. Beath, "Selenium," Academic Press, New York, 1964.

9.3.2 Molybdenum

Significant amounts of molybdenum is associated with some of the bedded sandstone uranium deposits in Arizona, Wyoming, South Dakota, New Mexico, Utah, and the Gulf Coast region of Texas and with a number of lignitic sandstone beds in southwestern North Dakota, northwestern South Dakota, and northeastern Utah.[28]

The concentration of molybdenum in soils is on the order of 2.5 ppm (see Table 9.18); in inorganic form, it is usually associated with iron oxides, probably adsorbed as molybdate ions. Molybdenum becomes increasingly available to plants with increasing soil pH. Content in vegetation is normally from less than 0.1 to more than 3 ppm. Chronic molybdenum toxicity in ruminants is associated with molbydenum concentrations from 20 to 100 mg/kg in the diet.[29]

Kubota[30] has described the distribution of molybdenum in soils and plants of the United States and cited an occurrence of molybdenosis in cattle attributed to molybdenum in surface-exposed uranium ore in Texas. Crystallized molybdenum on the surface of overburden piles at a uranium mine in Karnes County, Texas, has been described by Kallus[23] and is probably the same case referred to by Kubota.

*Defined as plants which can accumulate selenium to levels 100 to 10,000 times greater than the levels in most other native and crop plants. Sometimes referred to as selenium accumulators.

Table 9.23. Selenium Content of Indicator Plants[a]

Period	Formation	Concentration, ppm[b]		
		Minimum	Maximum	Average
Tertiary and Quaternary	Verde	197	2002	1270
Tertiary	Ogallala	118	2362	1258
	Arikaree	58	530	185
	Chadron	134	--	72
	Bridger	192	3320	1392
	Wasatch	77	2310	725
	Fort Union	93	3683	711
Cretaceous	Lance	151	1890	693
	Mesaverde	154	543	320
	Pierre-Benton	53	4474	716
	Judith River	53	1195	316
	Pierre	157	2849	744
	Steele	62	4450	953
	Mancos	68	1999	504
	Colorado	51	1815	366
	Niobrara	199	3939	689
	Benton	74	640	279
	Carlile	86	519	299
	Greenhorn	100	640	275
Jurassic	Morrison	63	3360	557
	Sundance	84	1612	667
	Kayenta	126	864	402
Triassic	Chinle	79	914	425
	Moenkopi	142	3060	713
Permian	Phosphoria	199	904	440
	Rico-Cutler	139	313	226
	Cutler	96	233	165
Carboniferous	Hermosa	142	171	157
	Paradox	--	--	364
	"Amsden"	--	--	177

[a]From I. Rosenfeld and O. A. Beath, "Selenium," Academic Press, New York, 1964.

[b]Parts per million is on a dry weight basis.

9.3.3 Arsenic

Observed arsenic contents of rocks and soils are given in Table 9.18. Arsenic is present in rocks as arsenide in sulfides; upon weathering to form soils, the arsenic is oxidized to arsenate, AsO_4^{-3}, likely associated with iron oxides.[25] The arsenic contents of topsoil and overburden in samples taken from a uranium mine in Fremont County, Wyoming, were 0.5 ppm.[31]

Most plants do not contain more than 1 ppm arsenic; according to Berry and Wallace,[32] arsenic apparently becomes toxic to plant roots before the tops can accumulate substantial amounts. However, some plant species are relatively tolerant of arsenic and can accumulate up to 10 ppm. Concentrations of 3.4 ppm arsenic can be toxic to sheep.[32]

9.3.4 Vanadium

The vanadium content of rocks and soils is indicated in Table 9.18. In the uranium resource regions, vanadium usually occurs in sandstone deposits associated with uranium in coffinite and uraninite. Carnotite is the principal secondary vanadium-uranium mineral. These minerals mainly fill the sandstone pores, but also can replace the sand grains and plant fossils.[33] Vanadium in soils is generally correlated with iron in soils. One area of Fremont County, Wyoming, contains 20 to 40 ppm vanadium.[31]

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10. TERRESTRIAL BIOTA

10.1 GENERAL ASPECTS

The present distribution of vegetation in the uranium resource regions has resulted from interactions of climate, time, soils, landform, and human activity. In turn, vegetation community types are naturally associated with certain species of animals. In some cases, the distribution and abundance of these animals have been markedly affected by human actions. Natural vegetation that is expected to exist in a given geographic region in the absence of the human factor and after a sufficient length of time has been termed the "potential natural vegetation" of that region,[1] and the terrestrial biota of the uranium resource regions are described in this document on the basis of the regions' potential natural vegetation. A map of the corresponding vegetation communities accompanies each description. There is no attempt to be taxonomically exhaustive or inclusive. In particular, descriptions of invertebrate species, reptiles, and amphibians are neglected. Detailed species enumeration is considered more appropriate to individual environmental impact statements that address site-specific characteristics. The descriptions that follow are intended only to provide an overview of the major vegetation communities and the mammals and birds commonly associated with them. Lists of terrestrial animals and plants designated by the Federal Government as rare, threatened, or endangered are given in Appendices A (animals) and B (plants).

10.2 THE SIX REGIONS

10.2.1 Northern Rocky Mountains

The natural vegetation of the Northern Rocky Mountains region consists primarily of western ponderosa pine forest, Douglas fir forest, cedar-hemlock pine forest, and mountain grasslands (see Fig. 10.1).

The western ponderosa pine ecosystem has a wide range of adaptability and can occur on semiarid low mountains and foothills, as well as at moderate elevations. The forest stands are open and have a ground cover of grasses, sedges, and forbs. Herbage production under the open stands of timber (500 saplings/ha, or 200 saplings/acre) is 560 to 670 kg/ha (500 to 600 lb/acre);* however, in more dense stands of timber (over 4900 saplings/ha or 2000 saplings/acre), herbage production is at most 280 kg/ha (250 lb/acre).**[2] Common understory species include Idaho fescue, bluebunch wheatgrass, needle-and-thread, and Sandberg bluegrass. Shrubs include rose and hawthorn. The larger mammals of this ecosystem include the Rocky Mountain elk, mule deer, mountain lion, and coyote. Smaller animals include the bushy-tailed wood rat, white-footed mouse, bobcat, cottontail rabbit, squirrels, and chipmunks. The most abundant resident birds include the pygmy nuthatch, sharp-shinned hawk, Rocky Mountain nuthatch, mountain chickadee, Cassin's purple finch, red-shafted flicker, western red-tailed hawk, and red-backed junco.[2]

The Douglas fir ecosystem consists of 50% or more of Douglas fir, with an understory that includes maple, blueberry, snowberry, rose, blackberry, and western hemlock. Where the area has been clear cut and seeded to pasture, production of grass can reach 1100 to 3400 kg/ha (1000 to 3000 lb/acre).[2] Representative large mammals include elk, deer, black bear, grizzly bear, moose, mountain lion, and bobcat. Smaller mammals include mice, squirrels, chipmunks, and the bushy-tailed wood rat. Commonly observed birds include the chestnut-backed chickadee, redbreasted nuthatch, gray jay, and Steller's jay.[2]

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*All herbage production figures in this section are given in terms of weight of dried material.

**Dense stands of timber occur as a result of logging; the stands are "growth retarded," i.e., growth rings are 20-40 per inch, instead of 15 or fewer rings per inch. The quality of herbage for livestock and game is improved by thinning of these dense stands--the nondigestible fraction of forage decreases, and carbohydrate fraction increases (Ref. 2).

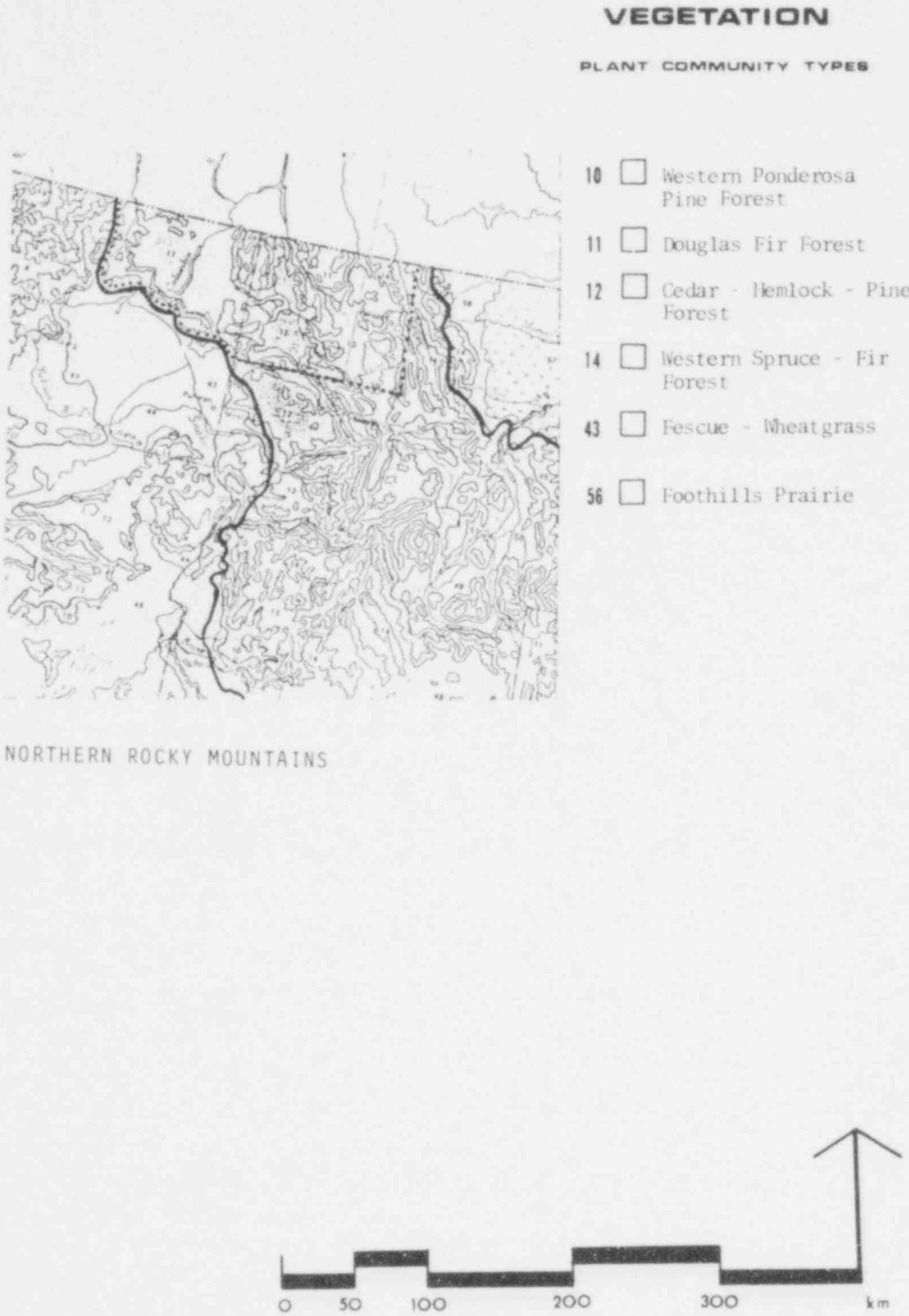

Fig. 10.1. Plant Community Types of the Northern Rocky Mountains Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

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Adjacent to Douglas fir and ponderosa pine forests along the extreme western boundary of the region is fescue-wheatgrass grassland. A foothills prairie is located in the southeastern portion of the region. Productivity of these mountain grasslands depends on precipitation and ranges from 2500-3400 kg/ha (2250 to 3000 lb/acre) to 0-840 kg/ha (0-750 lb/acre).[2] In the foothill grasslands, antelope and mule deer are winter visitors; at medium to high elevations the grasslands seasonally support Rocky Mountain elk and mule deer. Predators at the high elevations are the bobcat, black bear, and coyote. Representative birds include robin, horned lark, marsh hawks, sparrow hawks, and golden eagles.[2]

Other forest vegetation communities occur at elevations above that of the Douglas fir, and include the arborvitae-hemlock zone, spruce-fir forest, and the alpine zone.

10.2.2 Western Great Plains

The major ecosystems of the Western Great Plains region are delineated in Figure 10.2. The northern half of the region is predominantly a wheatgrass-needlegrass ecosystem, and the southern half is primarily grama-buffalo grass. A large expanse of Nebraska Sand Hills prairie occurs in the east-central portion.

The wheatgrass-needlegrass community of the western Dakotas is a moderately dense, short to tall, gently to moderately rolling grassland dominated by western wheatgrass, blue grama, needle-and-thread, and green needlegrass. Forbs and woody plants are sparse. Herbage production ranges up to 1700 kg/ha (1500 lb/acre), 70% of which is forage.[2]

The grama-buffalo grass communities are short, fairly dense grasslands dominated by blue grama. Associated dominants are western wheatgrass, needle-and-thread, and buffalo grass. Herbage production ranges to 1100 kg/ha (1000 lb/acre), 60% of which is forage.[2]

The Nebraska Sand Hills prairie is a medium-tall grassland dominated by big bluestem, sand bluestem, and prairie sandreed. Herbage production averages 2800 kg/ha (2500 lb/acre), 70% of which is forage.[2]

Other communities occupy smaller areas in the region. The floodplain ecosystem consists of the cottonwood-hardwood tree type along larger river bottoms and the greasewood-grass type along terraces and floodplains of the major rivers. This system plays a role in animal migration routes and is greatly affected by adjacent ecosystems through runoff and erosion. In turn, the floodplain ecosystem stabilizes riverbanks, provides animal cover, and maintains water quality.

The badlands ecosystem occurs along river and stream breaks and isolated buttes and slopes. The vegetation is complex and consists of at least seven distinct plant communities.[3] These communities are sensitive to disturbance, and revegetation through natural succession requires decades.

The short-grass prairie of eastern Montana and northeastern Wyoming is the driest grassland ecosystem of the region. The dominant grass is blue grama, and the subdominant, on clayey soil, is western wheatgrass. Bison were once the dominant mammalian herbivore, but now, domestic cattle and antelope are dominant. During periods of extended drought, the boundaries of the system expand north and east into the mid-grass prairie ecosystem.[4]

The mid-short-grass prairie ecosystem in eastern Montana or the mixed-grass prairie differs from the short-grass prairie in that western wheatgrass, needle-and-thread, and green needlegrass are dominant or codominant with the shorter blue grama. On clay soils western wheatgrass is dominant, and in wetter silty soils needlegrass is dominant. The antelope is the most abundant native mammal herbivore. This ecosystem is replaced to some extent by the short-grass prairie following dry years, heavy grazing, or other disturbances.

The grassland-sagebrush ecosystem in southeastern Montana and northeastern Wyoming is dry and supports scattered sagebrush and short-and mid-grass prairie species as dominants. While most plants in this ecosystem are shallow-rooted, the bulk of the plant biomass is produced in the roots. This ecosystem is sensitive to droughts, which occur, frequently. This triggers grasshopper plagues that have devastating impacts on wildlife populations.[5]

The sagebrush steppe ecosystem within the northern Wyoming and southeastern Montana area is dominated by big sagebrush. The larger animals are antelope, jackrabbit, and sage grouse.

The ponderosa pine forest ecosystem in eastern Montana, western North and South Dakota, northeastern Wyoming, and western Nebraska consists of dense to open stands of ponderosa pine with a shrub layer beneath the pine and a grass-forb strata close to the soil surface. It is located primarily on the crests of hills and ridges where uplands break into drainageways. The vegetation provides cover and nesting habitat for some animals that could not otherwise exist on the

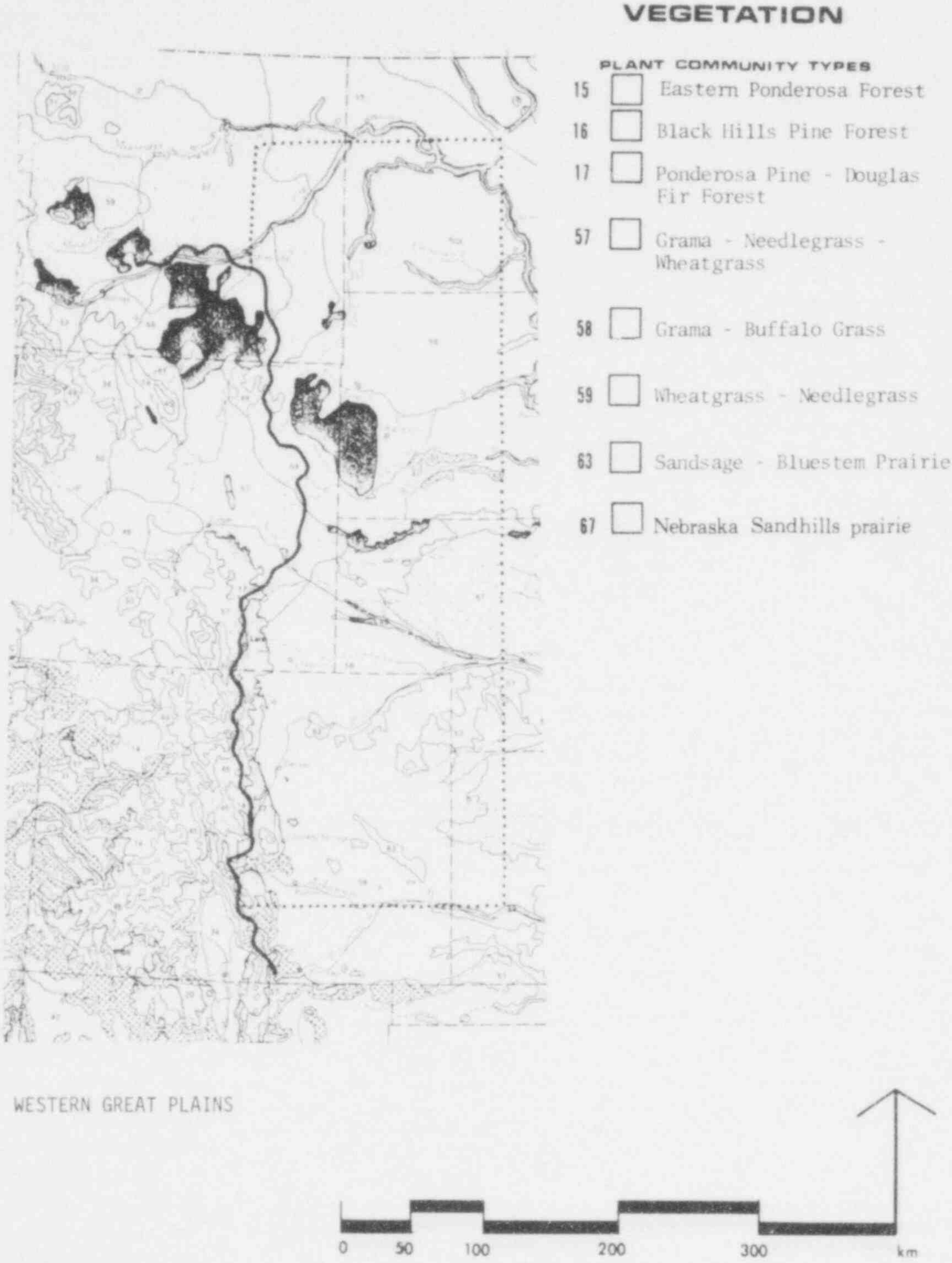

Fig. 10.2. Plant Community Types of the Western Great Plains Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

Western Great Plains. Ponderosa pine is at the northeastern extreme of its range, and its ecosystem is susceptible to overuse and excess runoff. Restriction of grazing at the edges of the ecosystem permits it to expand; dryness permits the grasslands to invade the ponderosa pine ecosystem.

The Black Hills ponderosa pine ecosystem is in the Black Hills of western South Dakota and eastern Wyoming. This ecosystem supports a diverse mammalian fauna.[6] Deer, in particular, are prevalent; in 1968 there were more than 120,000 white-tailed and mule deer in the Black Hills deer herd.[7]

The ponderosa pine-Douglas fir ecosystem occurs in the southern portions of the Laramie Mountains. Species commonly occurring in the understory are pinegrass, Idaho fescue, and bluebrush wheatgrass. The mammalian fauna include deer and bear.

The fauna commonly associated with the major plant communities of the region are listed in Table 10.1.

Table 10.1. Characteristic Animal Species of Major Plant Communities in the Western Great Plains Region[a]

Short-Grass Prairie	Mid-Short-Grass Prairie	Grassland-Sagebrush
Antelope	Antelope	Antelope
Whitetailed jackrabbit	Whitetailed jackrabbit	Sage grouse
Blacktailed prairie dog	Mule deer	Jackrabbit
Pale striped ground squirrel	Coyote	Badger
Badland meadow mouse	Prairie dog	Vesper sparrow
Burrowing owl	Burrowing owl	Hawk
Marsh hawk	Marsh hawk	Coyote
Western meadow lark	Western meadow lark	Red fox
Horned lark	Badger	Skunk
Baird's sparrow	Red fox	White-footed mouse
Common badger	Black-footed ferret	
Northern coyote	Pocket gopher	Ponderosa Pine
Northern red fox		Mule deer
Black-footed ferret	Sagebrush-Steppe	Raccoon
Pocket gopher	Antelope	Red fox
	Jackrabbit	Coyote
Floodplain	Sage grouse	Northern chipmunk
Mule deer	Badger	Plains skunk
Golden eagle	Grasshopper mouse	White-footed mouse
Red-tailed hawk	Western meadowlark	Red-tailed hawk
Prairie falcon	Vagrant shrew	Bobcat
Prairie rattlesnake	Cottontail rabbit	Long-tailed weasel
Short-horned lizard	Chipmunk	Golden eagle
Jack rabbit	Pocket gopher	Woodpecker
Wyoming cottontail	Kangaroo rat	Robin
Red fox	Deer mouse	
Northern coyote	Sagebrush vole	Badlands
Badger	Coyote	Beaver
Skunk	Red fox	White-tailed deer
Ground squirrel	Bobcat	Mule deer
Prairie dog		Raccoon
Weasel		Red-tailed hawk
White-footed mouse		Mink
		Magpie
		Garter snake
		Long-tailed weasel
		Spotted skunk
		Striped skunk
		Red fox
		Coyote

[a] Compiled from G. A. Garrison et al., "Vegetation and Environmental Features of Forest and Range Ecosystems," Agriculture Handbook, No. 475, U.S. Forest Service, Dept. of Agriculture, 1977; and S. C. Kendeigh, "Ecology with Special Reference to Animals and Man," Prentice Hall, Inc., New Jersey, 1974.

10.2.3 Wyoming Basin

The most abundant vegetational types in the Wyoming Basin region are sagebrush and grasslands. Plant communities dominated by these vegetation types occur mainly at elevations from 1200 to 2200 m (4000 to 7000 ft).[8,9] The central and southern portions of the region support sagebrush communities, and the northeastern portion is predominantly short-grass plains (see Fig. 10.3). In general, the uranium resources in the region are overlain by these two types of vegetation. Forest communities, primarily Douglas fir and ponderosa pine, occur at elevations above about 2000 m (6000 ft), but are uncommon in the region.

The sagebrush ecosystem is dominated by shrubs, principally sagebrush, with such grasses as crested wheatgrass, fescue, bluegrass and bromegrass in the understory.[2] Productivity of this ecosystem depends on the amount of annual precipitation. Herbage production can range from 1700 to 2200 kg/ha (1500 to 2000 lb/acre) where rainfall is over 30 cm (12 inches) per year, to 0 to 550 kg/ha (0 to 500 lb/acre) where rainfall is less than 25 cm (10 inches) per year. In the latter areas, the sagebrush is shorter and more scattered. Dominant species include black sagebrush and low sagebrush.[2]

Mammals of the sagebrush ecosystem include pronghorn antelope, which use this rangeland throughout the year, mule deer, which use the sagebrush range only during the winter, prairie dogs, Great Basin coyotes, black-tailed jackrabbits, pygmy cottontails, Ord's kangaroo rats, and Great Basin kangaroo rats. Bird populations are low during the breeding season, averaging about 25 pair per 100 acres (60 pair/100 ha).[2] Major bird species include the marsh hawk, red-tailed hawk, Swainson's hawk, golden eagle, bald eagle, Cooper's hawk, prairie falcon, burrowing owl, long-eared owl, sage grouse, and chukar.

The grassland portion of the region consists of mid- and short-grass communities; the eastern plains and foothills support needlegrass, bluestem, buffalo grass, and blue grama.[8] The central portion of the region supports short-grass communities dominated by blue grama, bluegrass, junegrass, needlegrass, and crested wheat-grass. Areas with alkali soils support extensive stands of greasewood, saltbush, and alkali spikegrass. Riparian communities are vegetated largely by willows and cottonwoods. Herbage production ranges from 1700 to 2200 kg/ha (1500 to 2000 lb/acre) to 0-550 kg/ha (0-500 lb/acre).

Mammals of the grasslands ecosystem include the pronghorn antelope, mule deer, white-tailed deer, jackrabbit, and desert cottontail. Small rodents, such as prairie dogs, are preyed upon by coyote, the black-footed ferret, and other mammalian and avian predators.[2] Bird populations include the lesser prairie chicken, sage grouse, greater prairie chicken, sharptailed grouse, horned lark, lark bunting, and western meadowlark.[2]

10.2.4 Southern Rocky Mountains

Six major vegetation zones occur in the Southern Rocky Mountains region (see Fig. 10.4). From lowest to highest altitudes these zones are: (1) oak-mountain mahogany, (2) pinyon-juniper, (3) ponderosa pine, (4) Douglas fir, (5) Engelmann spruce-subalpine fir, and (6) alpine. The oak-mountain mahogany and pinyon-juniper zones generally occur in the foothill regions at elevations between 1500 to 2100 m (5000-7000 ft). Valleys in the foothills often contain deep soil and support a variety of grasses, including western wheatgrass, blue grama, and needle-and-thread grass. The dominant vegetation of the foothills north of Denver is mountain mahogany. South of Denver a variety of oaks forms the dominant vegetation. The most common oak species in many areas is gambel oak.

The pinyon-juniper vegetation zone is widespread in southern and western Colorado. Communities within this zone vary from dense stands of trees to open savannas. Although the ground cover is relatively sparse, grasses are generally present in openings between the trees. The pinyon-juniper zone in southern Colorado is often interspersed with stands of oak, sagebrush, and ponderosa pine.

The ponderosa pine zone occurs from 1800 to 2600 m (6000 to 8500 ft).[10] The dominant plant species of this zone is ponderosa pine. Oaks and pinyon-juniper stands are intermixed with ponderosa pines at the lower edges of the forest. At higher elevations, ponderosa pine form dense stands. Douglas fir is found on north-facing slopes and is intermixed with the pines at still higher elevations.[10]

Douglas fir occurs as a distinct community immediately below the subalpine zone. On moist sites, white fir and blue spruce occur as secondary components of the community. Stands of pine are supported on dry exposed ridges within the upper montane and subalpine zones. Fires in the Douglas fir community result in the establishment of quaking aspen stands on moist sites and lodgepole pine on dry sites.[11]

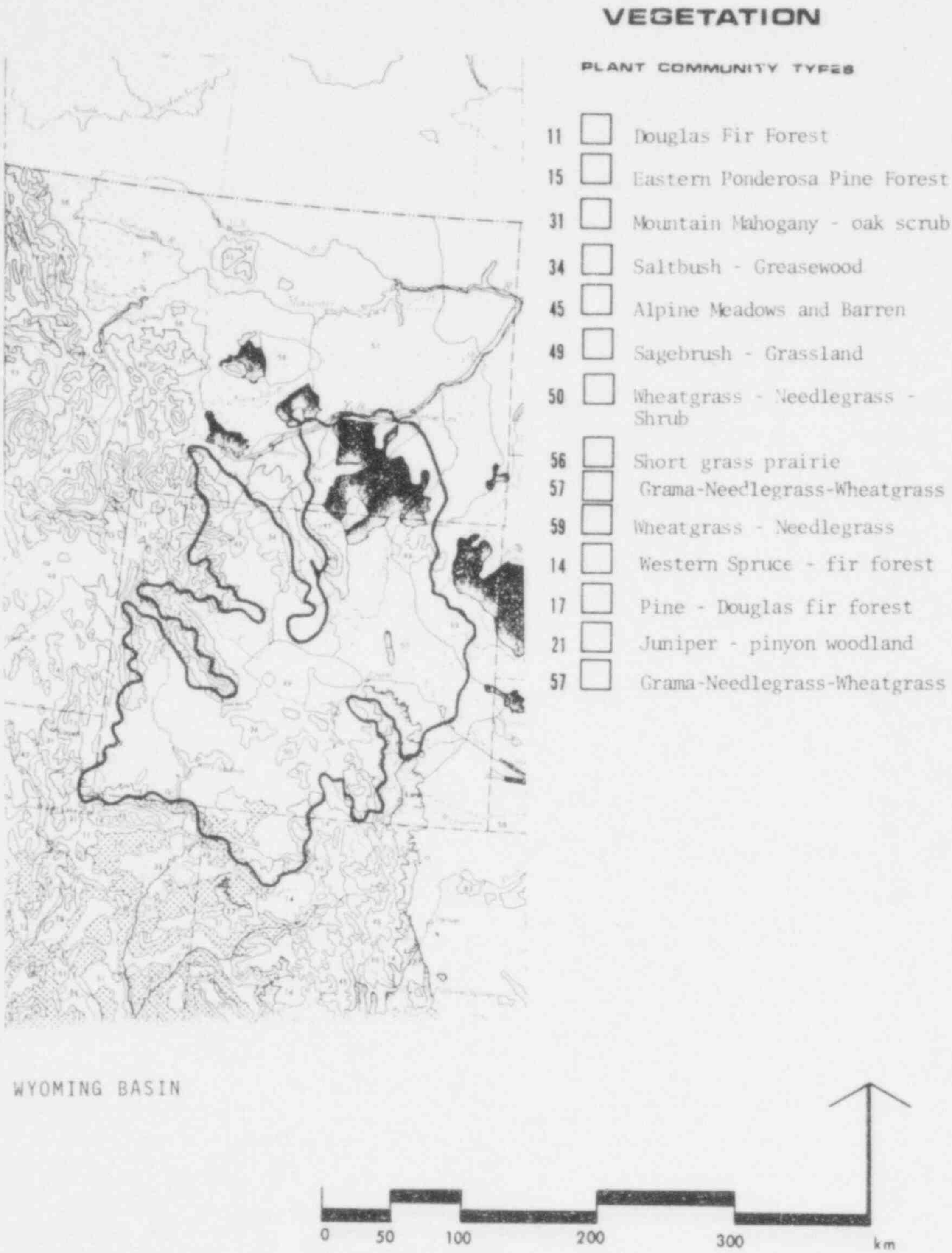

Fig. 10.3. Plant Community Types of the Wyoming Basin Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

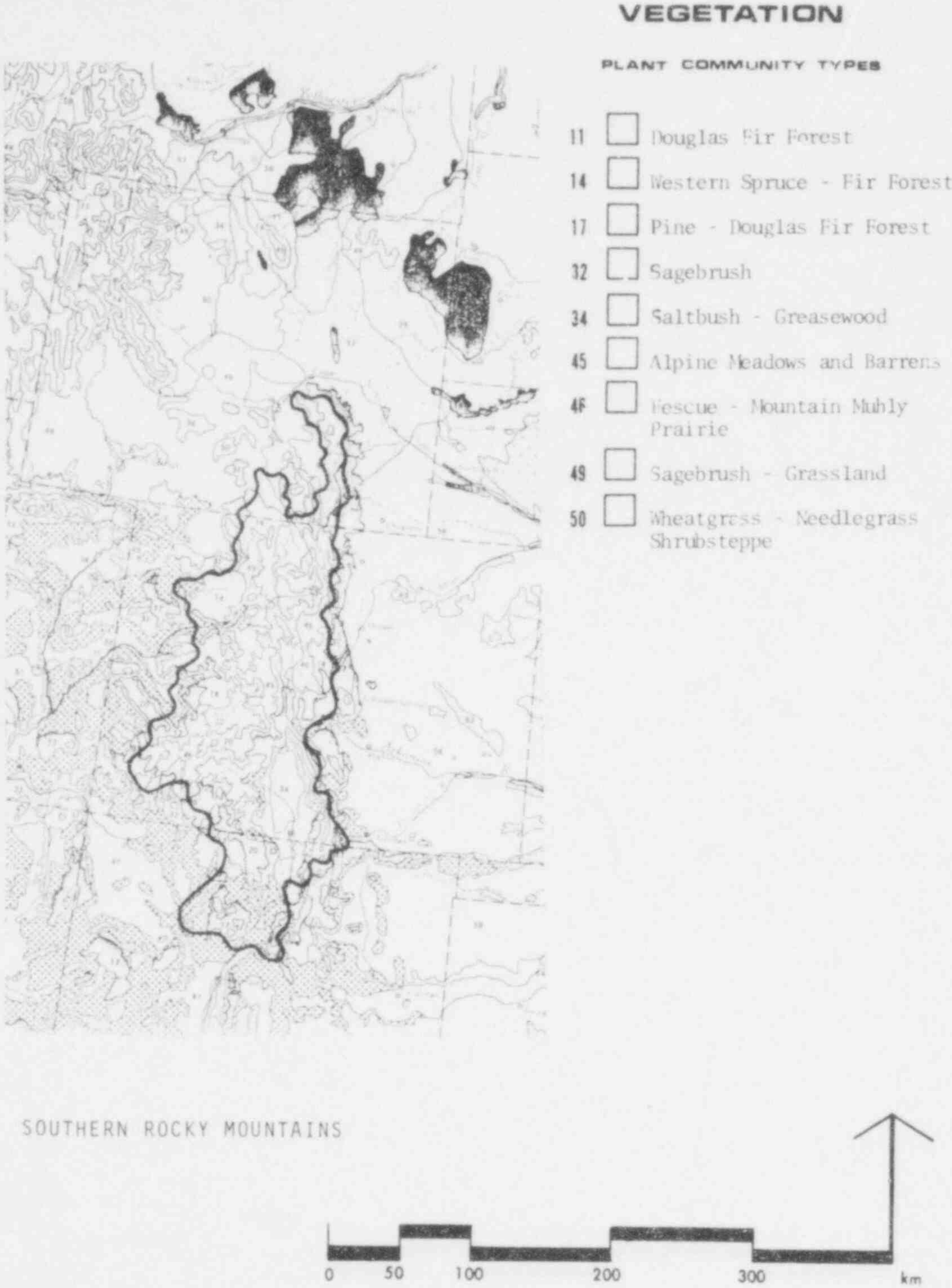

Fig. 10.4. Plant Community Types of the Southern Rocky Mountains Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

Englemann spruce and alpine fir form dense stands in the subalpine zone within about 600 m (2000 ft) below timberline.[11] Englemann spruce is more common, larger, and longer-lived than alpine fir. Blueberry dominates the sparse ground cover on the dry eastern slopes. Ground cover on the more moist western slopes is comprised of a variety of herbs and bryophytes. Near the upper limits of the subalpine zone the forest is less dense and trees are dwarfed and distorted. Bristlecone pine occurs at the timberline in southern regions of the Rocky Mountains, and limber pine is more common in the central portions.[11]

The alpine zone generally occurs above 3500 m (11,500 ft) in Colorado. This zone is covered predominantly by a variety of grasses and sedges, with several species of willow growing as prostrate forms.[10] Plant community type and species composion are affected by duration of spring snow cover, slope stability, and soil moisture.

A diverse fauna exists in the foothills zone because of the transition from open woodlands of ponderosa pine to a more closed coniferous forest lacking understory species at higher elevations. Thrushes, warblers, and finches occupy the woodland and pine savanna areas.[12,13] Small mammals, such as chipmunks and golden mantle ground squirrels, are also found in these areas.[13] Larger mammals include elk and mule deer. The mule deer is the most important large mammal, both from a recreational standpoint and as an influence on vegetation (through browsing).[12] This is particularly true during the fall and winter, when the deer inhabit the pinyon-juniper woodlands. The mule deer spend the spring and summer in the mountain forests and meadows.[12]

Bird species of the upper montane forests include kinglets and Audubon warblers; pipits and rosy finches inhabit the alpine zone. Pika and yellow-bellied marmot are characteristic mammals of the upper montane zone. Bighorn sheep, the only large herbivore of the upper montane zones, are increasingly abundant in mountainous areas west of Fort Collins.

10.2.5 Colorado Plateau

The natural vegetation of the Colorado Plateau region is delineated in Figure 10.5. Juniper-pinyon woodland occurs throughout the region on mountains and rims of the plateau below elevations of about 2500 m (8200 ft). Grama-galleta steppe vegetation and Great Basin sagebrush occur at lower elevations in the southern portion of the region. To the north there are large communities of saltbush-greasewood. Pine and Douglas fir occur at elevations of 2300 to 2900 m (7500 to 9500 ft), above the pinyon-juniper woodlands, and spruce and fir occur at elevations of 2900 to 3300 m (9500 to 11,500 ft).

Pinyon-juniper woodlands form stands of about 1000 trees/ha (400/acre). The understory consists primarily of big sagebrush, western wheatgrass, blue bunch wheatgrass, blue grama, and Indian rice grass and comprises about 3% of the total ground cover.[14] Herbage production varies from 700 to 900 kg/ha (600 to 800 lb/acre) on deeper soils, and from 0-225 kg/ha (0 to 200 lb/acre) on drier, shallower soils.[2]

The grama-gelleta steppe vegetation includes woody plants, such as Mormon tea, and succulents. Herbage production ranges from 550 to 850 kg/ha (500 to 750 lb/acre).[2] Greasewood, saltgrass, and pickleweed are dominant on more moist areas of the saltbush-greasewood community. Herbage production varies from 550 to 850 kg/ha (500 to 750 lb/acre). Blackbrush or shadscale, greasewood and saltbush, with saltgrass, winter fat, and bud sagebrush are dominant on drier sites. Herbage production is about 300 to 550 kg/ha (250 to 500 lb/acre).[2]

Animal species of the juniper-pinyon, sagebrush and saltbush-greasewood communities are listed in Table 10.2. The predominant vertebrates of areas of the saltbush-greasewood community with only 10% ground cover are lizards during the day and small rodents at night.[12] Principal game animals in the Colorado Plateau region are mule deer, elk, moose, big-horn sheep, antelope, sage grouse, turkey, and waterfowl. American bison are present at two locations in Arizona, and there are small herds in southern Utah.[15] A small portion of the central United States migratory bird flyway crosses central Utah, eastern Colorado, and eastern New Mexico.[12]

10.2.6 Texas Coastal Plains

The vegetation of the Texas Coastal Plains region generally consists of forest, prairie, savanna, and shrub. The forests and prairies occur within the northern half of the region and the savannas and shrub land within the southern half. The arbitrarily designated boundaries of the region encompass the western-most reaches of the southeastern oak-hickory-pine forest, the southern-most extremities of the central prairie and oak-hickory forest, the western-most extent of the gulf coastal prairie, and the eastern-most encroachment of the southwestern savannas.

Of the eight natural vegetation types occurring within the region, four overlie areas of uranium mineralization in southern Texas.[16] The majority of these uranium-rich areas are beneath the

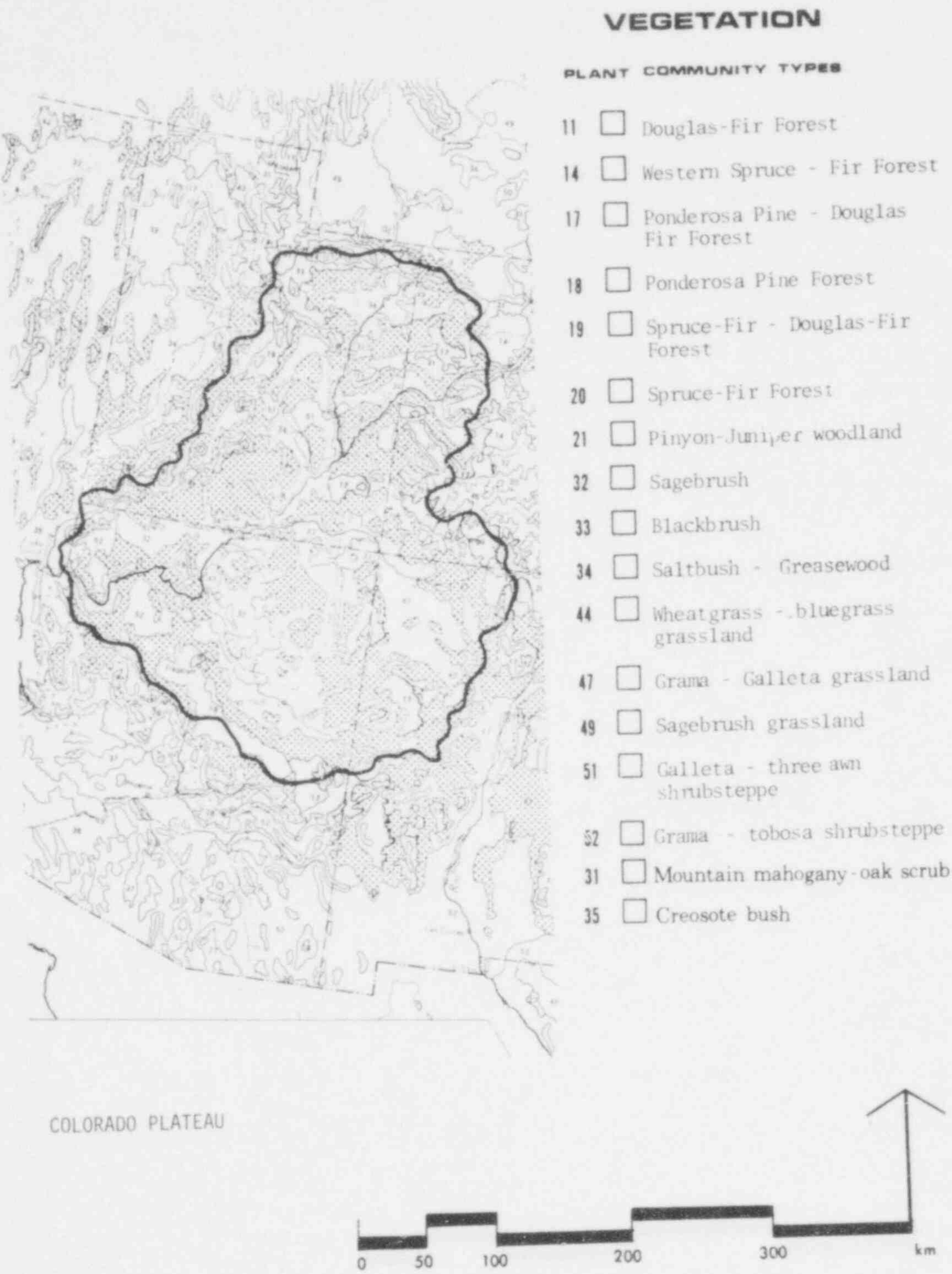

Fig. 10.5. Plant Community Types of the Colorado Plateau Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

Table 10.2. Characteristic Animal Species of Major Plant Communities in the Colorado Plateau[a]

Pinyon-Juniper Community		
Northern grasshopper mouse	Vagrant shrew	Red tailed hawk
Western harvest mouse	Dusky shrew	Mountain quail
Pinon mouse	Little brown bat	Mourning dove
Deer mouse	Long eared myotis	Raven
Canyon mouse	Silver-haired bat	Pinon jay
Bushy-tail woodrat	Hoary bat	Collard lizard
Long-tail vole	Western big eared bat	Common king snake
Porcupine	Mexican free tailed bat	Western rattlesnake
Mountain cottontail	Shorttail weasel	Golden mantle squirrel
Jackrabbits	Striped skunk	Cliff chipmunk
Bighorn sheep	Badger	Least chipmunk
Deer	Red fox	Great basin pocket mouse
Turkey vulture	Coyote	Ord kangaroo rat
Sparrow hawk	Bobcat	
Golden eagle		
Great Basin Sagebrush and Saltbush-Greasewood Communities		
Great basin kangaroo rat	Merriam shrew	Catbird
Western harvest mouse	Big brown bat	Spotted towhee
Deer mouse	Western big-eared bat	Lark sparrow
Sagebrush vole	Mexican free-tailed bat	Sage sparrow
Desert cottontail	Shorttail weasel	Short-horned lizard
Jackrabbits	Longtail weasel	Western fence lizard
Pronghorn antelope	Spotted skunk	Common whipsnake
Mule deer	Striped skunk	Common king snake
Bighorn sheep	Badger	Western rattlesnake
Turkey vulture	Gray fox	Desert toad
Sparrow hawk	Kit fox	Tiger salamander
Golden eagle	Coyote	Ord kangaroo rat
Red-tailed hawk	Bobcat	
Sage hen	Ground squirrels	
Sharp-tailed grouse	Whitetail prairiedog	
Great-horned owl	Least chipmunk	
Burrowing owl	Desert woodrat	
Raven	Merriam kangaroo rat	

[a]Modified from C. Yocum, V. Brown, and A. Starbuck, "Wildlife of the Intermountain West," Naturegraph Co., San Martin, California, 1958.

mesquite-acacia savanna that occupies much of the southern half of the region. Other areas of uranium mineralization have been found within the bounds of the Fayette prairie, the oak-hickory forest, and the ceniza shrub zone (see Fig. 10.6).

Beginning at the northern end of the region and proceeding southward, the following vegetative community types occur:

Oak-hickory-pine forest
Found only in the northeastern corner of the region, this "medium tall to tall forest of broadleaf deciduous and needleleaf evergreen trees"[17] is dominated by white oak, post oak, various species of hickory, shortleaf pine, and loblolly pine.

Oak-hickory forest
Occupying the north-central portion of the region and projecting as two fingers into the prairie and savanna, this "medium tall to tall broadleaf deciduous forest"[17] merges with the oak-hickory-pine forest on its eastern edge and either changes to post oak-blackjack oak savanna or alternates with tall-grass prairie along its southern and western edges.[18] Dominant species are white oak, red oak, black oak, bitternut hickory, and shagbark hickory.

Fayette prairie
The east-central section of the region contains a medium-tall, rather dense, grassland interspersed with open groves of broadleaf deciduous trees of the oak-hickory vegetation type. This

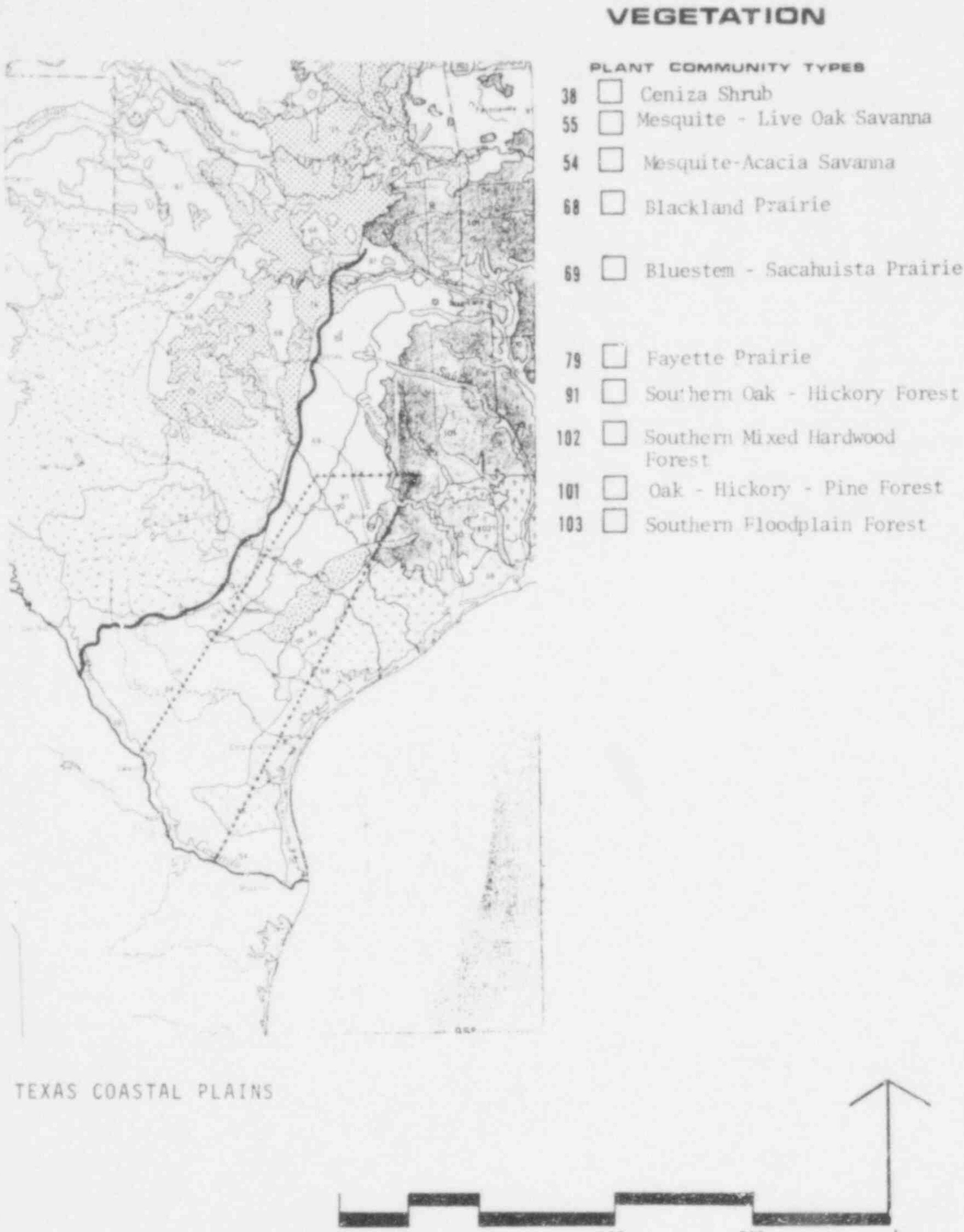

Fig. 10.6. Plant Community Types of the Texas Coastal Plains Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

system borders the north-south attenuated Fayette prairie on both its eastern and western edges. The dominant grasses are little bluestem and buffalo grass.

Bluestem-sacahuista prairie
Occuring along the extreme eastern border of the northern half of the region, this "medium-tall to tall, dense to open, grassland" is dominated by seacoast bluestem and coastal sacahuista.

Mesquite-acacia savanna
The bulk of the southern half of the region supports "dense to open grassland with broadleaf deciduous low trees and shrubs scattered singly and in groves."[17] Dominant species are mesquite, blackbrush acacia, seacoast bluestem, and plains bristle grass. Heavy grazing has allowed the encroachment of various species of brush and cacti, but desirable grasses still persist under the protection afforded by these invaders.[19]

Mesquite-live oak savanna
The southeastern corner of the region can be characterized as rather open, medium-tall grass, dominated by seacoast bluestem, with low to medium-tall broadleaf evergreen trees, dominated by sand live oak, and low broadleaf deciduous trees and shrubs, dominated by mesquite scattered singly or in groves.

Ceniza shrub
Occupying the Rio Grande valley and bluffs along the extreme southern boundary of the region are "open to dense stands of broadleaf deciduous and evergreen shrubs with a patchy synusia grass."[17] Ceniza, creosote bush, and mesquite are the dominant species.

The Texas Coastal Plains uranium milling region includes range extremes for many species of mammals, birds, reptiles, and amphibians.[20,21] The southern-most extremities of prairie and hardwood savanna support the southern-most populations of vertebrate species which inhabit grasslands. They also form a boundary for the northern reaches of habitat suitable for wildlife adapted to the more arid conditions of the southwestern United States and Mexico.

The transition zone between oak-hickory-pine forest and oak-hickory forest forms the boundary between the ranges of many southeastern and southwestern species. The westernmost populations of many southeastern species occur within the oak-hickory-pine forest zone within the region, and the easternmost populations of many southwestern species occur within the oak-hickory forest and prairie interspersed with hardwood groves. The great diversity of wildlife within the region is due to the major north-south and east-west climatic and vegetational transitions that occur within this artificially delineated area.

Wildlife species inhabiting grasslands within the Texas Coastal Plains region include mourning doves, bobwhite quail (in forest edge areas) various sparrows, mockingbirds, bullsnakes, whiptail lizards, eastern cottontail rabbits, and white-tailed deer. Bobwhite, white-tailed deer, eastern cottontail, and mourning doves are important game species. Overgrazing and agriculture have reduced available wildlife habitat over much of the region.

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11. AQUATIC BIOTA

11.1 GENERAL ASPECTS

Aquatic biota are characterized for the rivers selected for discussion in Chapter 7. Detailed lists of species are not given; instead, biota are characterized by giving the general species composition of the selected rivers. A list of the federally designated endangered and threatened species of fish is given in Appendix C. Each state also may classify species as endangered on a statewide basis, and such species may or may not be included on the Federal list.

11.2 THE SIX REGIONS

11.2.1 Northern Rocky Mountains

The surface water in the Northern Rocky Mountains region comes primarily from snowmelt, and maximum discharge is usually in the late spring. Flooding is common in the narrow, steep-sided valleys of these drainages. Biological production tends to be limited by the low mineral content and by the specific conductance (averaging less than 100 μmhos/cm)[1] of most of the rivers.

Primary production in the Pend Oreille River is low and is provided primarily by periphytic algae. There are few aquatic macrophytes in the river. Bank vegetation falling into the stream provides most of the organic matter required for heterotrophic life. The stream substrate consists of sand, gravel, and cobble. The higher water velocities in most rivers prevent severe siltation. Drainage from logging and mining areas, however, has caused siltation in the lower reaches of some rivers, e.g., the South Fork of the Coeur d'Alene River.

Macrobenthic life is not abundant in the Pend Oreille River. The dominant organisms are stoneflies, mayflies, caddisflies, elmid beetles, and dipteran larvae. Mollusks and crustaceans are not abundant in the Northern Rocky Mountains. Food for fish is limited by low benthic production, and many fish species depend heavily upon terrestrial insects that fall into the stream.

The major fishery resources of the Northern Rocky Mountains are the salmonid fishes, which have been constrained by the reduction of suitable spawning habitat in tributaries impacted by logging, mining, and channel alterations.[2] From 1958 to 1972, commercial fishermen were allowed a daily limit of 200 Kokanee (land-locked sockeye salmon) from Pend Oreille Lake. However, commercial fishing was discontinued in 1973 because of the reduction in Kokanee population size.[3] Since 1959, catch rates for sport fishermen (trolling) have ranged from 1.7 to 3.2 fish per hour.[3] In addition to salmon and other coldwater species, some warmwater sport fishes, such as bass and crappie, have been introduced. Many of the sport fish populations are supported by supplemental stocking of such fish as trout and walleye reared at hatcheries.

11.2.2 Western Great Plains

Streams in the Western Great Plains are of two distinct types: those which drain the dissected arid plains and those which originate in the forested uplands, such as the Black Hills. The streams of the arid plains are ephemeral and subject to severe annual variations in discharge, turbidity, temperature, and specific conductance.[4] Some of the tributaries of the Cheyenne and Belle Fourche rivers are typical. These streams are generally slow-flowing, saline-rich waters meandering through braided channels. Productivity is limited by the unstable sand and silt substrates. Periphytic algae, salt-tolerant marsh vegetation, such as salt grass, and cattail provide most of the primary productivity. Macrobenthic production is poor, restricted by scant food supplies, unsuitable substrate, and occasional loading of toxic trace elements. Some mayflies, stoneflies, caddisflies, dipteran larvae, and dragonfly larvae are present, but population densities are lower than those in the upland streams of the Black Hills area.

In contrast to streams draining arid plains, streams that drain the Black Hills show less annual variations in discharge, lower turbidity, cooler water temperature, and lower loads of dissolved solids.[4] The substrates of these streams, which support a diverse biotic community, consist of gravel and cobble and are more stable. Primary production is high; it consists of periphytic algae and macrophytes, such as waterweed and water moss. Deposition of forest litter in the streams provides organic matter for macrobenthic life. Stoneflies, caddisflies, mayflies, dipteran larvae, crayfish, and amphipods are abundant and provide food for fish.

The headwaters of the rivers in the Western Great Plains region contain fish communities of limited diversity, usually trout and several forage species. The fish communities change with the quality of the water and geology of the various basins. The number of species increases in downstream reaches of these rivers.[5,6] The majority of the fish are forage species, minnows, and suckers; many of the sport species have been introduced (such as brown trout and rainbow trout). Fourteen of the 34 species found in the Cheyenne River are introduced.[5]

11.2.3 Wyoming Basin

The headwater streams in the Wyoming Basin generally originate in mountainous terrain. They usually have gravel substrates and sufficient mineral and nutrient content to support the production of some periphytic algae.[7] The use of water from these rivers for irrigation is increasing, and degradation of water quality is apparent in the mainstems.[7] Irrigation return flow and organic waste from livestock and domestic effluents increase the total dissolved solids and nutrient loads downstream. This stimulates plant growth, and primary production is high during summer, when the river bottoms are frequently covered with periphyton and occasional patches of aquatic macrophytes. The hard water, available food supplies, and gravel substrates encourage macrobenthic development in the mainstems. Mayflies, stoneflies, caddisflies, blackflies, midges, crayfish, and dragonflies are abundant in unsilted sections. Benthic production, however, is not as abundant in shallow, silt-laden pools. Occasional river impoundments act as sediment traps, decreasing turbidity downstream and improving the habitat for benthic life.

The species composition of fish in Wyoming Basin rivers exhibits distinct changes that can be correlated with availability and quality of water. Many of the headwater streams are intermittent and contain fish only during the spring when snowmelt and rain produce high-water conditions. At these times, such fish as trout, suckers, and some minnows move into these intermittent streams to spawn. In such streams, survival of the young fish depends on rapid hatching and development and subsequent movement into the main streams. Fish communities of the major rivers contain more diverse assemblages than do the intermittent tributaries.

Several sport fish have been introduced to supplement the sport fishery for cutthroat trout.[7] In the major impoundments of the region, introduced fishes dominate the sport fishery. Several of these species, such as trout and walleye, migrate into the rivers to spawn.

11.2.4 Southern Rocky Mountains

Surface water quality in the Southern Rocky Mountains region is primarily a function of altitude. Headwater streams, such as the Upper Arkansas River, are maintained by snowmelt and have maximum discharge in late spring.[8] Total dissolved solids (TDS) loads are usually less than 100 mg/L, but sufficient nutrients derived from terrestrial litter are present for the production of abundant macroinvertebrate fauna.[8] Primary production is low because of low temperatures, high velocity, and low nutrient content of the waters. Abundant growth of periphytic algae occurs on gravelly substrates during favorable periods, usually in summer. Well-developed populations of mayflies, stoneflies, caddisflies, elmid beetles, and dipteran larvae utilize this organic detritus and provide an abundant food supply for fish.[9,10]

As altitude decreases, the dissolved mineral content, temperature, and turbidity of these streams increase. Nutrient loads also increase, principally as a result of irrigation return flow and organic wastes from livestock and domestic sources. Primary productivity increases and aquatic macrophytes become established in the impoundments. The stream substrates become more silted, and more tolerant benthic invertebrates, such as chironomids (midges), oligochaetes (segmented worms), and mollusks, become more abundant.

Fish community composition also changes with changes in altitude and water quality. The high mountain streams contain several species of trout and forage fish, including minnows and sculpins. As altitude decreases and temperature and turbidity increase, the species composition of fish becomes more indicative of warmwater communities; species such as bass, sunfish, and suckers, which are more tolerant of these conditions, become dominant. As these rivers are further affected by nutrient inputs and irrigation return water, predator-sport species decline and species highly tolerant of increased temperature, high mineral content, and turbidity become dominant, e.g., catfish and carp.

11.2.5 Colorado Plateau

Snowmelt is the primary source of headwater streams in the Colorado Plateau, such as the San Miguel, Dolores, Animas, and Rio San Jose rivers. These streams flow through the canyon-land terrain in the upstream areas of the Colorado River Basin. Extreme seasonal fluctuations in discharge, turbidity, and temperature are common; aquatic communities are stressed by early summer flooding and early fall desiccation. These severe conditions limit biotic development, and primary production is low. Periphytic green algae and diatoms provide the major portion of the organic matter needed for heterotrophic life, since there is little development of phytoplankton or macrophytic communities.[1] Locally abundant phytoplanktonic growth can occur in stream segments affected by domestic wastes, livestock feedlot drainage, and irrigation return flow. A significant fraction of the organic matter also is provided by terrestrial leaf litter.

Generally, stream gradients are quite steep and the habitat consists of fast-water areas of riffle-pool configuration.[11] The substrate is mostly coarse gravel and rubble, although sand and some silt are present in pools, particularly in downstream sections. Although suitable substrate may be available for macrobenthic development, other factors, such as high specific conductance [which comes from natural salt brine seepage into some of the streams (see Sec. 7 and Table 7.7)], may constrain production.[12] Macrobenthic development is present where water quality and substrate suitability permit. In one study on the Dolores and San Miguel Rivers, 93 taxa of macrobenthic organisms were identified.[12] The major organisms found were caddisflies, dipterans, mayflies, and stoneflies.[12]

In general, the lower trophic levels in the streams are not particularly well developed, and man-induced changes in the natural assemblages are common, especially in areas affected by mining and processing of mineral ores.

The fish communities of the upper Colorado River basin have low species diversity. Only 29 species were found during a study of the mainstream of the Colorado River.[13] Only ten of these were native to the system; the others had been introduced. The assemblage included two native species on the Federal list of endangered species, the humpback chub (*Gila cypha*) and the Colorado River squawfish (*Ptychocheilus lucius*).[14] Some of the native species have declined in abundance because of biotic and abiotic factors.[13] Colorado River dams have altered the flow regime and destroyed flowing river habitat. Impoundment discharges are cooler and less turbid than the original river. This change in water quality, the loss of flowing river habitat, and the introduction of species more tolerant to the prevailing conditions have contributed to the decline of native species through competition from the better-adapted introduced species (trout, catfish, bass, and sunfish).

Smaller tributary streams of the region are generally intermittent, and diversity of fish species is low;[15,16] however, those species that persist are highly tolerant of variable flows, temperature extremes, and high loads of suspended solids.

Fish species diversity in the Rio San Jose and Rio Puerco in New Mexico is low, with the potential of less than 25 species to be found in these rivers.[16] The majority of the species are low-order consumers, primarily minnows. Since many of these rivers are used for irrigation, the species that do inhabit these and similar rivers of the area are subjected to wide variations in temperature and discharge. In the past, fishery management of the Rio San Jose included stocking of rainbow trout and stocking of impoundments with northern pike.[17] However, in recent years management has been discontinued, and it is doubtful that many of either species are still present.[17]

11.2.6 Texas Coastal Plains

Emergent aquatic macrophytes provide the organic matter to support heterotrophic organisms in the Nueces River. Historically, the river has a prolific development of aquatic macrophytes. Water hyacinth develops in nuisance proportions in the lower reaches of the river. Phytoplankton populations are well developed in the impoundments. Diatom blooms occur in January and February and again in September and October. Blue-green algae dominate the phytoplankton in May, June, and July, corresponding to maximum discharge during these months.[18] In the springs of the headwater region, major contributors to the plant biomass are coontail, chara, water milfoil, cattail, yellow water lily, and watercress.[19] Aquatic invertebrates in the Nueces River include mayflies, blackfly larvae, dragonflies, elmid beetles, water bugs, freshwater shrimp, and crayfish, all of which provide food for fish.[20]

Many other drainage basins within the Texas Coastal Plains probably have similar aquatic biota; however, biota of some drainages are disturbed by domestic wastes, oilfield salt brines, and irrigation return water.

Fish species diversity varies in the Texas Coastal Plains rivers. For example, the Nueces River system contains 76 species, compared to 75 and 54 species in the Guadalupe and San Antonio river systems, respectively.[20] Almost one-third of the species found in the Nueces River system are estuarine or coastal; the remainder are freshwater species.[20] The low gradients and relatively unobstructed nature of these rivers allow estuarine and coastal species to invade and to dominate the fish community of the lower reaches. The highly productive estuaries serve as spawning and nursery grounds for many species. Bass and sunfish make up the dominant group of sport fishes within upper reaches of most rivers in the region. In the Nueces River system, 12 species of this group are found. Trout, yellow perch, and walleye have been stocked in some river systems in the region.[20]

The small, intermittent tributaries of the coastal plains rivers are important for the production of forage species, which utilize these streams for reproduction when sufficient water is available. In general, these forage species are adapted to the variable environmental conditions and have life cycles which allow for rapid recolonization when conditions are favorable.

One endangered fish species, the fountain darter (*Etheostoma fonticola*), is known to occur in the region (in Comal and San Marcos Springs and waters downstream in the Guadalupe River system).[21]

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12. DEMOGRAPHIC AND ECONOMIC PROFILES

12.1 GENERAL ASPECTS

Demographic and economic profiles of selected regions of the wWestern United States are presented in this Chapter. Although the effects of uranium development would be felt over a wide area, the demographic and economic profile for each region is focused on that part of the region where the effects of resource development are considered to be most concentrated.

For the purposes of this report, a "subregion" is defined as the area within commuting distance of all existing uranium mills within each region. These subregions, which can be regarded as the areas most likely to be impacted as a result of uranium developments and related economic activities, are shown in Figure 12.1. The Colorado Plateau subregion was further divided to better reflect demographic and economic characteristics of the area.

12.2 DEMOGRAPHY

Although the geographical extent of the six regions covers about 13% of the nation's land area, the combined total estimated 1976 population of the regions (5,049,000) was only a little over 2% of the national total (Table 12.1).[1] Principal population clusters. are in the Front Range of the Rocky Mountains in Colorado, the Wasatch Front in Utah, central Arizona, and the Texas Coastal Plains area. These encompass such metropolitan areas as Denver, Salt Lake City, Flagstaff, and San Antonio (Fig. 12.2). The average population density of the six regions in 1976 was estimated to be 4.3 people/km^2 (11.2/mi^2) (Table 12.2). The Texas Coastal Plains region had 7.8 people/km^2 (20.2/mi^2) the highest density among the regions. In contrast, the most sparsely populated region was the Wyoming Basin with 1.4 people/km^2 (3.7mi^2) (Table 12.2). The average population density of the subregions 2.8 people/km^2 (7.3/mi^2) was lower than that of the regions as a whole.

Historically the United States has become increasingly urbanized. On the basis of 1975 estimates, most of the states in the West have a greater percentage of their inhabitants in urban areas than does the nation as a whole (Table 12.3).[2] During the decade of the 1960s, the subregions with the more intensive mining and milling activity grew at a rate slower than the regions as a whole and slower than average U.S. growth. Since 1970 the subregions have grown at a faster rate, about equal to the western regions as a whole.

During the period 1960 to 1976, the population in the six regions was estimated to have increased by 28.5%, while the population of the entire United States increased by 19.2% (Table 12.1). The Western Great Plains region had the highest growth, 37.5% and the Texas Coastal Plains region had the lowest, 5%.[1]

According to the 1970 census, the average household size was 3.2 persons, which is not significantly different from the rest of the nation.

The distributions of minorities in the regions are given in Table 12.4. Hispanic-Americans make up 12% of the total population, more than twice the average for the nation. Less than 1% of the population is Black, and 12% is predominantly American Indian. In two subregions, American Indians and Hispanic-Americans make up a majority of the population. Particularly, in one of the subregions in the Colorado Plateau (Subregion B, consisting of Rio Ariba, Sandoval, McKinley, and Valencia counties) over 80% of the 1970 population was recorded as belonging to minority groups. The six regions contain both a large portion of the American Indian population and a large share of American Indian lands in the United States.[1]

12.3 ECONOMY

12.3.1 Income

Estimated personal income in the six regions totaled $25 billion in 1976. Per capita income and household income averaged over the six regions are close to the national average, but per capita

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Fig. 12.1. Selected Subregions within the Six Regions.

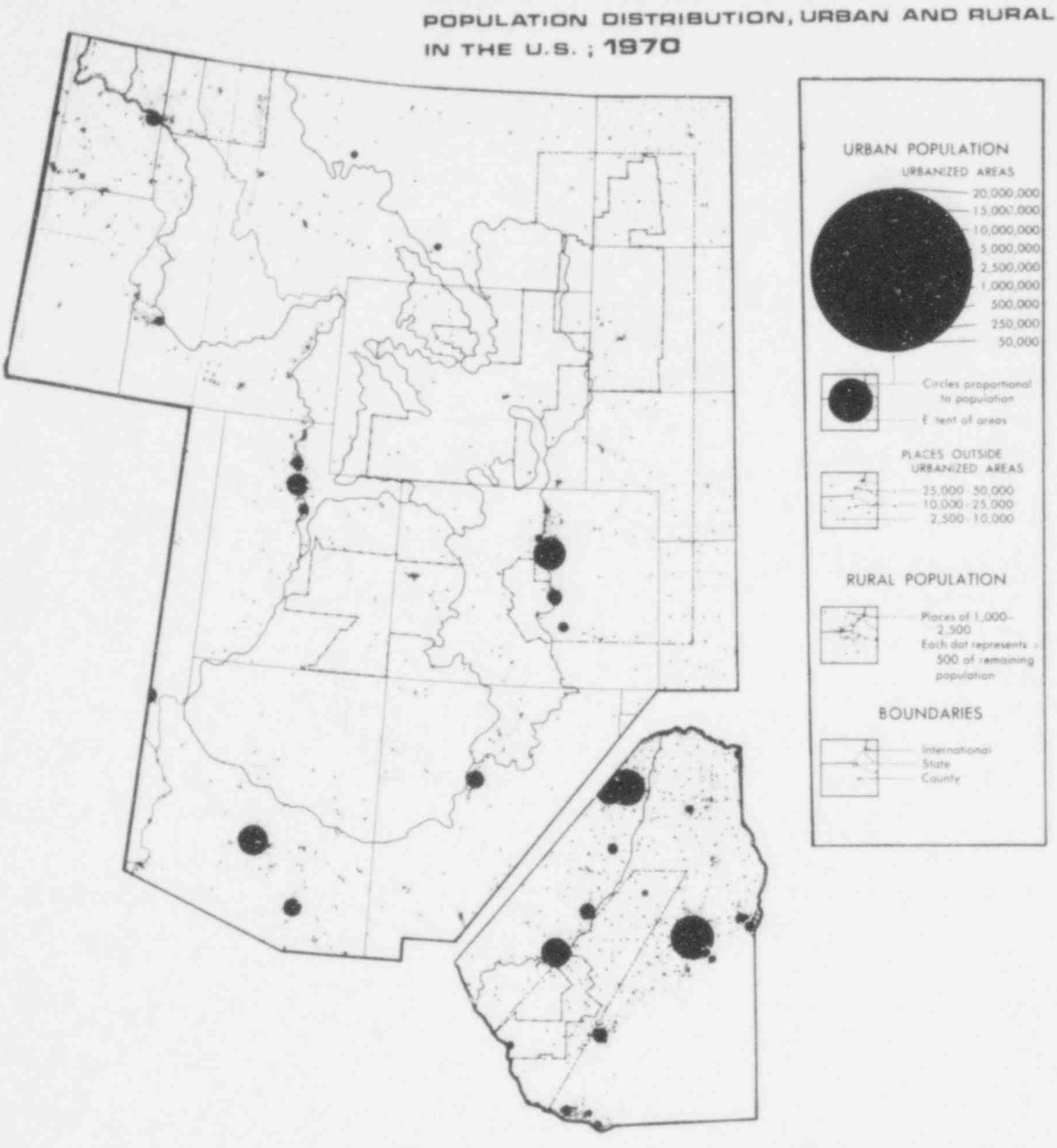

Fig. 12.2. Urban and Rural Population Distribution in the Six Regions in 1970. (Modified from: "Population Distribution, Urban and Rural in the United States, 1970," 1970 census map, Geography and Population Div., Bureau of the Census, U. S. Dept. of Commerce, 1971.)

Table 12.1. Regional Population Changes[a]

Regions	Population 1960	Population 1970	Population 1976 (Estimate)	% Increase 1960-70	% Increase 1970-76
Northern Rocky Mountains	443,000	465,000	521,000	5.0	12.0
Subregion	284,000	288,000	322,000	1.4	11.8
Western Great Plains	1,954,000	2,363,000	2,686,000	21.0	13.7
Subregion	171,000	171,000	181,000	0	5.8
Wyoming Basin	260,000	269,000	315,000	3.5	17.1
Subregion	127,000	135,000	161,000	6.3	19.3
Southern Rocky Mountains	233,000	267,000	317,000	14.6	18.7
Subregion	8,000	9,000	16,000	12.5	77.7
Colorado Plateau	430,000	464,000	557,000	8.0	20.0
Subregion A	100,000	113,000	121,000	13.0	7.1
Subregion B	64,000	71,000	83,000	11.0	16.9
Texas Coastal Plains	608,000	615,000	653,000	1.0	6.2
Subregion	104,000	105,000	109,000	0.9	3.8
All Regions	3,928,000	4,444,000	5,049,000	13.1	13.6
All Subregions	857,000	892,000	992,000	4.1	11.2
United States	179,373,000	203,211,000	213,847,000	13.3	5.2

[a]Source: "1970 Census Data and Estimates for 1976," Urban Decision Systems, Inc., 1977.

Table 12.2. Regional Area and Population Density, 1976 Estimate[a]

Regions	Area, square miles[b]	Population	Population Density per mi^2	Population Density per km^2
Northern Rocky Mountains	26,189	521,000	19.9	7.7
Subregion	4,914	322,000	65.5	25.3
Western Great Plains	134,842	2,686,000	19.9	7.7
Subregion	34,292	181,000	5.3	2.0
Wyoming Basin	85,497	315,000	3.7	1.4
Subregion	46,488	161,000	3.5	1.3
Southern Rocky Mountains	47,410	317,000	6.7	2.6
Subregion	4,626	16,000	3.5	1.3
Colorado Plateau	124,868	557,000	4.5	1.7
Subregion A	26,211	121,000	4.6	1.8
Subregion B	13,030	83,000	6.4	2.5
Texas Coastal Plains	32,416	653,000	20.1	7.8
Subregion	7,000	109,000	15.6	6.0
All Regions	451,222	5,049,000	11.2	4.3
All Subregions	136,561	992,000	7.3	2.8
United States	3,537,855	213,847,000	60.4	23.3

[a]Source: "1970 Census Data and Estimates for 1976," Urban Decision Systems, Inc., 1977.
[b]Conversion: 1 square mile = 2.59 square kilometers.

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Table 12.3. Urban Population by State[a]

State	Population, thousands	Percent of State Total
Arizona	1,771	79.5
California	19,958	90.9
Colorado	2,207	78.7
Idaho	713	54.3
Kansas	2,247	66.1
Montana	694	53.6
Nebraska	1,482	61.6
Nevada	449	80.9
New Mexico	1,016	70.0
North Dakota	618	44.3
Oregon	2,091	67.1
South Dakota	666	44.6
Texas	11,194	79.8
Utah	1,059	80.6
Washington	3,409	72.6
Wyoming	332	60.4
United States	203,212	73.5

[a]Source: "Critical Water Problems Facing the Eleven Western States," U.S. Department of the Interior, Washington, D.C., p. 9, April 1975.

Table 12.4. Regional Minority Populations, 1970 Census (expressed as percent of total population)[a]

Areas	Black	Hispanic American	Other	Total Population[b]
Northern Rocky Mountains				
Region	0.6	0.8	2.3	465,000
Subregion	0.9	0.9	1.7	228,000
Western Great Plains				
Region	2.9	10.3	1.9	2,363,000
Subregion	0.7	0.9	6.7	171,000
Wyoming Basin				
Region	0.4	4.3	3.5	269,000
Subregion	0.6	5.6	3.4	135,000
Southern Rocky Mountains				
Region	0.3	40.6	2.2	267,000
Subregion	0.6	2.0	0.7	9,000
Colorado Plateau				
Region	0.8	13.7	26.7	464,000
Subregion A	0.2	8.6	5.2	113,000
Subregion B	0.8	33.1	49.8	71,000
Texas Coastal Plains				
Region	11.2	35.5	0.6	615,000
Subregion	1.6	59.5	0.5	105,000
All Regions	3.3	14.6	4.4	4,444,000
All Subregions	0.8	12.0	7.0	892,000
United States	11.1	5.0	1.1	203,212,000

[a]Source: "1970 Census Data and Estimates for 1976," Urban Decision Systems, Inc., 1977.

[b]Includes white and nonwhite.

income varies widely interregionally. The region with the highest per capita income (1976 estimate) was the Wyoming Basin, with $5654, about 11% higher than the national level. The lowest was the Texas Coastal Plains with $3588, about 30% lower than the national level (Tables 12.5 and 12.6).

The per capita income in the six regions increased by 78.5% during the period 1970-1976 (from $2747 to $4902), which was 16.5% higher than the average national growth rate. The per capita income averaged over all the subregions increased by 89.9% during the same period. In the period from 1970 to 1977, the Wyoming Basin region experienced the most rapid increases both in per capita income (97.9%) and total personal income (131.3%). This is quite different from the historical growth trends in this area (total personal income increased by 122% in Wyoming from 1950 to 1970).[1]

The median family income in the six regions increased from $8648 in 1970 to $14,545 in 1976, nearly parallel to the national trend. In the Wyoming Basin region, the family income had nearly doubled during the period and was the highest among the six regions (Table 12.6).

Since 1970, the regions and subregions have been catching up to the rest of the United States in terms of median family income. In 1970, only the Wyoming subregion had a median family income greater than the national average. By 1976, the average median income of the subregions had surpassed that of the nation, and that of the regions was about the same as that of the rest of the country. This growth in income in the six regions and subregions was not shared proportionately by each subregion. In subregions of the Colorado Plateau and the Texas Coastal Plains, income growth from 1970 to 1976 was slower than in most of the other subregions. In 1970 these subregions also had a much lower income base than did the other subregions. From Table 12.6 it can be seen that the average increased prosperity in the subregions, when compared with that of the rest of the country, can be attributed mainly to the central areas of the north (Northern Rocky Mountains, Wyoming Basin, and the Western Great Plains). The southern areas (Colorado Plateau, Southern Rocky Mountains, and the Texas Coastal Plains) tended to lag behind the neighboring states to the north and the United States as a whole.[1]

12.3.2 Employment

Employment in the western United States has been increasing at a rate about twice that for the United States as a whole. Total nonagricultural employment in the states constituting the six regions increased from 7,500,000 in 1960 to 12,500,000 in 1975 (Table 12.7). During the same period, the total U.S. employment in nonagricultural sectors increased from 54,232,000 to 76,985,000. In contrast, the total farm and ranching population in the six regions declined from 4,549,000 in 1950 to 2,209,000 in 1970 (Table 12.8). That decline was proportional to the decline in farm population in the rest of the country.[3]

The data in Table 12.9 represent the work force by region and subregion in 1970. The Northern Rocky Mountains region experienced the greatest unemployment rate (8.1%), while the Western Great Plains and Texas Coastal Plains regions had the lowest rates. Overall, the average unemployment rate of the six regions was 4.8%, which was slightly higher than the national average (4.5%). The average unemployment rate in the subregions in the same year was about 20% higher than the averages for the nation and the six regions combined. In 1976, the annual average unemployment rate in the individual counties in the six regions varied from 24.3% in Rio Ariba County (New Mexico) in the Colorado Plateau to 1.1% in Sioux County (Nebraska) in the Western Great Plains. On a regional basis, the unemployment rate in 1976 in the Wyoming Basin region was the lowest with 4.3% unemployed, and that of the Northern Rocky Mountains region was the highest with about 9% unemployed.[1]

The total labor force in the six regions was about 1,674,000 workers in 1970. As seen in Table 12.9, the Wyoming Basin region experienced the highest male participation rate (the percentage of those people eligible to work, who are working or looking for work) in the labor force among the six regions. The average female participation rate in 1970 was 37.4% for all the regions and 35.4% for all the subregions. These values were lower than the national average of 39.5%. A breakdown, by occupation, of the number of workers in the regions and subregions is given in Table 12.10. The fraction of managerial and service workers in the six regions is slightly higher than the corresponding fraction for the whole country. The largest employment sectors in the western states are wholesale and retail trade (Table 12.7).

12.4 THE SIX REGIONS

12.4.1 Northern Rocky Mountains

In 1976 the population density of the Northern Rocky Mountains region was 8 people/km^2 (20/mi^2) [520,000 people in an area of about 67,000 km^2 (26,000 mi^2)] (see Table 12.2). The density in

Table 12.5. Per Capita and Average Household Income, 1970 Census and 1976 Estimates[a]

Regions	Per Capita Income, dollars		Percent Increase, 1970-1976	Household Income, dollars		Percent Increase, 1970-1976
	1970	1976		1970	1976	
Northern Rocky Mountains	2857	4618	61.6	8596	13,281	54.5
Subregion	3011	4861	61.5	8868	13,701	54.5
Western Great Plains	3056	5461	78.7	9476	15,945	68.3
Subregion	2372	6340	167.3	7833	19,364	147.2
Wyoming Basin	2857	5654	97.9	8868	17,223	94.2
Subregion	2957	5609	89.7	9498	17,820	87.6
Southern Rocky Mountains	2567	4679	82.3	8391	13,840	64.9
Subregion	2679	4620	72.4	7731	13,420	60.7
Colorado Plateau	2110	3715	76.1	7604	12,435	63.5
Subregion A	2425	4277	76.3	7634	12,542	64.3
Subregion B	1716	3181	85.4	7361	12,193	65.6
Texas Coastal Plains	1983	3588	80.9	6499	11,017	69.5
Subregion	1815	3272	80.3	6460	10,896	68.7
All Regions	2747	4902	78.5	8703	14,632	68.1
All Subregions	2259	4861	89.9	8245	14,802	79.5
United States	3140	5086	62.0	9801	14,649	49.5

[a]Source: "1970 Census Data and Estimates for 1976," Urban Decision Systems, Inc., 1977.

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Table 12.6. Income Distribution, 1970 Census and 1976 Estimate (percent of total)[a]

Family Income, dollars	Northern Rocky Mountains				Western Great Plains				Wyoming Basin				Southern Rocky Mountains			
	Region		Subregion		Region		Subregion		Region		Subregion		Region		Subregion	
	1970	1976	1970	1976	1970	1976	1970	1976	1970	1976	1970	1976	1970	1976	1970	1976
Less than 2,000	5.3	2.4	5.1	2.0	5.0	2.1	7.1	1.9	5.2	1.8	4.7	1.9	8.8	4.5	10.4	6.3
2,000-2,999	5.2	2.4	5.0	2.1	4.1	1.8	5.7	1.5	4.8	1.7	3.8	1.5	6.2	3.2	5.8	3.5
3,000-4,999	11.0	6.2	11.1	5.9	10.2	4.6	13.5	3.7	10.8	4.4	8.9	3.8	13.6	7.3	17.9	8.0
5,000-6,999	13.0	7.2	11.6	7.1	12.8	5.7	17.1	4.4	13.7	5.2	11.2	4.5	14.5	8.0	18.5	9.8
7,000-7,999	8.1	3.8	7.4	3.6	7.3	3.2	8.3	2.4	7.7	2.9	7.4	2.4	7.4	4.2	7.4	5.6
8,000-9,999	15.9	8.3	14.8	7.9	14.4	7.6	15.5	5.2	15.9	6.1	16.6	5.8	13.8	8.7	14.1	11.6
10,000-11,999	13.4	9.5	13.6	8.4	13.1	7.8	11.5	5.8	13.4	6.7	15.5	5.9	10.3	8.8	9.0	11.5
12,000-14,999	13.1	16.8	14.1	15.3	13.9	12.5	9.7	9.5	13.0	11.6	14.8	10.8	10.4	13.9	6.8	13.7
15,000-19,999	8.8	19.9	10.2	21.0	11.1	21.3	6.7	18.1	8.8	20.9	10.3	22.7	8.5	16.6	5.9	14.0
20,000-24,999	3.1	11.1	3.6	12.5	4.0	14.2	2.4	15.4	3.2	15.3	3.5	17.6	3.1	10.4	2.0	7.0
25,000-49,999	2.8	10.8	3.1	12.4	3.5	17.1	2.2	26.9	2.8	20.0	2.6	20.5	2.8	12.3	1.3	7.3
More than 50,000	0.4	1.5	0.5	1.8	0.6	2.8	0.4	5.2	0.6	3.5	0.7	3.1	0.5	2.1	0.7	1.6

Family Income, dollars	Colorado Plateau						Texas Coastal Plains				Totals				United States	
	Region		Subregion A		Subregion B		Region		Subregion		Regions		Subregions			
	1970	1976	1970	1976	1970	1976	1970	1976	1970	1976	1970	1976	1970	1976	1970	1976
Less than 2,000	11.8	6.9	8.1	3.7	16.5	11.1	14.1	6.9	14.0	6.7	7.2	3.4	7.6	3.2	5.9	2.7
2,000-2,999	6.4	3.8	6.7	3.1	6.5	4.3	10.1	5.0	10.9	5.1	5.4	2.6	5.9	2.5	4.4	2.3
3,000-4,999	13.3	7.9	15.9	7.8	12.1	7.9	17.9	11.0	19.6	11.8	11.9	6.1	12.9	6.1	10.0	5.7
5,000-6,999	14.8	8.2	15.7	9.2	14.4	7.6	15.2	11.0	15.6	12.1	13.5	6.9	13.8	6.9	11.9	6.6
7,000-7,999	7.7	4.2	7.8	4.7	7.5	4.0	7.1	4.9	7.1	5.6	7.4	3.6	7.6	3.6	6.7	3.6
8,000-9,999	14.2	8.7	14.4	10.0	13.0	8.0	11.3	9.8	11.1	11.4	14.2	7.7	14.6	7.4	13.9	7.8
10,000-11,999	10.9	9.4	10.6	9.7	9.9	9.1	8.3	9.3	7.6	8.4	12.1	9.2	12.1	7.8	12.9	8.6
12,000-14,999	9.8	14.5	9.7	14.4	9.5	13.5	7.3	11.6	6.3	11.6	12.2	13.6	11.6	12.7	13.7	14.6
15,000-19,999	6.7	16.9	6.6	17.1	6.3	16.0	5.0	13.6	4.4	12.7	9.3	19.1	8.2	19.4	11.7	19.7
20,000-24,999	2.2	9.3	2.3	9.4	2.0	9.0	1.8	7.5	1.6	6.5	3.3	12.4	2.8	13.0	4.3	12.6
25,000-49,999	1.8	9.0	2.0	9.6	1.7	8.4	1.6	8.0	1.4	6.8	2.9	14.2	2.4	15.1	3.9	13.4
More than 50,000	0.3	1.2	0.3	1.3	0.1	0.7	0.3	1.4	0.3	1.2	0.5	2.3	0.4	2.3	0.8	2.3

[a]From: "1970 Census Data and Estimates for 1976," Urban Decision Systems, Inc., 1977.

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Table 12.7. Employees in Nonagricultural Occupations in 1975 (in thousands)[a]

State	Manufacturing	Wholesale and Retail Trade	Government	Services	Transportation, Public Utilities	Finance, Insurance, Real Estate	Contract Construction	Mining	Total
Arizona	97	175	169	136	39	42	42	24	724
Colorado	135	227	212	183	60	56	57	18	948
Idaho	47	67	61	46	16	11	16	4	268
Kansas	161	190	172	133	55	38	39	11	797
Montana	22	60	65	45	19	10	12	7	240
Nebraska	85	142	125	100	40	34	27	2	554
New Mexico	27	81	105	68	23	17	24	20	365
Nevada	12	51	46	110	17	11	12	4	264
North Dakota	16	56	54	40	13	9	14	2	203
Oklahoma	150	209	203	141	55	47	43	40	887
Oregon	182	197	177	145	50	45	35	2	831
South Dakota	20	54	56	45	12	9	9	3	209
Texas	800	1077	816	766	288	256	280	129	4,413
Utah	67	104	110	76	27	20	23	13	441
Washington	242	282	273	219	71	66	55	2	1,209
Wyoming	8	30	35	21	12	5	14	18	143
Sub-Total	2072	3002	2679	2274	797	676	702	337	12,496

[a]Source: "Statistical Abstract of the U.S.," Bureau of the Census, U.S. Dept. of Commerce, Table No. 596, p. 367, 1976.

Table 12.8. Farm Population by State, 1940 to 1970[a]

State	Farm Population, thousands of people				Percent Decrease	
	1940	1950	1960	1970	1950 to 1960	1960 to 1970
Arizona	114	77	74	34	3.9	54.2
Colorado	253	198	143	94	27.8	34.5
Idaho	203	165	148	102	10.3	31.4
Kansas	607	114	340	252	23.4	25.8
Montana	176	136	115	90	15.4	21.7
Nebraska	498	391	329	253	15.9	23.0
New Mexico	178	132	72	45	45.5	37.5
Nevada	16	13	13	9	--	25.8
North Dakota	328	254	207	154	18.5	25.6
Oklahoma	930	553	294	209	46.8	28.9
Oregon	259	228	165	119	27.6	28.2
South Dakota	307	254	217	172	14.6	21.0
Texas	2,160	1,292	806	471	37.6	41.6
Utah	105	81	65	38	19.8	41.1
Washington	340	274	199	133	27.4	33.4
Wyoming	73	57	47	33	17.5	29.4
TOTAL	6,507	4,549	3,235	2,209	28.9	31.7
United States	30,547	23,048	15,635	9,712	32.2	37.9

[a]From: "Farm Population Estimates, 1910-1970," Economic Research Service, U.S. Dept. of Agriculture, Statistical Bulletin Notes.

Table 12.9. Labor Force, Unemployment, and Participation Rate, 1970 Census[a]

Regions	Labor Force, number		Unemployment Rate, %		Participation Rate,[b] %	
	Male	Female	Male	Female	Male	Female
Northern Rocky Mountains	112,326	62,376	8.1	8.2	68.1	35.4
Subregion	41,938	41,938	7.1	7.8	67.6	37.3
Western Great Plains	577,505	352,147	3.8	4.7	68.8	40.1
Subregion	38,932	21,606	4.6	5.3	63.6	35.9
Wyoming Basin	69,912	36,931	4.1	5.8	71.6	37.7
Subregion	35,621	18,413	4.4	5.9	74.5	38.3
Southern Rocky Mountains	63,440	34,171	5.3	5.3	67.6	35.9
Subregion	2,430	1,130	3.4	4.6	68.6	31.7
Colorado Plateau	97,462	52,026	6.4	5.8	64.0	32.6
Subregion A	26,950	14,646	5.4	5.8	67.3	35.0
Subregion B	13,225	6,738	7.0	4.8	62.9	29.9
Texas Coastal Plains	142,416	73,423	3.2	4.8	64.6	32.1
Subregion	23,278	10,897	4.0	5.6	65.6	29.1
All Regions	1,063,061	611,074	4.5	5.3	67.8	37.4
All Subregions	182,374	115,368	5.6	6.4	67.3	35.4
United States	50,125,424	30,777,712	4.0	5.2	70.1	39.5

[a]From: "1970 Census Data and Estimates for 1976," Urban Decision Systems, Inc., 1977.

[b]Participation rate = the percentage of the civilian labor force.

Table 12.10. Type of Employment, 1970 Census (percent of employed labor force)[a]

Type of Employment	Northern Rocky Mountains		Western Great Plains		Wyoming Basin		Southern Rocky Mountains		Colorado Plateau			Texas Coastal Plains		All Regions	All Sub-regions	United States
										Subregions						
	Region	Sub-region	Region	Sub-region	Region	Sub-region	Region	Sub-region	Region	A	B	Region	Sub-region			
Professional	14.1	15.2	17.4	13.6	14.9	13.9	18.8	11.3	15.5	14.8	15.6	12.1	10.4	16.1	14.0	14.9
Managerial	12.7	11.7	13.8	21.8	17.1	15.1	14.2	22.6	13.4	15.4	9.8	13.6	15.6	13.8	15.1	10.3
Clerical	15.0	17.3	18.2	12.5	13.9	14.2	14.5	10.0	13.9	13.4	13.0	12.8	14.1	16.3	14.7	18.0
Sales	7.7	9.1	7.7	6.8	5.5	6.0	5.2	4.9	5.7	6.5	3.7	6.2	7.1	7.1	7.3	7.3
Crafts	14.0	13.0	12.0	10.9	13.3	15.0	12.9	14.5	13.7	13.6	15.4	13.8	12.9	12.8	13.3	13.8
Operatives	14.1	12.2	11.3	10.5	12.6	15.1	11.0	10.6	15.0	13.7	19.8	14.7	13.3	12.4	13.2	17.3
Service	15.0	16.2	13.7	16.0	14.3	13.8	15.7	16.9	15.0	13.9	15.6	15.1	14.2	14.3	15.1	12.6
Laborer	5.6	4.3	3.8	3.5	4.3	4.2	4.7	4.2	5.2	4.8	6.2	6.0	5.9	4.5	4.5	5.5
Farm Worker	1.7	0.9	1.9	4.3	4.1	2.7	3.0	4.8	2.4	3.9	0.9	5.7	6.5	2.6	2.8	1.3
Total Number Employed	169,000	108,000	891,000	57,600	102,000	51,400	92,400	3,400	140,000	39,300	18,700	208,000	32,600	1,602,400	311,000	77,313,500

[a]From: "1970 Census Data and Estimates for 1976," Urban Decision Systems, Inc., 1977.

the three-county subregion surrounding currently operating uranium mills was about 25 people/km^2 (65/mi^2). Spokane, with a 1970 population of about 170,000, is the largest urban area in the subregion. The ethnic composition of the region consisted of 96% Whites and 4% minorities in 1970.

The economic and labor force characteristics of the region as a whole and of the three-county subregion were similar in 1976. The per capita incomes were about $4600 for the region and $4900 for the subregions; these represented increases of about 62% from 1970. About 57% of the families in the region and 52% in the subregion had family incomes of less than $15,000, compared to the national average of 46% in that year (Table 12.6). Unemployment rates were relatively high in 1970 (Table 12.9).

12.4.2 Western Great Plains

With a land area of about 360,000 km^2 (139,000 mi^2) and a population of nearly 2,690,000 in 1976, the Western Great Plains region also had a population density of about 8 people/km^2 (20/mi^2). In the subregion shown in Figure 12.1, the density was only about a fourth as large--2/km^2 (5/mi^2). Rapid City is the largest urban area in the subregion (1970 population of about 26,000). About 10% of the regional population in 1970 consisted of Hispanic-Americans and 4% of Blacks and other minorities.

The 1976 per capita income in the region, about $5500, was up nearly 80% from 1970 (Table 12.5). The per capita income in the subregion was $6300, up nearly 70% from 1970. About 44% of the families in the region had family incomes of less than $15,000 in 1976, while only 34% of the families of the subregion were in that income category (Table 12.6). The 1970 unemployment rate in the subregion were relatively low, 4.6% for male and 5.3% for female workers (Table 12.9).

12.4.3 Wyoming Basin

The Wyoming Basin region is the most sparsely populated of the six regions included in this study--about 2 people/km^2 (5/mi^2) in 1976 (Table 12.2). The population density of the subregion surrounding currently active uranium mills was about the same as for the region. Casper is the largest city in the subregion (1970 population of nearly 40,000). Whites made up 92% of the regional population in 1970, Blacks and Hispanic-Americans 5%.

The 1976 per capita income in the region was estimated at about $5700, up 98% from 1970. In the subregion, the per capita income was nearly the same, $5600, up about 90% from 1970 (Table 12.5). About 57% of the families in the region and 40% of the families of the subregion had family incomes of less than $15,000 in 1976. The unemployment rates in the region and subregion were relatively low in 1970.

12.4.4 Southern Rocky Mountains

The Southern Rocky Mountains region, with a land area of about 122,000 km^2 (47,000 mi^2) and a population of 316,000, had a population density of about 3 people/km^2 (8/mi^2) in 1976. The subregion around operating uranium mills was only slightly over 1 person/km^2 (3/mi^2). There are two relatively large urban areas in the subregion--Colorado Springs and Pueblo, with 1970 populations of 135,000 and 97,000, respectively. Hispanic-Americans constituted about 40% of the population of the region in 1970.

The per capita incomes in 1976 were about $4700 for the region as a whole and $4600 in the subregion, increases of 82% and 72%, respectively, from 1970. About 60% of the families in the region had family incomes of less than $15,000 in 1976, while 70% of the families in the subregion were in that income category. In 1970, the unemployment rate in the subregion was low, 3.4% for male and 4.6% for female workers.

12.4.5 Colorado Plateau

The Colorado Plateau region in 1976 had a low population density of about 2 people/km^2 (5/mi^2). In the two subregions surrounding active uranium milling operations (Fig. 12.1 and Table 12.2) population densities were about 2 persons/km^2 (5/mi^2) in subregion A and slightly higher (6/mi^2) in subregion B. Albuquerque is the largest urban area near the subregions (1970 population of about 244,000). In 1970, Whites constituted 59% of the population, Hispanic-Americans and Blacks 14%, and other minorities (predominantly American Indians) 27%.

The 1976 per capita income in the region was estimated at about $3700, a 76% increase from 1970. The 1976 per capita income in the subregion A was $4300 (also up 76%) and in subregion B was

$3200 (up 85%). About 64% of the families in the region had family incomes of less than $15,000 in 1976. In 1970, the unemployment rates in this region were about 6% both for males and females.

12.4.6 Texas Coastal Plains

In 1976, the Texas Coastal Plains region had a population density of about 8 people/km^2 (20/mi^2). The subregion around operating uranium mills had a slightly lower density, 6 people/km^2 (16/mi^2). San Antonio (1970 population of 654,000) is the largest city in the subregion. About 36% of the regional population consisted of Hispanic-Americans in 1970.

The 1976 per capita income in the region was estimated at about $3600, the lowest among the six regions. This was an 81% increase from 1970. In the same period, the per capita income in the subregion increased by 80% to $3300. About 52% of the families in the region and 50% of those in the subregion had family incomes of less than $15,000 in 1976. The 1970 unemployment rate in the region was relatively low, 3.2% for male and 4.8% for female workers.

References

1. "Regional Profile: 1970 Census and 1976 Estimates," prepared by Urban Decision Systems Inc., for Argonne National Laboratory, 1977.

2. "Critical Water Problem Facing the Eleven Western States," U.S. Dept. of the Interior, 1975.

3. "Farm Population Estimates," U.S. Dept. of Agriculture, Economic Research Service, Statistical Bulletin Number 5237, 1976.

13. SOCIAL AND CULTURAL PATTERNS

13.1 GENERAL ASPECTS

General sociocultural profiles of the six regions are presented in this chapter. Each profile contains a brief historical sketch of the region, a short description of the major cultural traditions, and an overview of contemporary social, political, and economic systems. Highlighted in the historical sections are the major events that contributed to social and cultural traditions persisting in the regions today. The profiles of current social, political, and economic organizations and values are intended to emphasize basic contrasts which may be useful in distinguishing potential, regionally distinct impacts.

The method used in compiling these profiles was a combination literature review and statistical analysis. For each of the six regions, research was primarily focused on those counties that contain uranium resources. For these areas, information compiled from various library sources was used to identify major historical events and to characterize qualitatively cultural traditions in social structure, economics, politics, and social services. Any detailed descriptions, of Indian groups or cities, for example, generally were chosen because they pertained to the people and places found within the smaller county areas. The statistical analysis, based on 1970 census data, provided the basic quantitative data used in the profiles. While these figures are quoted periodically throughout this chapter and complement the information obtained through the literature review, a more thorough tabulation of quantitative results is found elsewhere.[1]

An analysis of the census material was used to select a sample of counties within each region. First, a select list of available census attributes was prepared. Next, a sample of counties was selected for each of the six regions. The sample included all the counties that contained uranium or were near known uranium deposits. In some regions, only a few counties were identified by this selection procedure. When this happened, the sample of counties was increased by including a number of the larger counties, even though they did not have known uranium sources. The final sample of 70 counties was distributed among the six regions as follows: the Northern Rocky Mountains, 5 counties, the Western Great Plains, 16 counties; the Wyoming Basin, 10 counties; the Southern Rocky Mountains, 9 counties, the Colorado Plateau, 19 counties; and the Texas Coastal Plains, 11 counties.

The selected census attributes were collected for the sample counties and subjected to statistical analysis. In particular, those attributes which showed variability among the different regions were analyzed.[1] Such variability could indicate different social, economic, or political traditions within the regions. Statistical data from sources other than the census analysis also were included in this chapter when they furnished additional insights.

The literature review and the statistical data have been integrated in the presentation of social and cultural patterns for the six regions. The "social" aspects are meant to describe the organization and actions of people who live and work together within a region, while the cultural patterns include those values and ideals that form the basis of the social level. Within this framework, the patterns are further divided into their social, political, economic, and social service aspects. "Social," in this context, refers to the organization and values found at the most personal level (e.g., at the level of the person, nuclear family, extended family, etc.); the "political" deals with notions of government, power, authority, and the like; "economic" pertains to the organization and values associated with financial exchanges; and, finally, "social service" refers to matters pertaining to the well-being of an individual or society (restricted to health and educational services in this chapter).

Each of these four aspects of social and cultural patterns are described for the six regions. However, in instances where the most fundamental cultural values of one group differ from those of others within the same region, the groups are taken as representative of different cultural traditions. Consequently, the descriptions of organizations and values make note of these differences and, when it is appropriate, qualitative statements are substantiated with statistical data. The first section in the description of each region is an historical sketch designed to provide a temporal framework within which relations among people of different cultural traditions are seen to develop.

13.2 THE SIX REGIONS

13.2.1 Northern Rocky Mountains

13.2.1.1 Historical Background

In 1805, the Lewis and Clark Expedition marked the beginning of American settlement in the West. These explorers demonstrated the practicability of an overland route to the Pacific and discovered vast amounts of untapped natural resources in the Northern Rocky Mountains. Soon British and French fur traders and trappers settled in the area and began trade with local Indians (e.g., the Colville and Spokane tribes). Likewise, miners arrived and, with their Chinese workmen, panned for gold in the streams and rivulets.[2]

By the late 19th Century, growing population centers reflected the prosperity of the area. One such city was Spokane in eastern Washington. At this time, miners already were extracting rich lodes of silver and lead from the surrounding territory, and the new transcontinental railroad facilitated the transport of these minerals to the city.[2] Moreover, hundreds of wheat farmers and their families began settling in the region. They turned to Spokane as a commercial and financial center where they could borrow money, as well as buy machinery and supplies. At one point, in fact, the population of Spokane was increasing by 5000 people per month.[2]

At the same time, Indian lands were being organized into reservations. The Colville reservation, northwest of Spokane, for example, was established in 1872. Within this reservation, lands were federally classified as suitable for grazing, irrigation, mineral exploration, and lumbering. However, even up into the 1970s, development of the natives' land has been hindered by the lack of established Indian rights regarding human and natural resources. The Colville people feel these will have to be articulated before development of natural resources can begin.[3]

13.2.1.2 Cultural Traditions and Social Organization

Today the Northern Rocky Mountains region is composed of people from two major cultural traditions: (1) Anglo-Americans, and (2) native Americans. The term "Anglo-American" (or "Anglo") will be used throughout this report and henceforth should be taken to refer primarily to those Americans who speak English as their mother tongue, are descended from immigrants of northern European origin, and who adhere to the dominant values expressed in American society today. The term "white" will be restricted in use to those situations in which "Anglo-Americans" contrast with "Indians." The terms "native American" and "Indian," on the other hand, will refer to descendants of the original inhabitants of the New World. Although these two terms refer to all native peoples in a collective manner, it is not necessarily true that the various distinct Indian groups perceive themselves in terms of some pan-Indian identity.

The Anglo-American population in this region descends from the 18th Century European settlers who came to farm, mine, and ranch in this area. Within particular communities, aspects of the original cultures--German, Scandinavian, French, etc.--may still persist today. Accordingly, the family structure most resembles the founding cultural tradition.[4] However, in this region, as well as in all others being considered in this report, the Anglo population is the one most likely to adhere to basic American values of family and person. Thus, the nuclear family is the fundamental social unit. It organizes persons who consider themselves to be free and equal individuals within the system of social organization.

Two Indian groups live in or near the Northern Rocky Mountains region: the Spokane and Colville tribes. The social structure of the Spokane Indians, for example, follows a pattern common among tribes in the area. Organization operates at several levels--from the household to the village unit up to a loosely structured confederation of all the Spokane groups.[5] The Spokane also share a common language.

13.2.1.3 Political Organization and Values

A preliminary statement will serve to characterize the general form of political organization and values within the United States. These observations will not be repeated in following sections, although they will serve to characterize the government form principally adhered to by Americans of northern European cultural traditions.

A system of federal, state, county, and local government forms the basis of political organization. This system puts value on individual freedoms under the law but, at the same time, prescribes certain duties to its citizens (e.g., to pay taxes, to educate their children in approved schools, to obey common laws, etc.). In turn, the government provides certain services to its citizens: schools, health facilities, highways, etc.

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Within this structure, minor changes are tailored to regional circumstances. For example, in the rural areas of the Northern Rocky Mountains, county governments, not local municipal ones, usually serve as the local political base.[6]

Indian groups often hold a separate form of jurisdictional power. In the Northern Rocky Mountains, the Colville Confederated Tribes, for example, has a tribal council consisting of 14 members who are popularly elected and who make policy decisions for the entire reservation.[7] This body is not entirely independent since it must work with the Bureau of Indian Affairs (BIA), a branch of the Federal Government. Within the past decade, the council has been dealing with the BIA in the hopes of properly establishing Indian legal rights and of demarcating the limits of Indian political powers.[3]

13.2.1.4 Economic Organization and Values

Income in the area stems largely from wheat farming, ranching, orchards, and mining. Within the five counties profiled in this section, the Columbia River provides water to irrigate crops and to produce hydroelectric energy for cities and towns. Spokane, once the bustling hub of this region, has suffered a loss of population during this century. Improved highway systems and a decline in rail traffic have meant that people can move their businesses into outlying towns and bypass local transportation centers.[2]

At the present, the native Americans in this area are negotiating to establish their economic rights. The Colville Indians, for example, consider the waters within their reservation (including rivers which form its boundaries) to be under their ownership. This claim has posed a financial threat to local farmers and ranchers whose livelihood depends on continued access to the present water supply.[3]

13.2.1.5 Health and Education

The quality and use of social services differs between the two major cultural groups. As early as the 1930s, the Spokane people were concerned about the contrast in educational opportunities for Indians and non-Indians. As a consequence, a public school was built on the reservation. By the mid-1960s, school attendance among native Americans was above the national average: 92% of the Indian children had graduated from high school, as opposed to a national average of 70%.[5] Nonetheless, Indians are attracted to non-Indian schools found throughout this area. These schools provide general education and occupational training for Indians and non-Indians alike.[5]

Health services likewise differ in white and Indian areas. While it is difficult to say whether the facilities in non-reservation sites are better, the people from these areas are definitely healthier. For example, in 1962, infant death rate among the Colville people was three times higher than it was in the State of Washington as a whole (65 deaths out of 1000 births for the Indians).[8] Morality rates from tuberculosis, influenza, and pneumonia also were high. Illnesses such as these often have been the result of substandard housing facilities, which fail to provide proper shelter in this cold weather zone.[8]

13.2.2 <u>Western Great Plains</u>

13.2.2.1 Historical Background

The introduction of the horse in the early 1700s revolutionized much of Indian life in the Western Great Plains. The Sioux, Cheyenne, and Arapaho, for example, used the animals to hunt bison (a primary source of livelihood), to raid enemy camps, and to serve as a medium of exchange and an indicator of personal wealth.[9] Not all groups, however, had their lifestyles changed as drastically. The Mandan tribe, located in what is now North Dakota, continued to live in villages and cultivate gardens much as they had done before their acquisition of the horse.[10]

British and French traders were among the first whites to enter this region. They came in search of gold and fur, but soon discovered that the Indians provided a vigorous market for European goods. At this time, metal goods (guns, knives, etc.) and certain foreign edibles (including whiskey) were permanently incorporated into the Indians' material culture.[9,10]

After the appearance of whites, destruction came to the Indians in various forms. A smallpox epidemic in 1837 reduced the Mandan population from approximately 1600 to about 200.[10,11] The United States military also took its toll, but not without Indian resistance. The Sioux culture, for example, was one based on warfare where a demonstration of bravery gave men prestige, rank, and wealth.[11] Clashes between groups of Indian warriors and military men were frequent throughout the late 1800s and were prompted by incidents such as the whites' trespassing onto Indian hunting grounds.[9] However, in 1890, the massacre at Wounded Knee spelled an end to this era, for at that time the Sioux nation, the last of the great Indian powers, fell under white command.[11]

With U.S. control of the Western Great Plains established, white settlers moved into the area and began raising cattle and dry farming. These ventures paralleled the Indians' in the region, and both groups--Indian and white--have benefited or suffered depending on the economic climate of the nation throughout the 20th Century.[9]

13.2.2.2 Cultural Traditions and Social Organization

Anglo-Americans and native Americans are the two basic cultural groups in the Western Great Plains. Anglo-Americans comprise 92% of the population in the region.[1] Here, people are almost entirely rural in their social orientation, so much so that even townspeople share many of the social attributes of their country neighbors. These include placing a high value on individual self-sufficiency and expressing attachment to the land.[12]

Traditionally, Indians within the region have had a society based on kinship relations. Although this system of social organization is reported to continue for the Mandan-Hidatsa (the Mandan began to combine with the Hidatsa in the 1870s),[10] the Sioux of the Pine Ridge Reservation generally have replaced kin ties with community ties as the base of their social structure. Especially within larger groups, community ties have grown to provide the source of group pride and a common Sioux identity.[9] However, even with the Sioux, traditional world views, once integrally associated with the kin groups, continue to manifest themselves in specifically Indian attitudes. For example, Sioux believe that man's actions in the world are not segmented into economic, political, and social functions. Rather, relationships should be multifunctional and personal, since the universe, for the Sioux, is a unity within which man is in no way superior to the elements of nature.[9]

13.2.2.3 Political Organization and Values

Because of the sparse population, local government in the Western Great Plains is often centered on the county level. Furthermore, general attitudes can be characterized by groups: ranchers tend to be conservative, dry farmers, radical and anti-establishment;[4] and Indians, suspicious of politicians and political motivations.[9]

As is true of all regions with reservation systems, the United States government exercises direct control here through the Bureau of Indian Affairs. In the past, the Sioux, for example, considered themselves completely dependent on the Bureau, which, to them, eptiomized the white man's world. However, of late, attempts are being made to bypass the organization and to handle matters within the tribal government.[9]

The Sioux tribal council, a parliamentary organization, is situated locally, available to all tribal members, and considered a symbol of native identity by the Sioux themselves. Yet, despite these apparent assets, the council has been unable to gain the widespread support of its people. The reasons for this include the Indian government's connection to the white world and conflicts between the BIA and tribal actions (because of conflicting structures and roles, the council often accomplishes little). Moreover, the Indian view of the world as one of personal interactions goes counter to bureaucratic norms. To a Sioux, the BIA is seen as the mediator between himself and the president, and not a faceless bureaucracy which deals only formally with people.[9]

13.2.2.4 Economic Organization and Values

The region is basically an agricultural-industrial area, with nearly 20% of all families in the county sample self-employed in farming.[1] Among these are sheep and cattle ranchers, dry farmers and irrigation farmers. Laborers, businessmen, and professionals round out the labor force. However, people in the latter two groups are generally considered outsiders even though they might be from the area. This is because their views and interests are considered foreign and clash with those of the farmers and ranchers. Economics and social structure also mix insofar as class hierarchies are based on occupational distinctions.[4]

The ranching and agriculture of the Indian groups reflect, in a small way, the general economic pursuits in the Western Great Plains. However, median incomes for the region begin to tell of the Indians' economically depressed situation ($7584 per year for Anglo-Americans, $4867 for American Indians).[1] To a degree, the Indians' marginal position in the economy is due to the poor land of the reservations and the lack of available transportation systems. This is particularly true of the Sioux at Pine Ridge. What is more, in the case of the Sioux, the people do not place a value on economic profit. Rather, any available surpluses are likely to be shared by kin members or spent on some immediate project. It is foreign to them to value money over kinship, for example, or the immediacy of a daily venture.[9]

13.2.2.5 Health and Education

Generally, there is a difference between the effectiveness of white social service facilities serving whites as opposed to white facilities serving Indians in this region. For instance, schools in white communities traditionally have served to reenforce basic white values and goals,[13] while those in Indian communities have not served Indian traditions.[9,10] Over the years, educational approaches on the Pine Ridge Reservation have ranged from forcing young Indians to change their language and culture to that of the white man, to being so ineffectual that the children leave with an inadequate command of their own language, not to mention English.[9] Unfortunately, the latter example has been used to characterize the situation at Pine Ridge today.[9]

The effectiveness of health facilities is markedly different in the two communities. Health care for the Sioux Indians remains substandard despite the input of federal funding.[9] One possible reason for the failure of this and other community projects is that funds are still directed through U.S. government agencies, leaving the Indians with no voice in how services are provided and with little incentive to participate in the programs themselves.[9,10]

13.2.3 Wyoming Basin

13.2.3.1 Historical Background

Although it is possible that the French or Spanish were the first whites to pass through the Wyoming Basin, history gives that specific honor to one member of the Lewis and Clark Expedition who left the group in 1806 and spent some months exploring the Basin region.[14] In addition, Sacajawea, the woman guide who accompanied the Expedition, was a Shoshone from the area.[15]

By 1825, Wyoming "mountain men" were the guides for settlers who crossed the southern Basin region along the Oregon Trail. This area was further settled with the coming of the transcontinental railroad in 1869. At this time, mining, farming, and ranching families began arriving, despite conflicts with Indian groups (e.g., the Sioux and Cheyenne).[14] This conflict between whites and Indians was even worse in the northern portion of the Basin, so much so that the region was not truly open to whites until several military campaigns after the Battle of the Little Bighorn. After 1876, however, with the Indian nations subdued and the confinement of existing Shoshone and Arapaho to the Wind River Indian Reservation, whites started ranching huge tracts of land, as well as mining for coal. The population of the area remained small, however, and Wyoming became a state in 1890 with well under the number of citizens normally required for statehood. Today, the area retains a low population density, although economic growth in mining and tourism has attracted new residents.[4,14]

13.2.3.2 Cultural Traditions and Social Organization

Native Americans and non-Indians, basically of European descent, make up the population of the region. The latter group includes people of Italian, Scandinavian, German, and Mexican descent. Over the decades, these groups have tended to remain in separate communities which, in many cases, were once the lands of their ancestors.[14] Despite this, these people are united by a strong belief in ranching traditions, especially as they relate to the maintenance of land and the natural environment.[16]

The Indians within the Wyoming Basin include the Shoshone and Arapaho, with the Crow and Cheyenne to the north. The first two groups live together on the Wind River Reservation in the Center of the region and number 2178 and 3048 people, respectively.[15] While traditionally a nomadic people with kinship-based social organization,[17] the members of these two tribes now generally live in towns and have social ties based on tribal, reservation, and family bonds.[15]

13.2.3.3 Political Organization and Values

Historically, Wyoming (the state which encompasses the largest part of the Wyoming Basin) has had a progressive state government. It was the first to give full rights to women (1896), including the right to vote and hold government office.[18,19] Subsequently in 1925, Nellie Taylor Ross became governor of Wyoming and the first woman in the United States elected to that post.[14]

As is true of many other reservations, the tribal council, under the direction of the Bureau of Indian Affairs, is the governing body at the Wind River Indian Reservation.[20] The situation at Wind River, however, is somewhat unique because two different people--the Arapaho and the Shoshone--share the same reservation (the former living in the east, the latter in the western half). The two tribes have separate councils which act jointly on matters of common interest. Moreover, a general council composed of all enrolled members of the two tribes meets at least twice each year.[15]

13.2.3.4 Economic Organization and Values

Today's newcomers to the Wyoming Basin continue to be attracted to the region for some of the same reasons that the first settlers came. Among these is the development of the area's rich natural resources. Coal, uranium, shale, oil, and natural gas are now being extracted in the Basin. Moreover, farmers and stock ranchers continue to supply the nation with food; the network of roads and railroads retains the use of routes once used by early settlers; and the tourist industry has grown to attract permanent residents and seasonal visitors.[4,18]

On the Wind River Indian Reservation, oil and gas revenues provide the major portion of tribal income. In addition to this, the Arapaho Ranch Enterprise (a cooperative Arapaho-Shoshone venture), irrigated farming, and wage labor are the major sources of work for 52% of the available labor force which is currently employed. Another 23% of this labor force is actively seeking work.[15] To aid this latter group, the business council of the two tribes is intent upon attracting business to the area.

13.2.3.5 Health and Education

Because so much of this area is rural, people in isolated areas often need to go long distances for medical and dental care. These services are centered in the area's cities (such as Casper, Wyoming) and in towns with 1000 or more inhabitants.[14]

The citizens of the Basin region place a positive value on the education gained from attending school.[14] This belief is substantiated statistically by the fact that some 59.8% of the population in the ten-county region graduated from high school. The mean level of education is 12.3 years.[1] This faith in education, moreover, is shared by the Indians of this area, who take pride in their skills and training.[21]

13.2.4 Southern Rocky Mountains

13.2.4.1 Historical Background

Among the earliest inhabitants of the Southern Rocky Mountains were the Utes, a mountain people, and the Cheyenne and Arapaho, plains Indians who lived to the north and east. Because of their knowledge of the area, members of these tribes provided valuable assistance to the explorers, trappers, traders, and settlers who arrived in this territory during the early half of the 19th Century.[22]

The Spanish were the first known Europeans to prospect and settle in the area. Many who came to look for gold and silver stayed on as farmers when mining efforts failed. Because of fluctuations in precipitation within the area, initial attempts at dry farming were extremely risky. Beginning in 1851, however, this situation was improved with development of the first irrigation system recorded within what is now the United States.[22]

The purchase of the Louisiana Territory in 1803 prompted further exploration of the region, this time by American citizens. Word in the East told of rich lands for hunters and trappers, and news of the discovery of gold in 1859 brought thousands of people looking for their fortune. Although the gold boom was over by 1890, mining continued and remains central in the lives of thousands in this area today.[22]

People began to consider farming the region when food shortages arose at the time of the gold rush. One reason for this was that transportation was too poor to get sufficient quantities of food into the region. Irrigation of the mountain valleys allowed people to grow crops, while other land was used for grazing of cattle.[22]

During the 20th Century, improved means of transportation have made the area more accessible; in part because of this, tourism has steadily increased throughout the region, and certain resort areas where skiing, hunting, fishing, and sightseeing are available have prospered.[22]

13.2.4.2 Cultural Traditions and Social Organization

The two major cultural traditions of the Southern Rocky Mountains are those of the Anglo-Americans and the Hispanic-Americans. Unless otherwise specified, the term "Hispanic-American" henceforth is used as a general term which refers to people of Spanish, Spanish-Mexican, Indian-Mexican, and Latin American descent. Native Americans are in the minority in the Southern Rocky Mountains. The Utes, for example, were pushed out of the mountains and onto the Colorado Plateau by white settlers late in the 19th Century.[23] A few Pueblo Indians, however, still live in the southernmost counties.

Anglo-Americans, including descendants of 18th Century settlers, comprise approximately 77% of the region's population.[1] This population is highly rural and resides mainly in small communities in the mountain valleys where mining, farming, and ranching persist. Today's transportation networks, however, tie these people with population centers--Denver, Colorado Springs, and Pueblo, Colorado--situated along the eastern boundary of the region. Owing to these physical ties, as well as to cultural links with the dominant American culture, the Anglo population here is seldom as isolated as its Hispanic neighbors.[22,23] The Hispanic-Americans of this region live mainly in the southern counties. Characteristically, they speak Spanish as their first language, are members of extended family groups, are Roman Catholic, and have few financial resources. "Cultural contact" between Anglos and Hispanics of the area, moreover, could be one reason for the Hispanics' increased awareness of their own cultural traditions.[23]

13.2.4.3 Political Organization and Values

People in the Southern Rocky Mountains are involved in politics at different government levels and for different political reasons. The importance of local, municipal government is growing, specifically in Colorado, where mountain communities may be small and somewhat isolated. At the state level, people of this region are divided on issues dealing with the needs of the east and west slopes of the Colorado Rocky Mountains; e.g., regarding policies on water projects, conservation, political representation, and the like. In addition, issues dividing Anglos and Hispanics are commonly voiced in the political arena.[23]

13.2.4.4 Economic Organization and Values

Historically, the region has been subject to a number of economic booms. Early ones included the gold rush of 1859 and the health spa craze of the 1880s. Today the area is experiencing growth due to developments in ski resorts, real estate,[23] and coal and uranium mining. This prosperity, however, does not cover the entire region. The area to the south--largely where Hispanic Americans reside--is one of the most economically depressed regions west of the Mississippi. Automation and a decline in the soft coal industry, for example, have put thousands out of work.[23] This situation is reflected in the figures for Taos County, New Mexico. In this southernmost county in the regional sample, 86% of the population is Hispanic; 36% of all families live at or below the poverty level (as it is defined by the U.S. Government); and the average income of the county ($6781) is well below that for the entire sample region ($8442).[1] The government is attempting to aid this area. The southern counties have been combined with a portion of the Colorado Plateau region and designated as the Four Corners Economic Development Region. Within this region, projects will aim at alleviating high unemployment, poor housing, and low incomes.[23]

13.2.4.5 Health and Education

People of this area have long shown an interest in education. As early as the 1800s, primary schools and a university were operating in Colorado. This interest in education has continued; in the 1960s, Colorado ranked first nationwide in its proportion of college graduates.[23] On the other hand, the recent influx of people to this region has seriously strained the educational system: space and funds are insufficient, and more busses are needed to transport students to appropriate training facilities.[23] Moreover, education among Hispanic-Americans presents the additional problem of language, since many of these students speak Spanish as their mother tongue.

For nearly a century people have been attracted to the region for health reasons. In the 1880s, tourists traveled to the eastern boundary of the Southern Rocky Mountains to use the resorts and natural health facilities (the sulphur and soda springs and a clean, high-altitude climate).[23] Yesterday's resorts have been replaced largely by cabins and camping grounds in today's national parks and wilderness areas, where people now flock to enjoy the natural beauty and healthfulness of a life lived close to nature. Notions of "natural health" and living a better life close to nature, however, belong principally to the dominant Anglo cultural tradition. Hispanic-Americans within this region suffer from noticeably poorer health, due partly to the poverty conditions in which they live.

13.2.5 Colorado Plateau

13.2.5.1 Historical Background

For purposes of this section, the Colorado Plateau has been broken into two subsections: the Northern Plateau (western Colorado and Utah) and the Interior Southwest (Arizona and New Mexico). This has been done because each subregion has a distinct history and population.

European explorers entering the Northern Plateau area in the late 18th Century encountered small bands of native Americans--principally the Ute. Although traditionally hunters and gatherers, the Ute had traded for horses when they were first introduced from the south, and the Indians were seminomadic by the time the Spanish arrived in the area. These early Spanish visitors were clergymen and traders. With time, however, trappers and overland immigrants increased the number of non-Indian people in the area. Early contact between these newcomers and the Indians was largely limited to trading.[24,25]

The southern half of the Colorado Plateau (the Interior Southwest) is the traditional homeland of large numbers of native Americans, including Navajo and Pueblo groups. Early contact with the Spanish resulted in the introduction of horse and sheep to the area. This was especially important to the warlike Navajo, who became expert pastoralists and fierce raiders in the Four Corners region.[26,27] The more peaceful Pueblo people, in contrast, continued to reside in fixed adobe villages and to practice agriculture.[28]

The Spanish presence largely took the form of early missionary work and trading. The missions, however, were rather unsuccessful, due largely to the inability of the missionaries to produce the supplies and gifts promised to the Indians. Anglo-American influence in the entire Colorado Plateau region officially commenced in 1846 after the war with Mexico when the United States took possession of the Southwest. Changes began one year later in the Northern Plateau region when the Mormons first arrived and began settling the area. They had come with the intention of transforming arid acres into a lush, green "Kingdom of God." As part of their project, they used nonviolent means to try to make farmers of the Ute Indians. This only partly succeeded, for in time, the Utes began raiding Mormon livestock. This led the Mormons to raise an army and relocate the Indians.[24] The Indians were ultimately placed on reservations to the southeast of the Mormon settlements.[25]

Conflicts between Mormon and non-Mormon Anglo-Americans characterized the second half of the 19th Century. The United States frowned on the Mormon form of government, which combined church and state. As a consequence, 2500 federal soldiers were dispatched to oust the Mormon leader and replace him with a nonreligious figure. Mineral finds brought in additional non-Mormon groups--miners, businessmen, bankers, etc.--who found the Mormons a somewhat closed community. However, these conflicts by and large ended at the close of the century with the granting of Utah's statehood and the establishment of a conventional democracy in lieu of a theocratic structure.[25]

Anglo-American influence in the Interior Southwest differed from that to the north, partly because of the large number of Indians in the southern area. In the two decades following the United States' possession of the Southwest, federal troops subdued the Navajo and established their reservation in 1868. Before the turn of the century, the transcontinental railroad also reached this area, bringing with it settlers who vied with the Indians for land.[25] Descendants of the early Spanish continued to live in this region and to retain a surprisingly pure form of the early Spanish lifestyle.[4]

Over the past century, military interaction has been replaced by administrative interaction. However, administrative involvement has not always meant that the government is immediately sensitive to cultural traditions. Among the Navajo, for example, allotments of land to family heads and individuals ignored, among other things, Navajo membership in extended families and the belief that people have "use" rights to land rather than ownership of it. Moreover, in the 1930s a program to abate soil erosion caused by overgrazing was realized in part by eliminating half the sheep. As well as bringing about an economic crisis on the reservation, the reduction was psychologically devastating to the Navajo. This was largely because the Navajo perceive sheep not only as an important indicator of wealth, but also as essential to the preservation of their traditional lifestyle.[27]

In 1950, the Navajo-Hopi Long-Range Rehabilitation Act meant the start of federal help in the economic development of the region. At this time, social service projects were aimed at increasing the standard of living on reservations; tribal mineral revenues from outside private investors meant that job-generating enterprises could be initiated by the Indians themselves. However, while industry brought jobs to many non-native people in the area, Indians seeking work often found themselves in unskilled positions. Hence, despite local industry and educational programs, the majority of the Navajo, at least, remain untrained, with about one-third of the employable people unemployed. In fact, underdevelopment continues to characterize reservation life and to contrast with surrounding state standards.[27]

13.2.5.2 Cultural Traditions and Social Organization

People of four distinct cultural traditions inhabit the Colorado Plateau--(1) Mormon Anglo-Americans, (2) non-Mormon Anglo-Americans, (3) Hispanic-Americans, and (4) native Americans.

The Mormon culture remains a major force in the northern region of the Colorado Plateau. Although once a highly ruralized society of Anglo-American immigrants, Mormons have progressively followed the urbanization trends of other small communities in the United States. The Mormon communities, however, still tend to be very close knit, with the Church of the Latter Day Saints the focus of most of life's activities. This religion emphasizes the importance of the family and of achievement within one's lifetime.[4]

The non-Mormon Anglo-Americans of the Colorado Plateau are largely descendants of 18th Century European settlers (e.g., Germans, Scandinavians, etc.). For the most part, they are Protestant farmers, ranchers, and miners who live in communities where aspects of original cultural traditions may still persist.[4] Anglos, both Mormon and non-Mormon, account for 85% of the population of the northern Colorado Plateau.[1]

Hispanic-Americans in the area include people of Spanish-Indian and Mexican descent. The majority of these speak Spanish as their mother tongue, are Roman Catholic, and live within an extended family unit. At the community level, numbers of families are integrated through a close network of social and religious institutions. Although some of these people are descendants of elite families and currently maintain a high economic and social status, a large portion of the Hispanic people are socially and economically disadvantaged.[29,30]

Various Indian groups live in this region, primarily in the southern half. Two of the most important for this study are the Navajo and Pueblo tribes. Traditionally, the Navajo have been nomadic pastoralists who form a tribe only insofar as they share a common culture and language. Thus, rather than focusing on the tribal unit, historically their social organization has been based on the household unit (with family size today averaging 6.5, compared to 3.6 nationwide) and the extended family. This extended family, which continues to be important today, is composed of a number of related households within an area and is the unit within which resources are shared. At this time, however, with growing trust in the Navajo Tribal Council, these native Americans increasingly think of themselves as sharing common interests within a unified tribal nation.[27] The Pueblo Indians, on the other hand, are traditionally a village-based people. Early Spanish influence in the area was important in shaping their family and community structures. This influence has proved to have a lasting quality since many of the Hispanic characteristics remain at the present.[28] Moreover, a spirit of pan-Puebloism is evident in the region despite the number of different cultural traditions which are present.[31]

It is worthwhile to include a list of traits which southwestern tribal representatives recently mentioned as the major characteristics of the belief system adhered to by native Americans in this area. It should be noted that at the same time that these traits summarize the Indian world view, they contrast sharply with non-Indian values. The traits include: "a preference for the group versus the individual, and emphasis on the present versus the future, a respect for age versus youth, a preference for cooperation, a choice of nonmaterial versus material goods, a desire to share versus a desire to accumulate wealth" (p. 56 of Ref. 27).

13.2.5.3 Political Organization and Values

In the northern region of the Colorado Plateau, Mormon involvement in politics continues. While the church hierarchy fails to have the political power it formally enjoyed, lay members of the church actively participate in Utah state and local governments. Throughout the region, there is a balanced two-party system, although the church hierarchy is generally conservative, with most members belonging to one political party.

To the south, the complexion of the cultural groups change, and Indians and Hispanic-Americans appear as participants in state and local governments. This is particularly true in New Mexico.[29] Moreover, aside from state and local politics, Indians in the Interior Southwest also actively participate in their own tribal governments. Although tribal councils, such as that of the Navajo, have been federally created, they are accepted now by the Indian people. Seen by its people as a center of an emergent tribal culture, the Navajo Tribal Council, for example, is entrusted with an authority and force under the United States government.[27]

13.2.5.4 Economic Organization and Values

Wealth is basically divided according to cultural traditions, with the two Anglo-American groups having a distinct economic advantage over Hispanic-Americans and Indians alike. The median annual incomes for each of these groups (averaged over the 19 counties in the sample) reflect this difference: Mormon and non-Mormon Anglo-American, $8232; Indian, $6509; and Hispanic-American, $6211.[1] These differences in income can be correlated to lack of education and to unemployment (e.g., 35% of employable Navajos are without work).[27]

Within the Colorado Plateau, 81% of the families living at or below the poverty level reside in the Interior Southwest, where the population is 33% Indian and 26% Hispanic.[1] Among these two lower income groups, compensation for a lack of income comes in the form of extensive sharing within extended families and from traditional subsistence activities. However, disruptions in the customary lifestyle can make this impossible. For instance, among the Navajo, government projects creating changes in settlement patterns, family structure, and land-use practices have likewise brought changes in such traditional economic pursuits as sheep herding and weaving.[27]

13.2.5.5 Health and Education

In the Northern Plateau region, educational programs have prospered, largely because tightly knit Mormon communities traditionally budget a great deal of money for schools and universities. Health care is also superior in this region, in keeping with Mormon belief that man's body should be maintained.[4]

In the Interior Southwest, language is a problem in the educational system. Among the Hispanic-Americans, Spanish is often the mother tongue of children sent to English-speaking schools.[29,30] Native languages are also spoken among the Indian groups, who use English only with reluctance.[27] However, with the Navajo, for example, children are obtaining an education which is both better and more extensive than what has been available to earlier generations. The problem at this point, however, is that educated Indians either leave the reservation after finishing school or never return after completing their education outside the area.[27]

Health facilities in the southern region include Indian facilities operated by the U.S. Public Health Service. Although per capita health care expenditures in this area often equal those of the United States as a whole, the people of the area are less healthy than the average citizen, owing to the generally poor living conditions. According to reports from the early 1970s, most Navajo families still sleep on dirt floors, and 90% of the Navajo homes are without indoor plumbing.[27] The former condition means that the Navajo are generally more susceptible to illnesses caused by prolonged contact with the cold and damp, while the latter condition means that infectious diseases could arise as the result of improper waste disposal.

13.2.6 Texas Coastal Plains

13.2.6.1 Historical Background

It is probably not the case that the native Americans who originally lived on the Texas Coastal Plains became "extinct" upon contact with the Spanish. More likely, the two peoples intermixed and became culturally indistinguishable. Whatever the case, the Coahuiltecan Indians who once hunted and gathered along the harsh coastal lands no longer survive, while Spanish traditions have persisted until today.[32]

The Spanish began to settle this region around 1750. Laredo, in the southwest, was begun as a family settlement along the Rio Grande, while San Antonio and Goliad, to the northeast, were built around missions and forts. The missions in the latter towns were early links in the Spanish colonization process. However, religious activities soon gave way to political ones as the region became involved in the independence movement in which local American settlers united against Spanish foreign rule. San Antonio was the site of the Battle of the Alamo in 1836. This battle was one in a series which finally secured independence for the Republic of Texas, although disagreement about the southern border of the Republic placed a portion of the Coastal Plains (including Laredo) in dispute.[33]

Texas achieved statehood in 1845, and this was followed by local changes, such as railroads in 1880 and 1881 and irrigation in the 1890s. Railways in the Coastal Plains helped establish ties to the greater United States while allowing for the exportation of crops made possibly by irrigation. The discovery of natural gas in 1908 and oil in 1921 led to further growth of the area. Today San Antonio continues to prosper as an urban center for the region's cattle industry, while the border town of Laredo receives thousands of tourists the year round.[33-35]

13.2.6.2 Cultural Traditions and Social Organization

Members of two cultural traditions--Anglo-Americans and Hispanic-Americans--are found in the Texas Coastal Plains. Overtly, this region is highly influenced by Hispanic traditions and traits, partly because of its proximity to the Mexican border, the area's longtime contact with Hispanic culture, and the sheer number of visitors and workers from Mexico. Architecture, food, and place names are but a few facets of life which reflect Hispanic influence.[33] Yet despite these aspects of shared traditions, the people of the region perceive the two cultural groups to be quite distinct. Characteristically, the Anglos (including people of German, French, and

Belgian descent)[33] are richer and politically more powerful than their Hispanic neighbors.[35] However, the latter people, who constitute nearly 50% of the area's population,[1] have become increasingly aware of their power as a group. This has been the cause of some tension in the region.[35]

13.2.6.3 Political Organization and Values

San Antonio is an important political center in the northern section of the region under consideration. Traditionally the Anglos of this city (a number of whom are businessmen and the owners of land in the Coastal Plains) have held political control. Their belief was that government is best served by trustworthy, competent, and compatible people.[35] However, recently the Hispanic-Americans of this area have begun to unite and to use their political strength in order to receive the services which have been promised their communities. Support for this relatively new organization (Communities Organized for Public Service, or COPS) has arisen from church leaders and Federal Government workers, as well as from many of the area's poor.[35]

The political organization of the southern portion of the Coastal Plains is unique because of its ties to the adjoining area in Mexico. City officials in Laredo, for example, are in constant communication with people in Nuevo Laredo across the border. By cultural definition, these ties are not strictly political ones, but extend to economic and personal relations as well.[36] However, the people who live on both sides of the border realize the uniqueness of their situation. In a certain way, they are tied to one another more than to their respective countries. Because of this, they are especially hopeful that their situation is understood by powerful outsiders, including the United States and Mexican governments, who might unknowingly damage the unique local organization of the region.[36]

13.2.6.4 Economic Organization and Values

Despite industries involving cattle, agricultural products, gas, oil, the military, tourists, and transportation,[37,38] the Texas Coastal Plains outside of San Antonio remains a relatively poor and isolated area. Unemployment, at least cycles of unemployment, and low wages are a constant factor of life here. Reasons for this include the scarcity of jobs, the ineffectiveness of unions, and easy access to vast numbers of Mexican workers who may be legally or illegally employed. Jobs in agriculture are available every year, but these are seasonal.[36] The consequences of these factors are reflected partly in median incomes ($7613 for Ango-Americans and $6473 for Hispanic-Americans), but perhaps more so in poverty figures: 34.8% of the Hispanic-Americans live at or below the poverty level.[1] Moreover, the mean income in 1970 for all families living at or below this level was $2220.[1]

These figures, however, cannot portray the uniqueness of the situation in which the notion of wealth or poverty is relative to the people's financial expectations. Hispanic-American citizens of this region have realized only recently that they have legal rights which will enable them to enjoy a standard of living closer to that of the generally richer Anglo community.[35] Moreover, no matter how poor the American region is, it always is considered richer than the Mexican region to the south. As a consequence, Mexicans continue to cross the international boundary in search of jobs on the American side. This is because for those to the south of the Rio Grande, the United States remains the land of opportunity and wealth.[36]

13.2.6.5 Health and Education

Cities and towns such as San Antonio and Laredo are centers for the social services in this region. Primarily because of its large military installations, San Antonio is the site of several related training schools, including an Army medical center and an Air Force flight training center.[38] Throughout the Coastal Plains, the large number of Spanish-speaking children means special considerations must be given to language programs in schools. What is more, schools along the border are constantly faced with Mexican children who wish to enroll because of the quality of the education there.[36]

People also turn to the area's cities for health care. As well as having numerous hospitals and health clinics which cater to patients' needs, San Antonio is a center for medical training and research facilities, principally those connected with the military.[38] However, a large percentage of the doctors of this region have gone outside the country for their education. For example, 50% of the doctors in Laredo were trained in Mexico and administer to Spanish- and English-speaking patients from both the United States and Mexico.[36]

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14. ARCHEOLOGY AND PREHISTORY

14.1 GENERAL ASPECTS

The purpose of this section is to delineate the types, relative frequency, and the distribution of prehistoric cultural resources in the six regions as determined through a survey of the available literature. Discussion has been divided into two parts: (1) a summary of the general cultural patterns known to have existed throughout the regions, and (2) a discussion of the types of cultural resources that have been listed in the National Register.

14.1.1 Cultural Traditions

The area comprising the six regions has long been marked by cultural diversity and changing cultural geography. In order to discuss efficiently the complex history of cultural continuity and change in the area, the anthropological concept of cultural tradition unit is introduced.

A tradition is defined on the basis of cultural traits shared by the members of one or more societies over time, as reflected in such material remains as house and settlement types and ceramic and stone tool styles and functions. Moreover, a tradition is defined in terms of the type of lifestyle manifested by societies, particularly their economic and sociopolitical organization.

In the summaries which follow, material remains used to identify specific traditions are discussed in chronological sequence, as are, to the extent currently known, such basic cultural patterns as subsistence, settlement, economic, and sociopolitical organization. Descriptive summaries of the material remains associated with each tradition are omitted, since they lie beyond the scope of this highly compressed review.

Each tradition (see Table 14.1) discussed in the following sections represents a broad adaptation to a general area, with subtraditions representing the more specialized adjustments to a particular set of microenvironments occupied and exploited by local populations. Key variables in an understanding of the nature of a particular tradition are the settlement system and subsistence strategy. Societies are most directly linked to their local environments through their technological and economic systems. The structure of the local environment, in combination with specific patterns of exploitation (based on available technology and economic organization), strongly influences the demography, settlement pattern, and sociopolitical configuration of human populations. Characterization of these aspects for a particular tradition makes it possible to predict, in a broad way, the types and frequencies of cultural remains that may be expected in a given area. Furthermore, these data can be related to an ecological analysis of the region to determine which areas are most likely to contain undiscovered prehistoric cultural remains.

It should be pointed out that broad cultural and material similarities existed among the six regions, particularly in the earlier periods. It is thought by many that the regions shared a Pre-Projectile-Point Horizon (an ill-defined period of time prior to the advent of stone projectile points used in hunting activities). The chronology, and even the existence, of this horizon has been variously interpreted. A few sites in early geological strata have been reported to contain clusters of crudely made tools not associated with projectile points.[1] Moreover, early materials known to be in excess of 15,000, and perhaps 20,000, years old are also reported in southern South America, which tends to support an argument for a greater antiquity at the North American sites. Presently, this horizon is identified by tool types only, and other aspects that more clearly define a tradition are not known. The Pre-Projectile-Point Horizon was followed by a lifestyle that emphasized hunting and appears to have involved two geographically distinct adaptive strategies (see Table 14.1). In the following periods, the differences among human societies in the six regions increased as local populations made more specialized and diversified adaptations to their specific environmental settings.

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Table 14.1. Major Cultural Traditions of the Six Regions[a]

DATES	COLORADO PLATEAU	SOUTHERN ROCKY MOUNTAINS	WYOMING BASIN	WESTERN GREAT PLAINS	NORTHERN ROCKY MOUNTAINS	TEXAS COASTAL PLAINS
A.D. 1500 – 1000	Southwest Tradition (Anasazi)	Plains Village Tradition	Plains Village Tradition	Plains Village Tradition	Northwest Riverine Tradition	(Late Period) Desert
700		Southwestern Tradition	Woodland Tradition	Woodland Tradition	Northern Forest Tradition	
0	transition					
B.C. 1000 – 4000	Desert Tradition	Plains Archaic Tradition	Plains Archaic Tradition	Plains Archaic Tradition	Desert Archaic Influence	Archaic Tradition (Middle Period)
5000 – 7000		Big Game Hunting Tradition	Big Game Hunting Tradition	Big Game Hunting Tradition	Old Cordilleran Tradition	Big Game Hunting Tradition (Early Period)
8000 – 20,000	Big Game Hunting Tradition					
	Pre-Projectile-Point Horizon →					
40,000						

[a]Dashed lines indicate the approximate beginning of a transition between major cultural traditions.

Modified from: (1) G. R. Willey, "An Introduction to American Archaeology," 1966; (2) J. D. Jennings, "The Desert West," in: Prehistoric Man in the New World, 1964; and (3) W. R. Wedel, "The Great Plains," in: Prehistoric Man in the New World, 1964.

14.1.2 Sites of Recognized Importance

The discussion presented for each region includes a description of the types of sites that are included in the National Register. However, it should be noted that such sites may not be (in fact, most often are not) representative of the full range of types and proportions of cultural resources present in a given area.

14.2 THE SIX REGIONS

14.2.1 Northern Rocky Mountains

The Northern Rocky Mountains region is included within the Interior Plateau Culture Area. This area appears to be the center of development for one of America's earliest cultural traditions--the Old Cordilleran.[2] Elements of the tradition persisted as local populations evolved a more specialized pattern of riverine exploitation, which was supplemented with hunting and gathering. By the time Europeans began trading in the area, indigenous populations were tribally organized societies living in large villages. Some of their material items and social patterns were also shared by the complex chiefdom cultures of the Northwest Coast.[2,3]

14.2.1.1 Prehistoric Cultural Development

The Old Cordilleran Tradition is the first of three major traditions recognized in the Northern Rocky Mountains region after the proposed Pre-Projectile-Point Horizon. The Interior Plateau and Northwest Coast appear to be the center for this tradition, which persisted until at least 5000 B.C.[2] Sites associated with this tradition are identified by characteristic styles of projectile points and have been related to an economic base consisting of unspecialized hunting of terrestrial and marine animals, fishing, and plant collecting.[2,3] Local populations were small and probably were organized into band-level societies. A specific settlement-system model capable of predicting site locations has not yet been developed.

Sometime between 5000 and 1000 B.C., more specific cultural adaptations were made to the major environmental zones of this area, resulting in two subtraditions: the Northwest Coast Tradition and the Northern Forest (inland) Tradition.[2] Circumstances and processes which led to these two adaptive trends are not well understood. For groups in inland areas, where seed processing continues in importance along with the utilization of riverine resources, either a variant of the Archaic Traditions or a tradition which follows that of the Old Cordilleran Tradition has been postulated.[4-6] These groups may not have had as strong a reliance on a riverine economy as that reported for later traditions. Settlement sites would have been located near water, along rivers and creek valleys, as well as by other microenvironments which provide plant and animal resources.

Between 1000 B.C. and A.D. 1300, Northwest Riverine populations increased in size and became more stable. A more complex social organization probably also developed. Villages, founded mainly along rivers, were the most permanent settlement type, although they were abandoned for parts of the year while the inhabitants hunted and gathered plant products.[2] River-fishing, particularly in the rich fishing areas along the plateau edge, was of great importance.[2] House types were variable over the region. In the north and west, earth-covered pit houses and plank and mat lodges were frequently used. Open camps were more typical in the south. Other aspects of the regional culture during this period were the burial in pits or cremation of the dead, the use of polished stone tools, and the production of wood, stone, and bone carvings with distinctive art styles.[2,5,7] Several of these aspects, such as mat and plank housing, wood and bone carving, and cremation, appeared as a result of contact with tribes in the coastal areas.[2] Some coastal institutions may also have been adopted by locally evolving inland populations. Although some subregional and chronological differences undoubtedly existed, a commonality in heritage was beginning to emerge, particularly in the north and west (i.e. in northeastern Washington, Idaho, and western Montana).

After A.D. 1300, established patterns continued until contact was made with European traders and missionaries in the early 1800s.[2] Both the Northwest Riverine and Northwest Coast traditions were quite similar. Also, there was much contact between the tribes within these two cultural traditions. In addition, some inland populations established contacts with western tribes of the Plains area.[2] Populations in the northern interior plateau continued to occupy river villages that served as fishing stations and as bases from which hunting groups ventured in search of game.[2] The northern settlement-subsistence system included other temporary satellite camps at special fishing grounds, root-gathering sites, and berry-picking locations.[2]

In the southern part of this area, horses, guns, tribal organizations, and war honors spread from groups like the Blackfoot to the Nez Perce and Flatheads, who were receptive to many of these influences.[2] Similar influences probably also affected indigenous populations living on the eastern side of the Northern Rocky Mountains.

The general settlement-subsistence systems of late prehistoric and early historic populations of the Riverine Traditions are fairly well understood, as they can be tied to ethnographically described systems. For periods prior to this, details are less clear and reconstructions are based on the premise that site function, location, and period of occupation would have been determined by the quantity and quality of particular seasonal resources. Microenvironmental studies would therefore be useful in predicting historic and prehistoric site locations. In the southern and eastern portion of the Northern Rocky Mountains, settlement-subsistence systems were more similar to those described for the Western Great Plains (Sec. 14.2.2).

14.2.1.2 Sites of Recognized Importance

The cultural resources in the Northern Rocky Mountains region of Washington, Idaho, and Montana that have been included in the Federal Register are primarily historical sites--e.g., missions, historic buildings, railroads, trails, and similar points of interest. Relatively few prehistoric sites are recorded in the Register.

14.2.2 Western Great Plains

In the Plains Culture Area, four overlapping cultural traditions have been identified.[2] In a broad way, the culture history of this area has been related to that of the Eastern Woodlands, with elements of an eastern origin adapted to western environments. The horse was introduced in the 17th and 18th Centuries, causing modifications both in the horticulturally based Plains Village Tradition and in the buffalo-hunting-based Plains Archaic Tradition which had persisted in some areas.[3] The Western Great Plains region is located within two subregions of the Plains Culture Area as defined by Willey:[2] the Middle Missouri and the Central Plains subregions.

14.2.2.1 Prehistoric Cultural Development

Although earlier occupations are suspected, the earliest tradition that has been well documented is the Big Game Hunting Tradition. Several early sites associated with this tradition are known in western South Dakota and Nebraska and adjoining states to the west.[2] Well-defined subsistence-settlement systems have not been developed.

Climatic change between 4000 and 3000 B.C. seems to be correlated with a decrease in human population numbers.[2] By 3000 B.C., a number of sites associated with the Plains Archaic Tradition appeared.[2] Artifacts comprising task-specific tool kits varied from region to region and were associated with hunting and gathering societies.[2,8] Archeological sites included camps at the base of bluffs, on river terraces, in caves, and in upland areas (e.g., buffalo kill sites).[2,9]

Emergence of the Plains Woodland Tradition is marked by the appearance of pottery and maize horticulture.[2,3] These features originated in the Eastern Woodlands and diffused into most of the Plains subregions between A.D. 1 and A.D. 1000.[2] The features may have been brought westward by people with a horticultural tradition who moved into what were then more agriculturally favorable areas.[10] Most of the earlier manifestations in the Central Plains subarea are known from small sites in creek valleys associated with a hunting-gathering economy.[10] Pottery was not plentiful in the Central Plains, and direct evidence for horticulture is scanty.[2] However, sites in the Missouri River drainage have more ceramics present, and a few burial mounds are reported in the river valleys.[2] In general, the larger archeological sites are likely to be found on terraces and floodplains flanking rivers and creeks, while hunting stations, kill sites, etc., would be expected in more remote locations.

The Plains Village Tradition began around A.D. 1000 when many changes occurred in several of the Plains subregions. In the Central Plains, sites continued to be located in creek valleys, although they increased in size, and the subsistence system relied more heavily on cultivation of beans, pumpkins, etc.[3,10] Permanent settlements contained scattered earth lodges and large storage pits.[3,10] In the Missouri River drainage area, houses were larger and some were aligned to form rows.[2] Subsistence in this area was based on horticulture, with a heavy reliance on bison hunting as well.[3] Regional differentiation in cultural patterns became more evident with time.[3]

Droughts and dust storms appear to have occurred in the western portions of the Dakotas and Nebraska in the late 1400s; this coincided with the abandonment of many village settlements.[3] The return of a more moist climate in later years coincides with the reappearance of village horticultural settlements, such as the cultural complex in the eastern Colorado-western Nebraska area which has been identified with the Plains Apache of the historic periods.[3,10] The introduction of the horse and gun to cultures of the Plains Village Tradition in the 17th and 18th Centuries led to further changes in local populations. Site locations are similar to those described for the Woodland Tradition.

14.2.2.2 Sites of Recognized Importance

The Federal Register lists many sites of cultural importance in the counties in the Great Plains region. The types of sites most often included are prehistoric bison kill sites and historic stagecoach stations, forts and mining areas. In this area, particularly South Dakota, there has been a strong interest in recognizing and preserving historic districts in local towns.

14.2.3 Wyoming Basin

The Wyoming Basin region is on the western edge of the Great Plains Cultural Area, as defined by Willey[2] and Spencer and Jennings.[3] The cultural history of this part of the Great Plains is not well defined in the literature, although the area is rich in cultural resources. The area is characterized by a persistence of cultural traditions associated with hunting and gathering subsistence. Changes in the organizational structure of local societies over time seems to be correlated with changes in subsistence strategies. Simple hunting and gathering societies evolved into a more complex tribal level of organization. By the Historic Period these societies had further evolved into a specialized nomadic life based on the exploitation of buffalo and the use of horses for hunting and transportation of family goods.

14.2.3.1 Prehistoric Cultural Development

The Pre-Projectile-Point Horizon, as defined by Willey[2] and Krieger,[1] also may have been represented in this region by 40,000 B.C. Between 20,000 and 10,000 B.C., the Big-Game Tradition is reported in the North American Plains as well as the Wyoming Basin.[2,3,11] The Big Game Tradition was a pattern of life organized around the hunting of large herd animals. Presence of the tradition can be identified by different types of lithic tools.[2,3,11] The associated settlement pattern includes, but is not limited to, camps and kill sites.[2] Additional site types are also thought to exist. Criteria for predicting the location of sites from this tradition in pre- and post-Pleistocene environments are not well developed. Between 5000 and 4000 B.C., the Big Game Tradition was modified to a more specialized hunting and gathering tradition. This tradition, the Archaic, is associated with larger settlements, and includes a more specialized tool complex and a cultural pattern reported throughout most of the areas of the United States, particularly in the Eastern Woodlands.[2] In the Plains, this tradition arose somewhat later than in other areas of the country and lasted until the beginning of the Christian era (ca. A.D. 1).[2] A well-defined subsistence-settlement system that could be used for site prediction has not been developed for this region. Sites can be expected in many microenvironments, such as at the base of bluffs and on hilltops, although larger settlements have been found on creek and river terraces or on bluffs adjacent to water sources.[9] Cave sites are also reported.[12]

By about A.D. 1, the Archaic gave way to the Woodland Tradition, which can be recognized by the presence of ceramics and indication of farming. This tradition was well developed in the river valleys of the Eastern Plains, although the importance of farming over hunting and gathering is difficult to assess in the Western Plains. Some elements of this tradition may have extended into the eastern valleys of the Wyoming Basin.

By A.D. 1000, a more developed agricultural tradition, the Plains Village Tradition, is defined in the Missouri River drainage.[2,13] Associated with earthen lodge villages located along rivers and creeks and with horticulture, buffalo hunting, and certain ceramic and lithic tool types, this tradition is directly linked to certain semisedentary tribes of the 18th and 19th Centuries (Mandan, Arikara, and Pawnee).[2,3,14] Some material elements of this tradition have been reported in cave sites and other localities in Wyoming.[12,14,15] Interpretation of available data from this region has led some authorities to suggest that a hunting-gathering economy based on bison exploitation persisted.[14] Pictographic caves are also associated with this period. This tradition was modified by adoption of the horse and by a nomadic to seminomadic settlement pattern after A.D. 1700. Population densities of the nomadic tribes probably were lower than those of more sedentary societies.

Archeological sites are varied and located in numerous microenvironmental settings (butte tops, valley rims, valley slopes, and creek and river terraces).[9] Areas near water and in sheltered locations, in addition to caves, are most likely to contain evidence of prehistoric cultural remains associated with woodland and village traditions. Sites may include lithic and ceramic remains and surface evidence of stone fireplaces and stone circles which surrounded the edge of the teepee (teepee rings).

14.2.3.2 Sites of Recognized Importance

Some site locations scattered throughout the counties of the region are listed in the Federal Register. These include a variety of site types, e.g., prehistoric/historic buffalo kill sites, prehistoric rock shelters, prehistoric petroglyphs, important historic passes, early historic mining sites, historic forts, and historic stage depots.

14.2.4 <u>Southern Rocky Mountains</u>

The Southern Rocky Mountains region is included in the boundary zone separating two different cultural areas--the Southwest and the Great Plains. Both of the latter areas strongly influenced local cultural traditions in the Southern Rocky Mountains region.[2,16]

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14.2.4.1 Prehistoric Cultural Development

Prior to A.D. 1, cultural traditions in north-central New Mexico and central Colorado (Table 14.1) closely paralleled the sequence of traditions of the Colorado Plateau (Sec. 14.2.5). Similarities in material culture and subsistence-settlement systems would be expected. Small band-level societies exploited a wide range of plants and animals located in varying ecosystems.[8] However, the archeological information necessary for a better understanding is not available.

Cultural development in the Southern Rocky Mountains region by A.D. 1 can be differentiated from the distinctive Anasazi developmental phases in the Colorado Plateau. In the north-central portion of New Mexico there was a regional subtradition (the Largo-Gallina) involving sedentary agriculturalists and more complex tribal societies which were influenced by material traits of the contemporary Anasazi.[2] Archeological sites can be differentiated by ceramic styles, house types, and the appearance of fortified settlements. Fortification of settlements is implied by the presence of heavy wooden stockades protecting the border communities of this area. It is possible that these "frontier" settlements were subject to attack from northern and eastern seminomads. Willey also reports other village settlements were present further north and east in the Northern Rio Grande region during the same time.[2] Settlements contained stone and adobe architecture (although pit houses persisted). Rock painting and petroglyphs became a distinctive type of material remain. However, the ceramics were plainer and cruder than those produced by the Anasazi.[2,17] Many settlements in central Colorado and eastern New Mexico disappeared by A.D. 1100. Some populations in this peripheral area may have moved further south, while others remained in the area and probably followed a simpler lifestyle, more like that of the earlier Desert Tradition.[2] However, some social institutions associated with the more complex tribal villages may have persisted among certain groups. Holdouts that remained in this area may have been the ancestors of the historic Utes and Paiutes.[2]

Remnants of village sites are most likely to be found in river and creek valleys or on mesas. Other sites, such as temporary hunting or collecting stations, are likely to be found in varied microenvironments (such as hill slopes, forested areas, etc.). In north-central Colorado and along the eastern flanks of the Southern Rocky Mountains (the Front Range), traditions and cultural histories probably followed those described for the Western Great Plains after A.D. 1 (Sec. 14.2.2).

14.2.4.2 Sites of Recognized Importance

Sites of recognized cultural importance for the counties of the region are given in the Federal Register. In general, the types of properties that are found in the Register are historic structures associated with mining and ranching settlements of the 18th and 19th Centuries. Few prehistoric sites have been recorded, reflecting the limited study that this area has received. However, it can be expected that numerous prehistoric sites will be found in the future.

14.2.5 Colorado Plateau

The archeology of the Colorado Plateau, particularly the later traditions, is among the best known in North America. The area is characterized by a complicated cultural history that led to stable and successful agricultural societies.[18] Although simply organized at the tribal level, village integration attained an extraordinary intensity in this area of the United States by way of a complex system of religious fraternities.[8]

14.2.5.1 Prehistoric Cultural Development

Evidence of the earliest occupants in this area is scanty. Willey and Krieger suspect that a Pre-Projectile-Point Horizon (ca. 40,000 B.C.) may be present in this as well as other western regions; however, few cultural remains dating from this period have been uncovered.[1,2] There is some evidence for the presence of a later Big Game Hunting Tradition prior to 7000-8000 B.C. This is represented by elephant kill sites and finds of diagnostic projectile points associated with this tradition;[1,18] however, data sufficient to define associated subsistence-settlement systems are presently lacking. As a result, prediction of site locations prior to 8000 B.C. is difficult at best.

By 7000-8000 B.C., the Desert Tradition appeared in the area. At this time, small societies composed of hunting and gathering bands began to exploit a much wider range of plant and animal resources located in varying ecosystems.[3,8] Despite some regional specializations in material remains, a general list of artifact types associated with this extensive subsistence adaptation has been developed. Perishable and nonperishable remains include basketry, milling stones for seed processing, small projectile points, fire drills, and fur cloth.[19,20] By 2000 B.C., some maize was cultivated.[3] In the Colorado Plateau, the Cochise variant of this tradition has been

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identified as the general base for the development of the complex Mogollon and Hohokam cultures.[3,21] Elements of this variant are also expressed in the Anasazi, as manifested by the skillful basketry and utensil types.[3] However, the developmental Anasazi cultures are not as well understood, and sites of this tradition are particularly important.[2,11]

Archeological sites of the Desert Tradition are typically found in caves and along river/creek floodplains.[3,4] It is also suspected that special-purpose sites exist in various eco-niches, such as near springs or in thorn brush, and are associated with special plant-collecting and small-game-hunting activities. More data on the subsistence-settlement system for this tradition are necessary for reliable prediction of site locations.

The Southwestern Tradition appears to have emerged between 100 B.C. and A.D. 400 as resident desert cultures received infusions of Mesoamerican cultural elements (ceramic designs, domestic plants) in addition to influences from the Southeast.[2,3] The subsistence base shifted to cultivation of the Mesoamerican maize-bean-squash complex, although some hunting and plant-collecting continued to be of importance.[2] A ceramic technology was also introduced.[3] Sedentary villages, which later evolved into larger towns, became the fundamental settlement unit.[2] Architectural types included individual pit-houses, jacals (stone or adobe houses), and multistoried buildings of stone or adobe masonry.[2,21] A tribal level of organization, with larger populations, was attained, and social, political and religious organizations were based upon the local community and region.[2,8]

Between A.D. 400 and 1000, four regional subtraditions based on maize horticulture and cotton farming developed in different geographic areas of the Southwest.[2,21] The Colorado Plateau was almost exclusively occupied by village settlements of the Anasazi subtradition, although some sites of Mogollon subtraditions may have existed along the southern boundary in Arizona. Moreover, along the northern and eastern peripheries in Utah, Colorado, and central New Mexico subregional variations on these traditions emerged.[2]

The Anasazi arose later than the other subtraditions but soon covered the largest area of the Southwest.[3] This tradition passed through several developmental stages and can be traced to the current Pueblo tribes inhabiting the same area.[3] Each stage is identified by stylistic attributes in specific material remains (e.g., pottery forms and design motifs, basketry techniques, village orientation axis, and house and settlement type).[2,3,22] The cultural climax of the Anasazi was reached between A.D. 1000 and 1300, when large towns such as Pueblo Bonito with developed architecture appeared for the first time.[2,23] Water-control projects, including the building of dams, terraces, and canals, were undertaken by one or more villages, and high levels of craftsmanship were attained in ceramics, textiles, and jewelry manufacturing.[2,3,21] In addition, more hybrid crops were being developed.[21]

From A.D. 1300 to 1700, populations were concentrated in larger but fewer towns located in open areas, and the total area of Anasazi occupation decreased.[2,21] Zuni and Hopi settlements were concentrated on the Little Colorado and northern Rio Grande and were encountered by the Spanish in the 16th Century.[2,23] Some of these settlements are still occupied today. A high level of skill and artistry was continually maintained in the arts and crafts during this era.[21]

Archeological sites of the Anasazi were typically located in caves, or on overhangs or mesas, and near valleys with water sources.[2,18] Some sites, such as those in the San Juan drainage, were placed in defensible locations.[23] Most settlements are associated with complex surface architecture. Sites with a Mogollon influence may be present in the southwestern border of this area. Town sites have less orderly layouts and typically are found on the summits of ridges near a strip of arable land.[3] Moreover, special-purpose sites associated with both traditions are likely to be found in the area surrounding the settlements. Some probably served for the collection and processing of wild foods, while others functioned as sacred areas and ceremonial sites. Important data concerning prehistoric land use and population dynamics may be obtained from sites of this tradition.

14.2.5.2 Sites of Recognized Importance

Numerous cultural resources of the counties included in the Colorado Plateau are listed in the Federal Register. This area has almost double the number of listed properties as the other five regions. Moreover, the ratio of prehistoric to historic sites is among the highest of all of the six regions. Listed properties in the Colorado Plateau include prehistoric architectural remains of village settlements, prehistoric pictographs, early historic pueblos, railroads, missions, scenic areas and monuments, and historic buildings.

14.2.6 Texas Coastal Plains

The Texas Coastal Plains region was characterized by a series of relatively static and conservative traditions and the persistence of societies consisting of small bands. Hunting, collecting, and fishing continued while more complex social, economic, and political developments were emerging in the Southwest and Southeast.[2] The Texas Coastal Plains area, which includes the "horn" of southern Texas and all of the coast, was ill-suited to native agriculture.[2] The area also was important as a corridor linking Mexico with the Eastern Woodlands of North America.[2]

14.2.6.1 Prehistoric Cultural Development

The cultural traditions of this region following the Pre-Projectile-Point Horizon era can be subdivided into three periods. The early period is represented by the Big Game Hunting Tradition (see Secs. 14.2.3, 14.2.4, and 14.2.5). Evidence for this tradition is found in the scattered remains of projectile points,[2] indicative of possible widely spaced camp sites. A well-defined subsistence-settlement system has not been developed for this area, and archeologically sensitive areas cannot yet be reliably predicted.

The Middle Period is represented by the Desert Archaic Tradition, which also dominated the Colorado Plateau until approximately A.D. 1. Willey[2] and Kelley[5] have subdivided this tradition into several temporal-spatial variants distinguished by diagnostic complexes of material remains. On or near the Texas coast, stone projectile points, shell tools, knives, gravers, etc., of specific styles are found in shell middens and are associated with a marine-riverine-adapted economy.[2] Archeological sites are probably to be found near seasonally available marine resources, as well as other microenvironments which produced usable plant and animal resources on a seasonal basis. Site types include open camps, burned rock middens (composed of organic debris), and rock shelters.[24]

In the southwestern part of Texas, the "horn" area, another Archaic Tradition has been identified. The economic base reflected the seed-gathering of the Desert Tradition, although seeds were ground with wooden implements rather than stone tools.[2] This phase lasted throughout the Middle Period and is primarily differentiated from the Early Period by the appearance of stemmed dart points.[2] Archeological sites are to be found in varied microenvironments, particularly along streams and creeks.

The beginning of the Late Period (ca. A.D. 700) and the Late Desert Archaic Tradition is defined by the presence of ceramics and small arrow points.[2] However, the subsistence-settlement system remained almost the same, and small bands of people continued to inhabit the inland areas. The population density was probably low. In the coastal region, typical sites include shell middens along the beaches and camps on the inland coastal plain.[2] Other special-purpose sites may also be expected. Several regional complexes are also defined for this period on the basis of differences in ceramic style.[2,25] Although differences in the coast-inland subsistence adaptations have been noted by Willey,[2] basic social, political, and economic organizations probably remained much the same.

This coastal region was also important as a corridor for Mesoamerican (Mexican)-Southeastern United States contacts.[2,26] Mesoamerican and Southeastern influences have been documented at a few sites in this area. However, the processes by which these influences arrived are not well understood.[2] Therefore, archeological sites in this area may provide important data for the understanding of certain evolutionary problems in North American culture history.

14.2.6.2 Sites of Recognized Importance

In the Federal Register several types of sites are listed for the counties of the Texas Coastal Plains region. With the exception of one prehistoric area, Federal Register properties are all of historic origin and include Spanish missions, forts and military sites, and colonial structures of various kinds.

14.3 SUMMARY AND CONCLUSIONS

From the foregoing discussion, it should be clear that the prehistory of the six regions is not well understood. At present, detailed maps identifying specific types, numbers, and densities of archeological sites are not available for any of the regions. Moreover, there are substantial gaps in the availability of spatial and temporal data, particularly for the earlier periods and traditions. As a result, major research questions still remain, even for those regions that have received the most archeological attention. Therefore, in each regional summary, four types of information that could be derived from the available literature have been emphasized: (1) the types of sites that could be expected and comments about general site function, (2) the ecological areas, particularly the topographic zones, most likely to contain material evidence of prehistoric subsistence-settlement activities, (3) specific research problems for a region or subregion which would affect the scientific importance and National Register evaluation of a particular site or cluster of sites, and (4) the types of prehistoric and historic period sites that have been included in the National Register of Historic Places. This information has been generally summarized in Table 14.2.

Given the fixed nature of the archeological resource base of the six regions and the increased rates with which that base is being destroyed by technological development, vandalism, and looting, it is essential that future land development activities provide for the identification, protection, preservation and/or scientific investigation of the resources by qualified professionals before they are disturbed or destroyed.

Table 14.2. Site Types and Locations for the Six Regions[a]

Colorado Plateau			Wyoming Basin			Southern Rocky Mountains		
Tradition	Site Type	General Topographic Location	Tradition	Site Type	General Topographic Location	Tradition	Site Type	General Topographic Location
Pre-Projectile Point Horizon[b]			Pre-Projectile Point Horizon[b]			Pre-Projectile Point Horizon[b]		
Big Game Hunting Tradition	1. Elephant kill sites 2. Camps 3. Caves	1. Open areas 2. Caves	Big Game Hunting Tradition	1. Kill sites 2. Band camps		Big Game Hunting Tradition		
Desert Tradition	1. Open air camps 2. Cave camps 3. Special purpose sites	1. Caves 2. River/creek flood plains 3. Scattered locations	Plains Archaic Tradition	1. Main camps 2. Satellite camps 3. Special purpose sites	1. Creek/river 2. Bluffs 3. Caves	Desert Tradition	1. Open air camps 2. Cave camps 3. Special purpose sites	1. River/creek flood plains 2. Caves 3. Scattered locations
Southwest Tradition	1. Open town sites 2. Irregation-water control sites 3. Cave town sites 4. Special purpose sites	1. Valleys 2. Near water sources 3. Overhangs and mesas 4. Scattered locations	Woodland Tradition	1. Villages 2. Kill sites 3. Special purpose sites	1. Creek/river terraces 2. Bluffs 3. Caves 4. Open plain	Plains Village Southwestern Tradition	1. Villages 2. Temporary hunting/collecting stations 3. Special purpose sites	1. River/creek valleys 2. Mesas 3. Scattered micro-environments
			Plains Village Tradition	1. Large villages 2. Kill sites 3. Special purpose sites 4. Pictograph/ghost caves 5. Tipi rings	1. Creek/river terraces 2. Bluffs 3. Caves 4. Open plain 5. Scattered locations			

Table 14.2. (continued)

Northern Rocky Mountains			Western Great Plains			Texas Coastal Plains		
Tradition	Site Type	General Topographic Location	Tradition	Site Type	General Topographic Location	Tradition	Site Type	General Topographic Location
Pre-Projectile Point Horizon[a]			Pre-Projectile Point Horizon[b]			Pre-Projectile Point Horizon[b]		
Old Cordilleran Tradition	1. Camps 2. Special collecting stations	1. Expected in all food producing micro-environments	Big Game Hunting Tradition	1. Camps 2. Kill sites		Big Game Hunting Tradition (early period)	1. Scattered camps	
Northern Forest (inland) Tradition	1. Camps 2. Special collecting stations 3. Special purpose sites	1. River-creek valleys 2. Scattered locations	Plain Archaic Tradition	1. Camps 2. Kill sites 3. Special purpose sites	1. Bluff bases 2. River creek terraces 3. Caves 4. Scattered locations	Desert Archaic Tra ition (mic le period)	1. Shell middens 2. Open camps 3. Rock middens 4. Rock shelters 5. Special purpose sites	1. Beaches 2. River/creek 3. Caves 4. Scattered locations on the inland plain
Northwest Riverine Tradition	1. Villages 2. Special hunting, collecting, and fishing satellite camps 3. Other special purpose sites	1. River terraces 2. Scattered locations	Plains Woodland Tradition	1. Camps/villages 2. Mounds 3. Hunting stations	1. River valleys 2. Scattered locations	Desert Archaic Tradition (late period)	Same as above	Same as above
			Plains Village Tradition	1. Villages 2. Hunting stations 3. Special purpose sites	1. River valleys 2. Scattered locations			

[a]Modified from: G. R. Willey, "an Introduction to American Archaeology, Vol. I, North and Middle America," Prentice Hall, Inc., Englewood Cliffs, New Jersey, 1966; J. D. Jennings, "The Desert West" in: Prehistoric Man in the New World, J. D. Jennings and E. Norbeck (editors), University of Chicago Press, Chicago, IL, 1964; W. R. Wedel, "The Great Plains," in: Prehistoric Man in the New World, 1964.

[b]Insufficient data available for site type and location in each region.

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15. ESTHETIC AND RECREATIONAL RESOURCES

15.1 GENERAL ASPECTS

There are many valid reasons for conserving the esthetic and recreational resources of the environment. With good design and planning approaches, conservation allows one to enjoy his surroundings while causing a minimal amount of damage to the environment. Conservation should be integrated with other activities in a region in order that esthetic and recreational resources can survive and be protected.

The increasing demand for recreational facilities is a result of major changes in the work and leisure patterns of Americans. With the emergence of a shorter workweek, flexible work patterns, and earlier retirement, there is a growing need for additional recreational areas. Since 1965, vacation participation in outdoor recreational activities has risen substantially.[1] There has been a marked increase in camping activity in remote or wilderness areas, and the number of people engaged in camping in developed campgrounds, canoeing, picnicking, swimming, nature walks, and fishing has more than doubled. Sailing, sightseeing, and hiking are also on the rise. These increases in recreational activity are evident in Table 15.1, in which are listed actual and projected participations in outdoor summer recreation for the period 1960 to 2000. The results of a 1965 survey of recreational lands in the relevant states of the six regions considered in this statement and the breakdown of public outdoor recreation in these lands are given in Table 15.2.

Table 15.1. National Participation in Summertime Outdoor Recreational Activities, 1960-2000 (millions of events, participants 12 years and above)

Activity	Actual		Projected	
	1960	1965	1980	2000
Bicycling	228	467	617	860
Horseback riding	55	77	111	179
Playing outdoor games or sports[b]	474	929	1594	2940
Fishing	260	322	422	574
Boating[c]	159	220	387	694
Swimming	672	970	1671	2982
Water skiing	39	56	124	259
Camping	60	97	173	328
Hiking	34	50	89	159
Walking for pleasure	566	1030	1539	2581
Nature walks	98	117	173	274
Picnics	279	451	668	1022
Driving for pleasure	872	940	1423	2146
Sightseeing	287	457	705	1169
Attending outdoor sports events	172	246	352	535
Attending outdoor concerts, plays	27	47	80	144

[a]Source: "Outdoor Recreation for America, 1965 and Projections," Bureau of Outdoor Recreation, U.S. Department of the Interior, Washington, D.C.

[b]Includes golf and tennis.

[c]Other than canoeing or sailing.

Table 15.2. Acreage and Percent Distribution of Public Outdoor Recreation by Outdoor Recreation Classification in 1965 in the Relevant States[a]

State	Total Acreage	Percent Distribution Based on Outdoor Recreation Classification[b]					
		I High Density[c]	II General Outdoor	III Natural Environment	IV Outstanding Natural	V Primitive	VI Historic and Cultural[c]
North Dakota	1,980	0.1	29.3	69.4	0.7	0.5	0.1
South Dakota	3,365	0.1	38.8	57.2	3.8	0.3	-
Nebraska	640	0.9	13.1	84.9	-[c]	0.5	0.5
Texas	2,910	6.8	24.9	55	1.1	12.2	-
Montana	29,988	0.7	6	82.6	1.3	9.4	0.1
Idaho	34,778	-	3.3	86.4	2.3	7.8	0.1
Wyoming	30,917	-	1.2	72.7	11	14.8	0.3
Colorado	23,965	-	2.5	92.2	0.6	4.6	0.2
New Mexico	27,389	-	10.4	82.4	1.3	5.8	0.1
Arizona	33,876	0.1	7.8	72.1	4.5	15.1	0.4
Utah	36,671	-	5.6	84.4	6.2	3.8	-
Washington	15,888	0.2	3.3	84	1	11.5	-

[a]Modified from: "1965 Inventory of Public Outdoor Recreation Areas," Bureau of Outdoor Recreation, U.S. Dept. of the Interior, Washington, D.C.

[b]Includes all Federal, State, and county recreational acreage.

[c]A dash represents less than 0.05%.

15.2 THE SIX REGIONS

15.2.1 Northern Rocky Mountains

The Northern Rocky Mountains are of several different geological types and tower over deeply cut, wooded valleys, as shown on Figure 15.1. Glacial remnants are among the area's unique features. At Glacier National Park, there are some small glaciers present, as well as a display of the work done by valley glaciers of the past. Meltwaters from the ice, which advanced southward from British Columbia, overflowed many times through a gap leading to Spokane, Washington, resulting in the creation of barren scablands and gigantic canyons, waterfalls, and other features of flood erosion.[2] The wildlife, vegetation, and scenery of the National Parks and Forests of the Northern Rocky Mountains region attract 8 to 10 million visitors per year.

Northeastern Washington offers an array of landscapes for outdoor recreational activities, ranging from lofty mountain summits to deep caves. Interpretative centers and heritage sites are provided within many major parks (see Table 15.3). More leisure time and a shorter workweek will create increased demands on recreational resources in this region. It has been estimated that by the year 2000, there will be a 50% increase in use of the lakes and reservoirs in Idaho alone.[3] Northwestern Montana long has been a major focal point of outdoor recreation in the state. Glacier National Park, the Bob Marshall Wilderness, Flathead Lake, and millions of acres of National Forests are but a few of the attractions (see Table 15.4).

15.2.2 Western Great Plains

The Western Great Plains region is dominated by open ranges of short grasses, with trees usually present only in valleys along rivers (see Fig. 15.2). Many rivers and their tributaries have cut moderately deep valleys in the flat country. Glacially deposited sand dunes also give the land moderate relief. Four states within this region are mentioned in this section to illustrate recreational activities available.

Outdoor recreational opportunities in North Dakota are plentiful during the entire year. Even though some North Dakotans have to travel far for some of the resource-based outdoor activities, it is predicted that by the year 1990, North Dakota will have a well-distributed supply of outdoor recreational opportunities.[4] The present status of recreational facilities and lands in North Dakota is illustrated in Table 15.5.

ESTHETIC RESOURCES

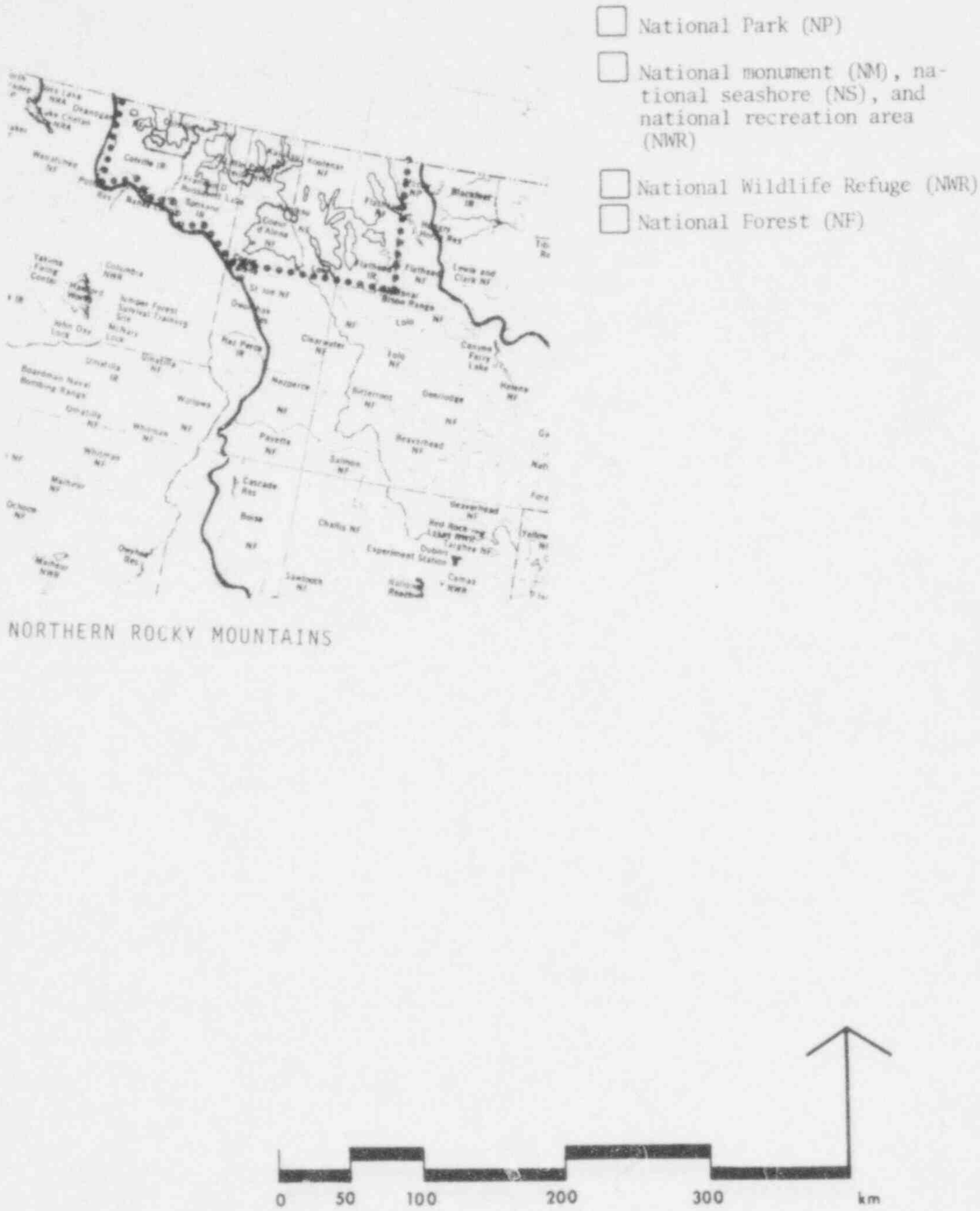

Fig. 15.1. Esthetic Resources of the Northern Rocky Mountains Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

Table 15.3. Major Developed Recreational Areas in Northeastern Washington[a]

Park	Location	Acres	Facilities and Activities
Bridgeport	3 mi. N Bridgeport, Hwy 17	824	Camping, golf course
Crawford (Gardner Cave)	12 mi, N of Metaline Falls, off Hwy 31	41	Hiking trails
Crown Point	SW of Coulee Dam, off Hwy 155	13	Heritage Site
Curlew Lake	10 mi. N Republic, Hwy 21	129	Hiking trails, snowmobiling
Lake Osooyos	1 mi. N of Oroville, Hwy 97	41	Snowmobiling
Mt. Spokane	30 mi. E Spokane, beyond Hwy 206	16,040	Snowmobiling, hiking trails, skiing, equestrian trails, campgrounds
Pend Oreille	13 mi. S Newport, Hwy 2	444	Hiking trails

[a]Modified from: T. D. Bussey, "Washington State Outdoor Recreation Guide - Northwest Experience," Northwest Experience Publishing Co., Moscow, Idaho, 1977.

Table 15.4. Regional Points of Interest in Northwestern Montana[a]

Moise National Bison Range

Established in 1908 by President Teddy Roosevelt, this 13,540-acre range is home to some 400-500 bison as well as elk, pronghorn antelope, whitetail and mule deer, and other wildlife.

Hungry Horse Dam and Reservoir

A major water body near Glacier National Park offering a variety of recreation and water-oriented activities.

St. Ignatius Mission

The mission was estbalished in 1954 for the Flathead Indians and offers the visitor a view of ecclesiastical architecture.

Glacier National Park

Spectacular scenery can be viewed along the Going-to-the-Sun Highway. The area has been subjected to intense glaciation, but presently there are relatively few active glaciers in the park.

Flathead Lake

This large, natural freshwater lake offers a variety of recreation and water-oriented activities.

Libby Dam

The dam and resulting reservoir offer a variety of recreation opportunities.

[a]From: "Montana Statewide Outdoor Recreation Plans," Parks and Recreation Division, Department of Fish and Game, Helena Montana, Vols. I and II, 1973.

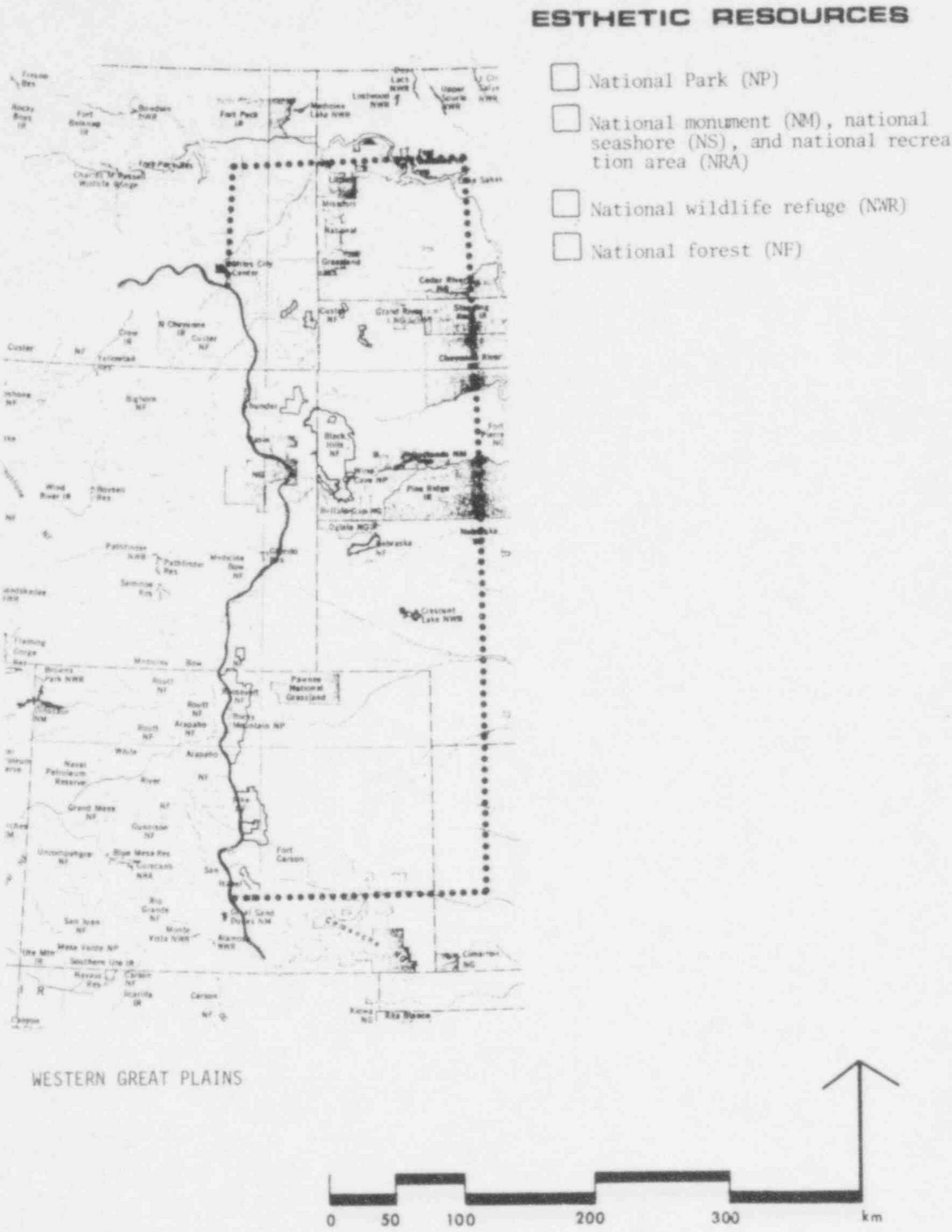

Fig. 15.2. Esthetic Resources of the Western Great Plains Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

Table 15.5. 1974 Inventory of North Dakota Outdoor Recreational Facilities and Lands[a]

	County															
	McKenzie	Grant	McLean	Mercer	Morton	Oliver	Sioux	Adams	Billings	Bowman	Dunn	Golden Valley	Hettinger	Slope	Stark	Total
Total acres	587,386	14,244	129,246	43,036	26,022	5,959	31,077	466	338,189	38,005	71,185	99,610	485	141,706	3,541	693,167
Surface water acres	53,777	5,261	100,636	38,781	18,954	5,081	24,550	142		1,990	40,898	151	190	394	914	44,679
Fishing acres	37,682	5,261	65,413	27,187	13,328	3,722	17,249	142		1,990	29,021	151	190	394	914	32,802
Boating, water skiing acres	37,555	5,202	64,195	27,034	13,094	3,171	17,036	118		1,922	29,021	105		200	849	32,215
Hunting acres	508,904	8,364	25,545	2,720	8,194	395	6,587	117	290,666	32,808	22,560	99,020		139,335		584,506
Swimming																
Beaches	4	4	8	3		1					1				3	4
Pools	1		3	2	5				1		1	2			3	7
Trails																
Hiking, horse-back miles	30	6	16		2				36		70					106
Bicycle miles																
Motorcycle, snowmobile miles				3	3				16		8					24
Camping acres	258	41	64	344	30	2		6	83	20	182	35		3	111	440
Picnicking acres	72	73	121	136	81	12	21	4	51	34	42	14	11	11	85	252
Golfing																
Acres	320		180	225	230		60	80		90		30	120		80	400
Sand greens	18		27	18	9			9		9		9	18		9	54
Winter Sports																
Ice skating rinks	2		3	2	10						2	2	2		4	10
Sledding acres																
Warming houses	2		1		3							2			4	6
Ski runs																
Ski tows																
Racing																
Car, motorcycle (no. miles)	1		1			1					1				2	3
Snowmobile (no. miles)			4	10							1		5			1.5
Seating	1,000					800					250				1,500	1,750

[a]From: "State Comprehensive Outdoor Recreation Plan," North Dakota Outdoor Recreation Agency, Mandan, North Dakota, 1975.

The western portion of South Dakota covers an area of 118,446 km^2 (45,732 mi^2), containing two of the largest and least populated recreational planning districts in the state.[5] Recreational facilities in this area relative to those of the entire state are given in Table 15.6.

Table 15.6. Park and Recreational Areas in the Western Great Plains Region of South Dakota[a]

Type of Area	Western Plains	Statewide Total
ROADS		
Miles of paved roads	29.0	119.6
Miles of gravel roads	3.0	63.8
BOATING ACCESS		
Number of ramps	25.0	53.0
Number of docks	18.0	34.0
CAMPGROUNDS		
Number of areas	14.0	43.0
Number of acres	194.0	508.6
PRIMITIVE CAMPGROUNDS		
Number of areas	7.0	11.0
Number of acres	20.0	51.0
PICNIC AREAS		
Number of areas	32.0	74.0
Number of acres	97.0	260.0
SWIMMING BEACHES		
Number of beaches	15.0	30.0
Feet of frontage	4,640.0	9,240.0
PLAYGROUNDS		
Number of areas	18.0	38.0
TRAILS		
Number of hiking trails	3.0	20.0
Miles of hiking trails	3.0	27.4
Number of nature trails	5.0	6.0
Miles of nature trails	3.0	13.0
Number of horse trails	1.0	3.0
Miles of horse trails	1.5	20.5
Number of snowmobile trails	1.0	3.0
Miles of snowmobile trails	1.2	5.2
MISCELLANEOUS		
Dumping stations	--	1.0
Visitor center	1.0	4.0
Historical site	8.0	17.0

[a]From: "The 1975 South Dakota Comprehensive Outdoor Recreation Plan," South Dakota Division of Parks and Recreation, Pierre, South Dakota, 1975.

The north-central section of the Western Great Plains region of Nebraska is dominated by the sparsely populated Nebraska Sandhills. Because this area is so far removed from the eastern population centers of the state, total annual recreational use is far below the amount that could be supported.[6] Most of the Nebraska Panhandle, located in the westernmost section of the state, is grazing land. Recreational resources include the Ogala National Grassland, Chadron State Park, Fort Robinson State Park, and part of the Nebraska National Forest. The Pine Ridge and Wildcat Hills escarpments are included in the 127,348 ha (314,439 acres) of woodlands in the Panhandle. A map of the recreational areas of western Nebraska is presented in Figure 15.3. The southwestern section of Nebraska contains numerous recreational facilities associated with 18,260 ha (45,085 acres) of reservoirs constructed for irrigation. A selected listing of public lands available for recreation in the north-central, panhandle, and southwestern sections of the Western Great Plains section of Nebraska is presented in Table 15.7.

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LEGEND

SYMBOL	TYPE OF AREA
▲	STATE PARK
▲	STATE RECREATION AREA
■	STATE HISTORICAL PARK
•	STATE WAYSIDE AREA
●	STATE SPECIAL USE AREA
I	STATE FISHERY

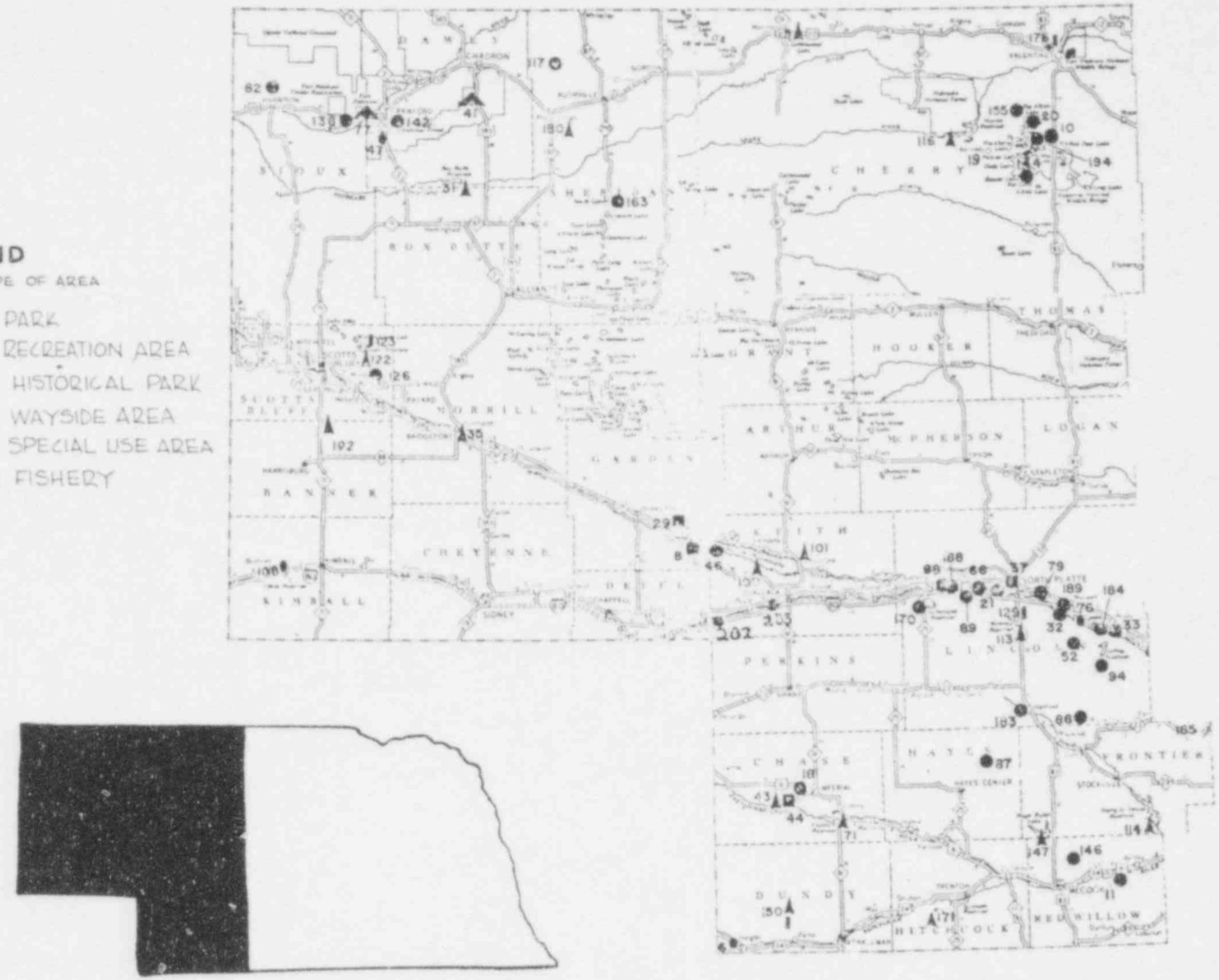

Fig. 15.3. Recreational Areas of Western Nebraska. (Modified from: "Statewide Comprehensive Outdoor Recreation Plan," Nebraska Game and Parks Commission, Lincoln, NE, 1973.)

Table 15.7. Public Lands Available for Recreation in the North-Central, Panhandle, and Southwestern Portions of the Western Great Plains Section of Nebraska, 1973

Subregion	Acres Total	Acres Land	Acres Water	Acres Marsh	Picnicking Acres	Picnicking Sites	Camping Acres	Camping Sites	Boat Ramps	Beaches Sites	Beaches Acres
STATE AREAS											
North Central	14,463	9,745	4,423	295	44	10	54	10	4	3	6
Panhandle	41,758	37,649	4,089	20	89	23	95	15	6	7	30
Southwestern	83,953	31,935	51,018	1000	302	39	137	22	20	14	98
Total	140,174	79,329	59,530	1315	435	72	286	47	30	24	134
FEDERAL AREAS											
North Central	206,275	194,755	9,887	1533	24	16			10		
Panhandle	199,193	195,476	2,945	772	116	29	125	21		7	[illegible]
Southwestern	90,504	90,424	80		7	1	20	4			
Total	495,972	480,655	12,912	2405	147	46	145	25	10	7	30

Modified from: "State Comprehensive-Outdoor Recreation Plan," Nebraska Game and Parks Commission, Lincoln, Nebraska, 1972.

In the northeastern section of Colorado, there are numerous moderate- to large-sized reservoirs. These reservoirs plus the surrounding public land provide for most of the large-scale recreational needs in this region. In Larimer and Weld counties in north-central Colorado, 28% of the land area is open for public recreation, primarily mountain-oriented and cold-water reservoir activities. Developed recreational resources do not exist in east-central Colorado (see Table 15.8). The southeastern corner of Colorado is largely a rural high plains area. The John Martin Reservoir site (Army Corps of Engineers) contains some sandhills and floodplain forests of the Arkansas River. The Canyon-Mesa Country of Baca, Bent, and Otero counties is mostly juniper woodland, which comprises a significant portion of the Comanche National Grasslands. Land types in the south-central region that are not currently in public ownership include the foothills oakbrush and pinyon-juniper woodlands, volcanic dikes, mountain scenery typified by the LaVeta Pass area, and the canyon country of the Purgatoire River.[7] The Trinidad and Pueblo Reservoirs will provide additional recreational resources to serve the south-central and adjacent regions.

Table 15.8. Major Recreational Resources of the Counties of the Western Great Plains Section of Colorado[a]

County	Location	Recreation Resources
Logan Morgan Phillips Sedgwick Washington Yuma	Northeast Corner	Sterling, Prewitt, and Julesburg Reservoirs Bonny and Jackson State Recreation Areas Tamarack State Wildlife Area Potential funded or in construction - Narrows Reservoir Potential undeveloped- South Platte River, State Land Board lands
Larimer Weld	North Central	Rocky Mountain National Park Pawnee National Grasslands Roosevelt National Forest Horsetooth and Carter Reservoirs Potential undeveloped - Red-Rock Canyon areas, South Platte River, foothills/hogback
Cheyenne Elbert Kit Carson Lincoln	East Central	Potential undeveloped - South Republican River
Baca Bent Crowley Kiowa Otero Provers	Southeast	John Martin, Two Buttes, Muddy Creek, Lake Meredith Horse Creek and Adobe Creek Reservoirs Great Plains reservoir system Comanche National Grasslands Potential undeveloped - Arkansas River
Huerfano Las Animas Pueblo	South Central	Comanche National Grasslands Portion of the Sam Isabel National Forest Pueblo State Recreation Area, Lathrop State Park Potential funded or in construction - Trinidad Reservoir

[a]Modified from: "1976 Colorado Comprehensive Outdoor Recreation Plan," Colorado Division of Parks and Outdoor Recreation, Denver, Colorado, 1976.

15.2.3 Wyoming Basin

The Wyoming Basin region has a ruggedness which exceeds that of the Appalachians (see Fig. 15.4). Although primarily classified as grazing country, distant forested mountain ranges border the meadowlands of the basin.

There are outdoor recreational opportunities throughout Wyoming; these include swimming, camping, horseback riding, ice fishing, snowmobiling, and sightseeing. Projections of participation in recreational activities for Wyoming to the year 1990 show substantial increases over that of 1970.[8] The projected increases range from 24% for lake or reservoir fishing to 128% for golfing. Many of the increases lie in the 50%-60% range.[8] In 1970, the most popular recreational activity was sightseeing and pleasure driving. This was followed in order of popularity by lake or reservoir fishing and overnight camping.

Fig. 15.4. Esthetic Resources of the Wyoming Basin Region. (Modified from: "The National Atlas of the United States of America., U.S. Dept. of the Interior, Washington, D.C., 1970.)

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15.2.4 Southern Rocky Mountains

The Southern Rocky Mountains region includes a series of ranges, each with distinctive landforms and scenery (see Fig. 15.5). The main vegetation types of the Southern Rocky Mountains are grasses and shrubs. Most of the residents of the region are becoming urbanized. Both urban and rural residents, however, place high values on the western heritage, scenery, and open spaces. The diverse landscape, which includes mountains and high mountain tundra, valleys, river systems, and desert lands, attracts numerous residents and nonresidents each year because of its diverse scenery and many recreational opportunities.

The State of Colorado has large government land holdings suitable for outdoor recreation. Nearly 40% of the state's land area is considered available for recreational activities. The present and projected needs for facilities and land committed to recreation in Colorado by the year 2000 are shown in Figure 15.6.[9]

15.2.5 Colorado Plateau

The Colorado Plateau region, with its drainage system that cuts into the earth and forms steep-walled canyons, is noted for its Painted Desert, high plateaus, volcanic mountains, sand deserts, and shale deserts with badlands (see Fig. 15.7).[2] The "paint" on the canyon walls is actually desert varnish formed by a stain of iron and manganese oxides. The canyons of the Plateau are composed of Redwall Limestone.[9]

Utah's outdoor recreational resources include state and national parks, historic sites, monuments, wilderness areas, wildlife refuges, and forests. Primary outdoor recreational activity and acreage needs in selected areas of the Colorado Plateau region of Utah (southeastern half of the state) are given in Table 15.9.

Recreational facilities in New Mexico include part of the Bandelier National Monument and the Santa Fe National Forest. Both Taos and Rio Arriba counties contain parts of the Carson National Forest. A large portion of the Santa Fe National Forest extends into Rio Arriba County (see Table 15.10 for the relative availability of recreational facilities in counties in the Colorado Plateau region of New Mexico). There are large areas of National Park lands in Santa Fe and Socorro counties.

Sandoval, Bernalillo, and Valencia counties contain almost half of New Mexico's population, but provide less than one-half an acre of recreational land per person.[11] A significant portion of the total state recreational needs is fulfilled by the private sector. Demand statistics for selected outdoor recreational activities in the state are given in Table 15.11.

The northern half of Arizona has a 97% population participation in recreation. This is the highest percentage for any area in the state.[11] Demand statistics for popular outdoor recreational activities in Arizona are given in Table 15.12.

15.2.6 Texas Coastal Plains

The number of recreational facilities in the region has greatly increased over the past 20 years in response to major public pressures. A map of the resources available for recreation in the region is presented in Figure 15.8. In addition to these recreation areas, the region is known for its fishing and resort facilities along the Gulf Coast. Planning regions and recreation participation in Texas in 1968-1970 are shown in Figure 15.9.

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ESTHETIC RESOURCES

- National Park (NP)
- National monument (NM), national seashore (NS), and national recreation area (NRA)
- National wildlife refuge (NWR)
- National forest (NF)

SOUTHERN ROCKY MOUNTAINS

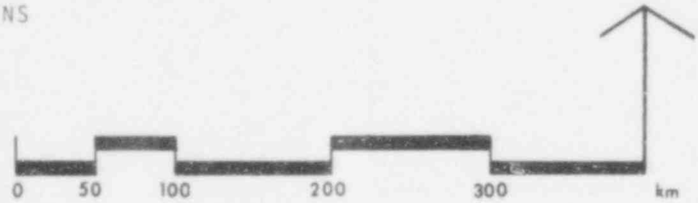

Fig. 15.5. Esthetic Resources of the Southern Rocky Mountains Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

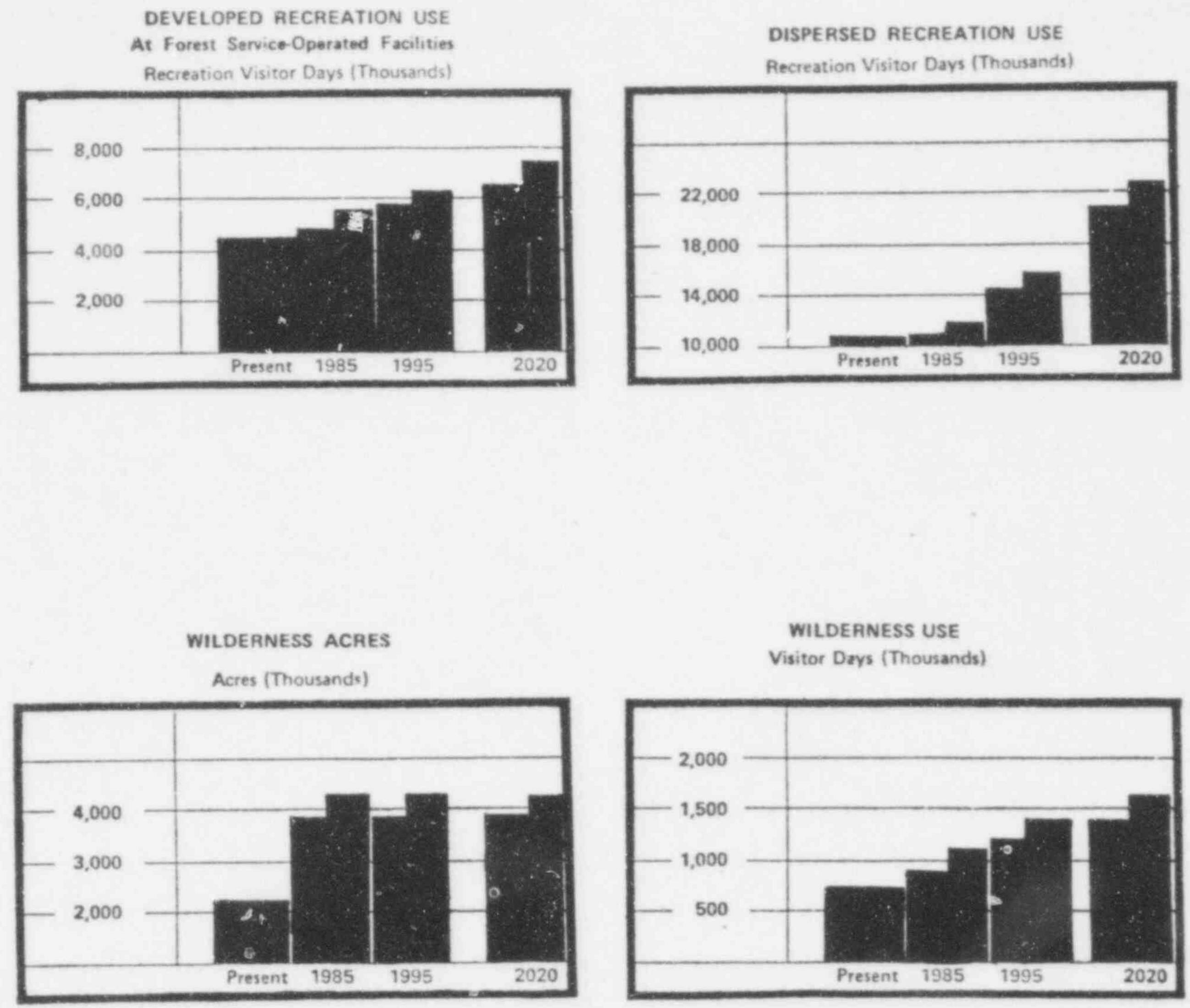

Fig. 15.6. Recreation and Wilderness Use in Colorado. (Modified from: "Outdoor Recreation and Wilderness," in the Nation's Renewable Resources--Forest Service, U.S. Dept. of Agriculture, Forest Resource Report, No. 21, June, 1977.)

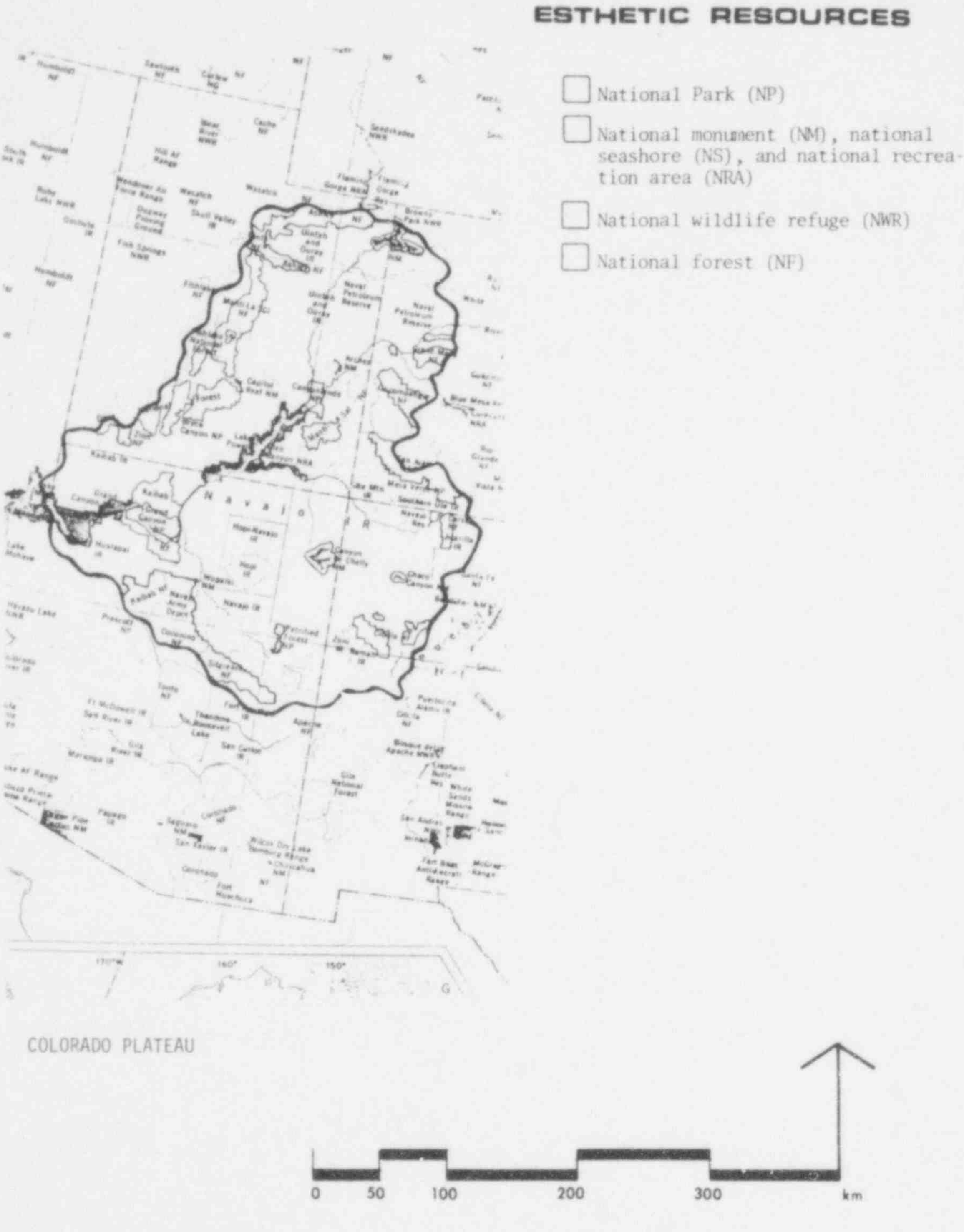

Fig. 15.7. Esthetic Resources of the Colorado Plateau Region. (Modified from: "The National Atlas of the United States of America," U.S. Dept. of the Interior, Washington, D.C., 1970.)

Table 15.9. Outdoor Recreational Requirements in Five of the Planning Districts of the Colorado Plateau Section of Utah, 1975 and 1985[a]

Primary Outdoor Recreation Activities	Year	Acreage Needed in Planning Districts: 1	4	5	6	8	Subtotals (acres)	Total Acres (1975+1985)
Snowmobiling: Acres of staging area needed	1975 1985	7 5	9 7	4 2	2 3	4 1	26 18	44
Trail Biking: Trails, @ 1.21 acres per mile of trail	1975 1985	72 --	116 --	17 --	37 --	24 --	266 (undetermined)	266
Horseback Riding (urban): Urban trails, @ 1.21 acres per mile of trail	1975 1985	24 11	55 18	10 3	12 10	11 1	112 43	155
General Winter Activities: Total acres needed (existing not inventoried)	1975 1985	3,362 1,448	7,266 2,374	1,349 274	1,505 1,014	1,342 192	14,874 5,302	20,176
Boating (and associated activities): Load-launch areas, @ 1.5 acres/lane	1975 1985	-- 7	-- 7	-- 9	-- --	-- --	(undetermined) 23	23
Swimming: Pools, @ 2 acres per 4,500 sq. ft. pool unit	1975 1985	2 4	4 14	-- 2	-- 10	8 4	14 34	48
Hiking: Urban trails, @ 1 acre per mile	1975 1985	5 5	18 7	3 2	6 2	4 2	36 18	54
Wildland Trail Hiking: Trail, @ 0.5 acres per mile	1975 1985	169 282	138 231	103 180	445 744	154 257	1,014 1,694	2,708
Bicycling: Improved paths, @ 1.2 acres per mile (offstreet)	1975 1985	69 34	131 55	36 36	27 34	28 15	291 174	465
Camping: Camping area, average of 5 units per acre or 0.2 acres per	1975 1985	-- (-31)[b]	-- --	-- --	173 493	4 50	177 543	720
Wildlife and General Winter Activities: Winter range, waterfowl areas, etc.	1975 1985	21,028 36,782	87,226 162,374	72,015 141,608	36,171 70,348	57,392 112,192	273,872 523,304	797,176
Totals	1975 1985	24,738 37,247	95,003 165,087	73,542 142,116	38,478 72,658	58,971 112,714	290,682 531,153	821,835

[a]Adapted from: T. E. Green, E. Tharold, Jr., and J. Stanley Elmer, "Utah State Comprehensive Outdoor Recreation Plan," Outdoor Recreation Agency, Dept. of Natural Resources, Utah, 1 April 1973.

[b]The negative value in parentheses indicates an excess of supply over demand, but only an "in-district" basis. Demand generated by other districts usually compensates for any excess.

Table 15.10. Relative Availability of Recreational Facilities in the Colorado Plateau Section of New Mexico (by county)[a]

County	(1) Population[b]	(2) Total Acres[c]	(3) Acres Devoted to Recreation	(4) Acres of Rec. Per Capita (3)÷(1)	(5) Percent of Acres for Recreation [(3)÷(2)]×100
McKinley	49,500	3,495,040	6,258	0.13	0.18
San Juan	61,700	3,530,240	90,685	1.47	2.57
Los Alamos	15,900	69,120	35,706	2.25	51.66
Rio Arriba	27,300	3,765,120	1,029,958	37.73	27.36
Sante Fe	60,900	1,221,760	125,979	2.07	10.31
Taos	18,900	1,444,480	474,630	25.11	32.86
Bernalillo	361,400	748,160	46,462	0.13	6.21
Sandoval	22,800	2,378,880	52,914	2.32	2.22
Valencia	44,000	3,621,120	95,632	2.17	2.64
Catron	2,100	4,414,720	2,809,217	1,337.72	63.63
Socorro	9,300	4,240,640	818,033	87.96	19.29
State[d]	1,122,500	77,866,240	9,372,968	8.35	12.03

[a]Modified from: "Outdoor Recreation--A Comprehensive Plan for New Mexico," New Mexico State Planning Office, Santa Fe, New Mexico, 1976.

[b]1974 Estimate. Wombold, L. M., and Adcock, L. D., "Population Estimates: July, 1974" (BIS #56), Bureau of Business and Economic Research, University of New Mexico, May 1975, Table 1.

[c]"New Mexico Statistical Abstract 1975," Bureau of Business and Economic Research, University of New Mexico, Table 1.

[d]Since only selected counties are included in this table, the totals for the state exceed the sums of the individual counties listed.

Table 15.11. Projected Aggregate Demand for Selected Recreational Activities in New Mexico (number of occasions)[a]

Grouped Activity	1975	1980	1985	1990
Hiking	1,368,327	1,586,000	1,755,000	1,916,000
Camping	1,230,260	1,426,000	1,578,000	1,723,000
Lake sports	1,276,281	1,479,000	1,636,000	1,787,000
Winter sports	805,594	934,000	1,032,000	1,129,000
Hunting and fishing	3,251,882	3,769,000	4,170,000	4,554,000
Equestrian sports	3,717,719	4,310,000	4,768,000	5,207,000
Team-oriented sports	4,282,337	4,963,000	5,492,000	5,997,000

[a]Modified from: "Outdoor Recreation - A Comprehensive Plan for New Mexico," New Mexico State Planning Office, Santa Fe, New Mexico, 1976.

Table 15.12. Major Categories of Recreational Activity Demand in Arizona for Selected Years (in thousands of participation days)[a]

Categories	1970	1975	1980	1985
Passive outdoor recreation	61,266	71,749	82,103	90,260
Active outdoor recreation	54,609	64,095	73,053	80,463
Water sports	40,346	47,483	54,203	59,706
Back-country recreation	16,318	19,064	21,640	23,729
Snow-related recreation	1,447	1,673	1,895	2,075
Total	173,986	204,064	232,894	256,233

[a]Modified from: "Summary of the Statewide Comprehensive Outdoor Recreation Plan," Arizona Outdoor Recreation Coordinating Commission, Phoenix, Arizona, June 1973.

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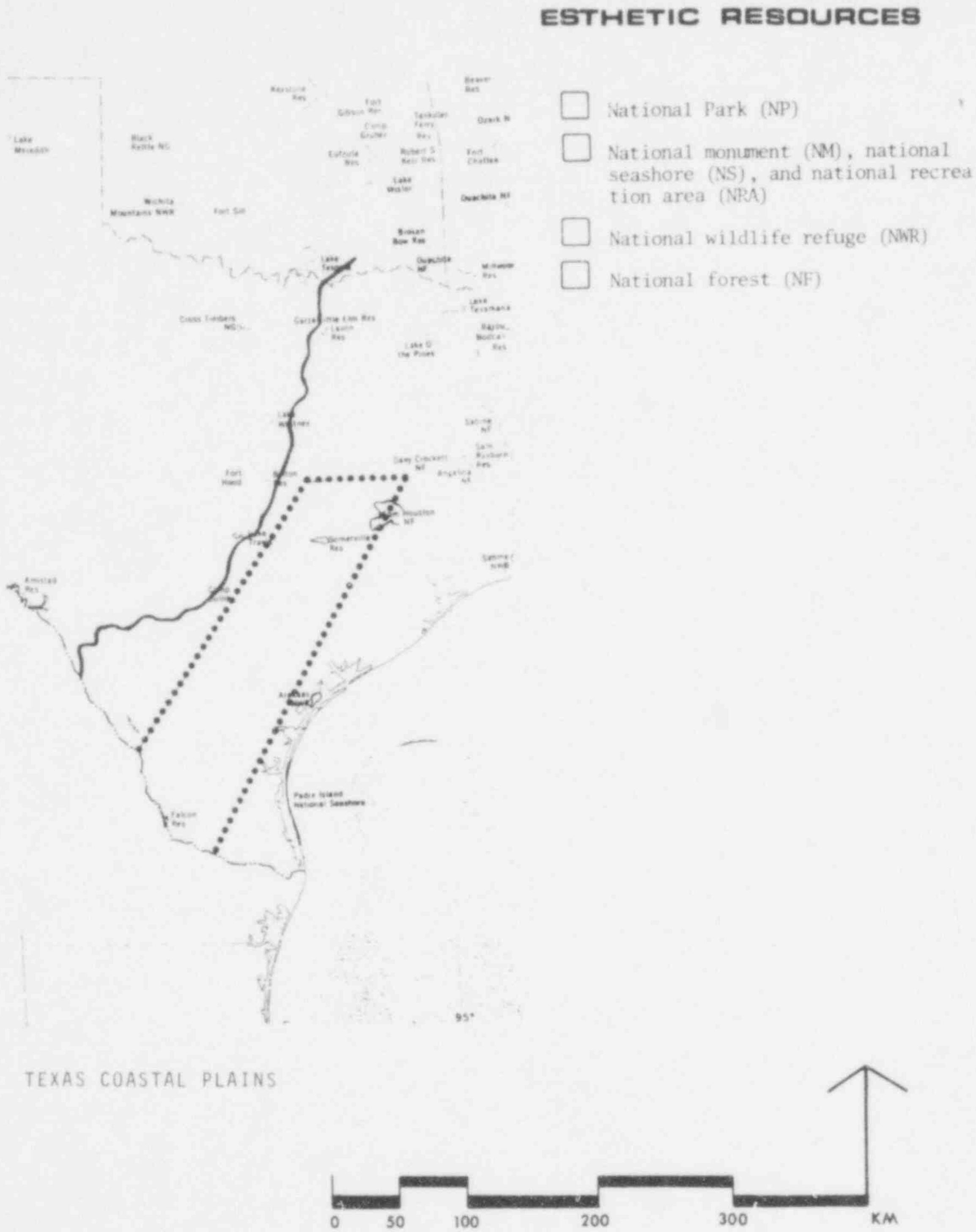

Fig. 15.8. Esthetic Resources of the Texas Coastal Plains Region. (Modified from: "The National Atlas of the United States of America." U.S. Dept. of the Interior, Washington, D.C., 1970.)

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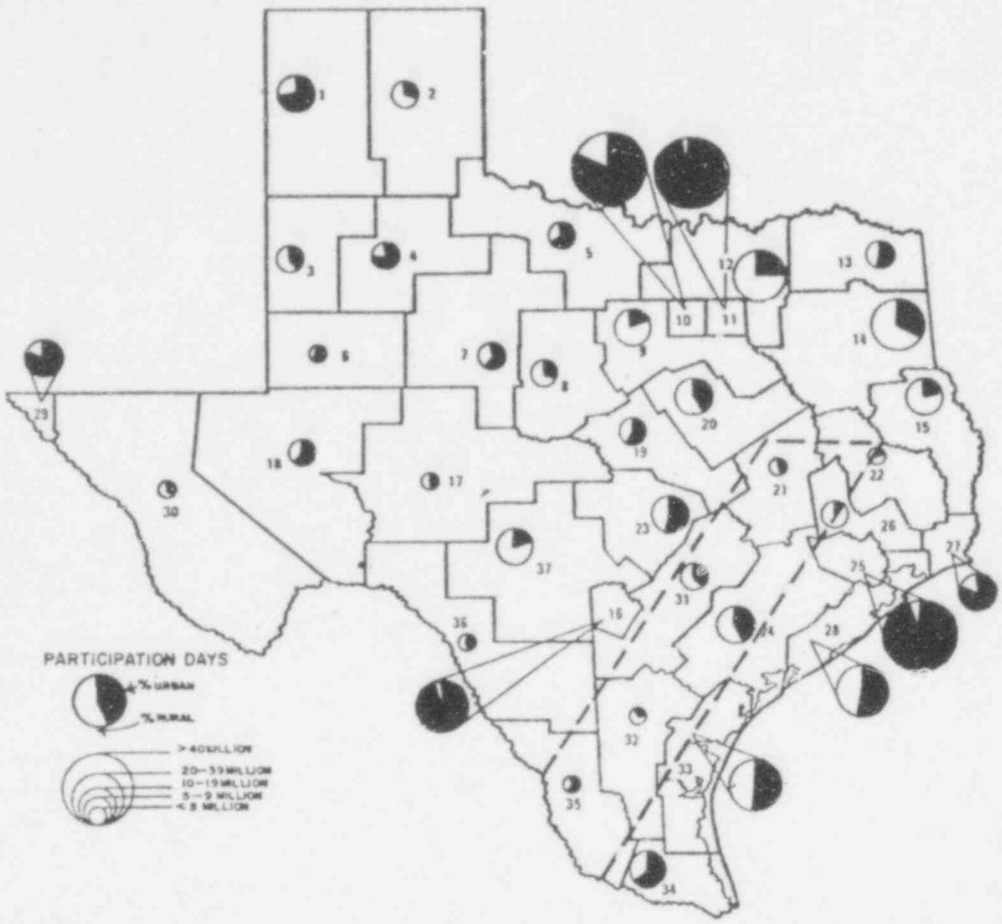

Fig. 15.9. Total Recreation Participation in Texas by Planning Region and Location, 1968/1970. (Source: "Texas Outdoor Recreation Plan--State Summary," Texas Parks and Wildlife Dept., Austin, Texas, December 1975.)

References

1. "Outdoor Recreation Statistics-1971," Bureau of Outdoor Recreation, U.S. Dept. of the Interior, Washington, D.C., 1971.

2. C. B. Hunt, "Natural Regions of the United States and Canada," W. H. Freeman and Co., San Francisco, CA, 1974.

3. "Idaho Statewide Comprehensive Outdoor Recreation and Open Space Plan," Bureau of Outdoor Recreation, Boise, ID, 1975.

4. "State Comprehensive Outdoor Recreation Plan," North Dakota Outdoor Recreation Agency, Mandan, ND, 1975.

5. "The 1975 South Dakota Comprehensive Outdoor Recreation Plan," Division of Parks and Recreation, Pierre, SD, 1975.

6. "State Comprehensive Outdoor Recreation Plan," Nebraska Game and Parks Commission, Lincoln, NE, 1973.

7. "1976 Colorado Comprehensive Outdoor Recreation Plan," Colorado Division of Parks and Recreation, Denver, CO, 1976.

8. "An Outdoor Recreation Plan for Wyoming, 1975," Wyoming Recreation Commission, Cheyenne, WY, 1975.

9. J. A. Shimer, "Fieldguide to Landforms in the United States," MacMillan Publishing Co., Inc., NY, 1972.

10. "Outdoor Recreation-A Comprehensive Plan for New Mexico," New Mexico State Planning Office, Santa Fe, NM, 1976.

11. "Summary of the Statewide Comprehensive Outdoor Recreation Plan," Arizona Outdoor Recreation Coordinating Commission, Phoenix, AZ, 1973.

16. THE RADIOLOGICAL BACKGROUND

The components that make up the radiation background of the six regions include both natural and technologically enhanced radiation sources. Natural sources include cosmic, cosmogenic, and terrestrial radiation, as well as radiation from inhaled radon. Technologically enhanced radiation is due chiefly to fallout from weapons tests. Medical use of radiation does not increase background radiation levels, but does represent a significant source of radiation to which the public is regularly exposed, the dose averaging about 80 mrem/yr. The background radiation doses are summarized in Table 16.1. As shown in the table, the doses from ingested radionuclides of cosmogenic and terrestrial origins, the doses to bronchial epithelium from inhaled radon daughters, and doses from fallout are essentially the same in all six regions. The only components that are significantly different are the cosmic radiation field and the external dose (gamma) from the terrestrial radiation field. Cosmic radiation intensity is principally a function of elevation.[1] External radiation is dependent on soil content of K-40, Rb-87, and the decay series of U-238 and Th-232.[2-4]

References

1. D. T. Oakley, and A. S. Goldin, "Cosmic Ray Population Exposure," in: The Natural Radiation Environment II, Vol. 1, p. 91, U.S. Energy Research and Development Administration, CONF-720805-P1, 1972.

2. A. W. Klement, Jr., C. R. Miller, R. P. Minx, and B. Shleien, "Estimates of Ionizing Radiation Doses in the United States, 1960-2000," U.S. Environmental Protection Agency, ORP/CSD 72-1, 1972.

3. "Ionizing Radiation: Levels and Effects, A Report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) to the General Assembly," with annexes, United Nations, New York, 1972.

4. "Natural Background Radiation in the United States," National Council on Radiation Protection and Measurements, Rept. #45, p. 108, 1975.

Table 16.1 Annual Dose (mrem) from Background Radiation

Radiation Source	Whole Body	Bone	Lung	Bronchial Epithelium
NORTHERN ROCKY MOUNTAINS				
Cosmic	50	50	50	
Cosmogenic (C-14)	1	1	1	
Terrestrial (external)	48	38	48	
Terrestrial (internal)	21	45	21	
Inhalation			<1.0	
Radon daughters				560
Fallout	4.5	30	4.5	
Total	~125	164	~126	560
WESTERN GREAT PLAINS				
Cosmic	54	54	54	
Cosmogenic (C-14)	1	1	1	
Terrestrial (external)	72	58	72	
Terrestrial (internal)	21	45	21	
Inhalation			<1.0	
Radon daughters				560
Fallout	4.5	30	4.5	
Total	~153	188	~154	560
WYOMING BASIN				
Cosmic	75	75	75	
Cosmogenic (C-14)	1	1	1	
Terrestrial (external)	72	58	72	
Terrestrial (internal)	21	45	21	
Inhalation			<1.0	
Radon daughters				560
Fallout	4.5	30	4.5	
Total	~174	209	~175	560
SOUTHERN ROCKY MOUNTAINS				
Cosmic	70	70	70	
Cosmogenic (C-14)	1	1	1	
Terrestrial (external)	84	67	84	
Terrestrial (internal)	21	45	21	
Inhalation			<1.0	
Radon daughters				560
Fallout	4.5	30	4.5	
Total	~181	213	~182	560
COLORADO PLATEAU				
Cosmic	60	60	60	
Cosmogenic (C-14)	1	1	1	
Terrestrial (external)	60	48	60	
Terrestrial (internal)	21	45	21	
Inhalation			<1.0	
Radon daughters				560
Fallout	4.5	30	4.5	
Total	~147	184	~148	560
TEXAS COASTAL PLAINS				
Cosmic	40	40	40	
Cosmogenic (C-14)	1	1	1	
Terrestrial (external)	24	19	24	
Terrestrial (internal)	21	45	21	
Inhalation			<1.0	
Radon daughters				560
Fallout	4.5	30	4.5	
Total	~91	135	~92	560

APPENDIX A. THREATENED, ENDANGERED, OR RARE TERRESTRIAL VERTEBRATE SPECIES*

Table A.1 Threatened, Endangered, or Rare Terrestrial Vertebrate Species in the Northern Rocky Mountains Region.

Table A.2 Threatened, Endangered, or Rare Terrestrial Vertebrate Species in the Western Great Plains Region.

Table A.3 Threatened, Endangered, or Rare Terrestrial Vertebrate Species in the Wyoming Basin Region.

Table A.4 Threatened, Endangered, or Rare Terrestrial Vertebrate Species in the Southern Rocky Mountains Region.

Table A.5 Threatened, Endangered, or Rare Terrestrial Vertebrate Species in the Colorado Plateau Region.

Table A.6 Threatened, Endangered, or Rare Terrestrial Vertebrate Species in the Texas Coastal Plains Region.

*The appearance of a species name in these tables does not necessarily imply that the species occurs at existing or potential uranium mill sites. References from which these lists were taken are given at the end of this appendix.

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Table A.1. Threatened, Endangered, or Rare Terrestrial Vertebrate Species in the Northern Rocky Mountains Region

Species	Habitat	States[a]					
		Colorado	Idaho[b]	Montana	Utah	Washington	Wyoming
Grizzly bear *Ursus arctos*	Mountainous, wilderness forests	T,e	T	T	T	T	T
Black-footed ferret *Mustela nigripes*	Prairie; associated closely with prairie dogs	E,e	E	E,e	E	E	E,r
Northern rocky mountain wolf *Canis lupus irremotus*	Wilderness forests	e		E,e			E
Whooping crane *Grus americana*	Migrant and summer resident (Idaho); prairie pools and marshlands	E,e	E	E,e	E	E	E,r
Southern bald eagle *Haliaeetus leucocephalus leucocephalus*	Riparian	E			E		
American peregrine falcon *Falco peregrinus anatum*	Nests in cliffs; generally in wilderness areas	E,e	E	E,e	E,e	E,e	E,r
Arctic peregrine falcon *Falco peregrinus tundrius*	Migrant	E,e	E	E,e	E,e	E,e	E,r
River otter *Lutra canadensis*	Riparian	e					
Wolverine *Gulo luscus*	High mountains, near timberline; wilderness						r
Burrowing owl *Speotyto cunicularia*	Open grassland, prairies; usually associated prairie dog						r

[a]Species status:
T = Listed as "Threatened" on the Federal Endangered Species list.
E = listed as "Endangered" on the Federal Endangered Species list.
e = "endandered" on state list.
r = "rare" on state list.

[b]Idaho at the present time has no state endangered or threatened species list.

Table A.2. Threatened, Endangered, or Rare Terrestrial Vertebrate Species in the Western Great Plains Region

Species	Habitat	States[a]						
		Colorado	Kansas	Montana	Nebraska	North Dakota	South Dakota[b]	Wyoming
Black-footed ferret *Mustela nigripes*	Prairie; associated with prairie dogs	E,e	E,e	E,e	E,e	E,r+e	E	E,r
Whooping crane *Grus americana*	Marshlands - migrant	E,e	E,e	E,e	E,e	E,r+e	E	E,r
Eskimo curlew *Numenius borealis*	Prairie - migrant	E	E,e	E,e	E,e	E	E	E
Southern bald eagle *Haliaeetus leucocephalus leucocephalus*	Riparian	E	E,e		E			
American peregrine falcon *Falco peregrinus anatum*	Nests in cliffs; generally in wilderness	E,e	E,e	E,e	E,e	E,r+e	E	E,r
Arctic peregrine falcon *Falco peregrinus tundrius*	Migrant	E,e	E	E	E,e	E	E	E,r
River otter *Lutra candensis*	Riparian	e				r+e		
Swift fox *Vulpes velox*	Open desert and plains				e	r+e		
Bobcat *Lynx rufus*	Rimrock and chaparrel areas					r+e		
Red fox *Vulpes fulva*	Mixture of forest and open country					r+e		
Meadow jumping mouse *Zapus hudsonius*	Low meadows and forests with dense undergrowth							r
Greater prairie chicken *Tympanuchus cupido*	Tall-grass prairie	e						
Prairie sharp-tailed grouse *Pedioecetes phasianellus jamesi*	Prairie, brusky parklands, open thickets	e						
White pelican *Pelecanus erythrorhynchos*	Lakes and marshes	t						
Lesser prairie chicken *Tympanuchus pallidicinctus*	Sage and bluestem grass	t						

Table A.2. Continued

Species	Habitat	States[a]						
		Colorado	Kansas	Montana	Nebraska	North Dakota	South Dakota[b]	Wyoming
Bald Eagle *Haliaeetus leucocephalus*	Riparian		e					
Prairie falcon *Falco mexicanus*	Canyons, open mountains, plains, prairies, deserts; wide ranging		t					
Least tern *Sterna albifrons*	Riparian; sandy islands		t		t			r
Mountain plover *Charadrius montanus*	Semiarid grassland, plains, plateaus				t			
Purple martin *Progne subis*	Open or lumbered forests towns, farms; generally near water							r
Scrub jay *Aphelocoma coerulescens*	Foothills, lower mountain slopes; scrub oak and juniper							r
Burrowing owl *Speotyto cunicularia*	Open grassland, prairies; usually with prairie dogs							r
Riffle beetle *Dubiraphia* sp.	Riparian		t					
Riffle beetle *Optioservus divergens*	Riparian		t					

[a]Species status:
E = listed as "Endangered" on the Federal Endangered Species list.
e = listed as "endangered" on state list.
r = listed as "rare" on state list.
r+e = listed as "rare and endangered" on state list.
t = listed as "threatened" on state list.

[b]South Dakota at the present time has no endangered or threatened species list.

Table A.3. Threatened, Endangered, or Rare Terrestrial Vertebrate Species in the Wyoming Basin Region

Species	Habitat	States[a]					
		Colorado	Montana	Nebraska	South Dakota[b]	Utah	Wyoming
Black-footed ferret *Mustela nigripes*	Prairie, associated with prairie dogs	E,e	E,e	E,e	E	E	E,r
Northern rocky mountain wolf *Canis lupus irremotus*	Wilderness forests	e	E,e				E
American peregrine falcon *Falco peregrinus anatum*	Nests in cliffs; wilderness	E,e	E,e	E,e	E	E,e	E
Arctic peregrine falcon *Falco peregrinus tundrius*	Migrant	E,e	E,e	E,e	E	E,e	E,r
River otter *Lutra canadensis*	Riparian	e					
Wolverine *Gulo luscus*	High mountains, near timberline, wilderness	e					
Swift fox *Vulpes velox*	Open desert plains			e			
Meadow jumping mouse *Zapus hudsonius*	Low meadows and forests with dense undergrowth						r
Spotted bat *Euderma maculata*	Arid habitats near high cliffs and canyons						r
Greater sandhill crane *Grus canadensis*	Marshlands, prairies, mountain meadows	e					
Least tern *Sterna albifrons*	Riparian; sandy islands						r
Purple martin *Progne subis*	Open or lumbered forests, towns; farms; generally near water						r
Scrub jay *Aphelocoma coerulescens*	Foothills, lower mountain slopes, scrub						r
Columbia sharp-tailed grouse *Pedioecetes phasianellus columbianus*	Prairie, brushy parklands, open tickets						r
Burrowing owl *Speotyto cunicularia*	Open grassland, prairies; usually associated with prairie dog						r

[a]Species status:
- E = listed as "Endangered" on the Federal Endangered Species list.
- e = listed as "endangered" on the state list.
- r = listed as "rare" on the state list.

Table A.4. Threatened, Endangered, or Rare Terrestrial Vertebrate Species in the Southern Rocky Mountains Region

Species	Habitat	States[a]		
		Colorado	New Mexico	Wyoming
Black-footed ferret *Mustela nigripes*	Prairie; associated with prairie dogs	E,e	E,e	E,r
Whooping crane *Grus americana*	Migrant; marshlands	E,e	E,e	E,r
Southern bald eagle *Heliaeetus leucocephalus leucocephalus*	Riparian	E	E,e	
American peregrine falcon *Falco peregrinus anatum*	Nests in cliffs; wilderness	E,e	E,e	E,r
Arctic peregrine falcon *Falco peregrinus tundrius*	Migrant	E,e	E	E,r
Wolverine *Gulo luscus*	High mountains near timberline; wilderness	e		
River otter *Lutra canadensis*	Riparian	e	e	
Lynx *Lynx canadensis*	Forested areas and swamps	e		
(Ariz.) Black-tailed prairie dog *Cynomys ludavicianus arizonensis*	Dry upland prairie		e	
Prairie vole *Microtus ochrogaster ssp.*	Open prairies, fence rows, railroad right-of-way		e	
Marten *Martes americana arigenes*	Fir, spruce and hemlock forests		e	
Mink *Mustela vison energumenes*	Riparian		e	
Meadow jumping mouse *Zapus hudsonius*	Low meadows and forest with dense undergrowth			r
Greater sandhill crane *Grus canadensis*	Marshlands, prairies, mountain meadows	e		
Least tern *Sterna albifrons*	Riparian; sandy islands		e	r
Red-headed woodpecker *Melanerpes erythrocephalus*	Groves, farm country, towns, scattered trees		e	

Table A.4. Continued

Species	Habitat	States[a]		
		Colorado	New Mexico	Wyoming
White-tailed ptarmigan *Lagopus leucurus altipetens*	Alpine summits; lower levels in winter		e	
Sharp-tailed grouse *Pedioecetes phasianellus columbianus*	Prairie, brushy parklands, open thickets		e	
Sage grouse *Centrocercus urophasianus*	Sagebrush plains		e	
Osprey *Pandion haliaetus*	Riparian		e	
McCown's longspur *Rhynchophanes mccownii*	Plains and prairies		e	
Baird's sparrow *Ammodramus bairdii*	Long-grass prairie		e	
Purple martin *Pronge subis*	Open or lumbered forests, towns, farms; generally near water			r
Brown-capped rosy finch *Leucosticte australis*	High alpine meadows and tundra			r
Scrub jay *Aphelocoma coerulescens*	Foothills, lower mountain slopes; scrub oak and juniper			r
Burrowing owl *Speotyto cunicularia*	Prairies; usually associated with prairie dogs			r
Rough green snake *Opheadrys aestivus*	Moist wooded habitats with abundant plant cover		e	
Jemez Mountain salamander *Plethodon neomexicanus*	In mixed forests above 8000 ft. in Jemez Mountains		e	
Western (boreal) toad *Bufo boreas boreas*	Desert streams, grasslands, woodlands and mountain meadows		e	

[a]Species status:
E = listed as "Endangered" on the Federal Endangered Species list.
e = listed as "endangered" on state list.
r = listed as "rare" on state list.

Table A.5. Threatened, Endangered, or Rare Terrestrial Vertebrate Species in the Colorado Plateau Region

Species	Habitat	States[a]			
		Arizona	Colorado	New Mexico	Utah
Black-footed ferret *Mustela nigripes*	Prairie; associated with prairie dogs	E,e	E,e	E,e	E,e
Utah prairie dog *Cynomys parvidens*	Prairie, mountain valleys, open or slightly brushy country				E,e
Southern bald eagle *Haliaeetus leucocephalus leucocephalus*	Riparian	E,e	E	E,e	E
American peregrine falcon *Falco peregrinus anatum*	Nests in cliffs; wilderness	E,e	E,e	E,e	E
Arctic peregrine falcon *Falco peregrinus tundrius*	Migrant	E	E,e	E	E
Yuma mountain lion *Felis concolor browni*	Rugged mountains	e			
River otter *Lutra canadensis*	Riparian	t	e	e	
Mexican pronghorn *Antilocapra americana mexicana*	Open prairies, sagebrush plains	t			
Desert sheep *Ovis canadensis mexicana*	Mountain slopes with sparse growth of trees; rugged terrain	t			
Wolverine *Gulo luscus*	High mountains, near timberline; wilderness		e		
Lynx *Lynx canadensis*	Forested areas and swamps		e		
Marten *Martes americana arigenes*	Fir, spruce, and hemlock forests			e	
Mink *Mustela vison energumenes*	Riparian			e	
(Ariz.) Black-tailed prairie dog *Cynomys ludovicianus arizonensis*	Dry upland prairie			e	
Snowy egret *Leucophoyx thula*	Marshes, ponds, irrigated lands	t			
Black-crowned night heron *Nycticorax nycticorax*	Marshes, lakes margins	t			

Table A.5. Continued

Species	Habitat	States[a]			
		Arizona	Colorado	New Mexico	Utah
Osprey *Pandion haliaetus*	Riparian	t			
Sharp-tailed grouse *Pedioecetes phasianellus columbianus*	Prairie, brushy grasslands, open thickets			e	
Sage grouse *Centrocercus urophasianus*	Sagebrush plains			e	
Least tern *Sterna albifrons*	Riparian: sandy islands			e	
Red-headed woodpecker *Melanerpes erythrocephalus*	Groves, farm country, towns, scattered trees			e	
Baird's sparrow *Ammodramus bairdii*	Long-grass prairies			e	
McCown's longspur *Rhychophanes mccownii*	Plains and prairies			e	
Gila monster *Heloderma suspectum*	Plains and deserts	t			

[a]Species status:
E = listed as "Endangered" on the Federal Endangered Species list.
e = listed as "endangered" on state list.
t = listed as "threatened" on state list.

Table A.6. Threatened, Endangered, or Rare Terrestrial Vertebrate Species in the Texas Coastal Plains Region

Species	Habitat	State[a] Texas
Red wolf *Canis rufus*	Brushy and forested areas, coastal marshlands	E,e
Whooping crane *Grus americana*	Coastal marshlands	E,e
Eskimo curlew *Numenius borealis*	Coastal marshlands	E,e
Southern bald eagle *Haliaeetus leucocephalus leucocephalus*	Riparian	E,e
American peregrine falcon *Falco peregrinus anatum*	Migrant	E,e
Arctic peregrine falcon *Falco peregrinus tundrius*	Migrant	E,e
Brown pelican *Pelecanus occidentalis*	Coastal waters	E,e
Attwater's prairie chicken *Tympanuchus cupido attwateri*	Tall-grass prairie	E,e
Ivory-billed woodpecker *Campephilus principalis*	Dense, old forests	E,e
Red-cockaded woodpecker *Dendrocopos borealis*	Old-age pine woodlands	E,e
Bachman's warbler *Vermivora bachmanii*	Dense, wet forests	E,e
American alligator *Alligator mississippiensis*	Coastal and riparian waters	E,e
Houston toad *Bufo houstonensis*	Loblolly pine areas	E,e

[a]Species status:
E = listed as "Endangered" on the Federal Endangered Species list.
e = listed as "endangered" on state list.

References

1. "Endangered and Threatened Wildlife and Plants," Fish and Wildlife Service, U.S. Dept. of the Interior, Washington, D.C., Part V, Federal Register, 14 July 1977.

2. "Protection of Endangered Species and Subspecies of New Mexico," State Game Commission Regulation No. 564, adopted 24 January 1975, amended 7 March 1975, 5 December 1975, and 21 May 1976.

3. "A List of Endangered Species of Montana Wildlife," Environment and Information Division, Montana Department of Fish and Game, July 1976

4. "Threatened Wildlife in Arizona," Arizona Game and Fish Dept., January 1976.

5. "Wildlife Regulations," Nebraska Game and Parks Commission (undated).

6. "Nongame, Threatened or Endangered Species," Kansas Forestry, Fish and Game Commission, Article XV (undated).

7. "Rare and Endangered Animals," North Dakota Game and Fish Dept., Rules and Regulations issued 15 September 1975.

8. "Classification of Wildlife in Washington," Dept. of Game, State of Washington, March 1977.

9. "Threatened and Endangered Wildlife, #1003 Designation of Species," in Proposed Regulations, Wildlife Commission, State of Colorado, Chap. 10, Article III, January 1976.

10. K. D. Keenlyne, "Endangered or Threatened Species in Wyoming," Casper, Wyoming, Special Report No. 3 (undated).

11. Texas Parks and Wildlife, Regulations 127.30.09.001-.006, as amended May 1976.

APPENDIX B. THREATENED AND ENDANGERED TERRESTRIAL PLANT SPECIES*

These tables list the threatened and endangered terrestrial plant species of the states which make up the six regions. When two or more regions encompass portions of the same state, the species list for that state is given with the region that includes the largest part of the state. [The regions and their relationship to the states are shown in Fig. 1.1 of the text of this document (page 1-2).]

Table B.1. Threatened and Endangered Terrestrial Plant Species in the States of the Northern Rocky Mountains Region.

Table B.2. Threatened and Endangered Terrestrial Plant Species in the States of the Western Great Plains Region.

Table B.3. Threatened and Endangered Terrestrial Plant Species in the States of the Wyoming Basin Region.

Table B.4. Threatened and Endangered Terrestrial Plant Species in the States of the Southern Rocky Mountains Region.

Table B.5. Threatened and Endangered Terrestrial Plant Species in the States of the Colorado Plateau Region.

Table B.6. Threatened and Endangered Terrestrial Plant Species of the Texas Coastal Plains Region.

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*The appearance of a species name on these lists does not necessarily imply that the species occurs at existing or potential uranium mill sites. These tables were compiled from "Endangered and Threatened Species, Plants, Part IV." Fish and Wildlife Service, U.S. Dept. of the Interior, the Federal Register, June 16, 1976.

Table B.1. Threatened and Endangered Terrestrial Plant Species in States of the Northern Rocky Mountains Region

		Idaho	
Constance's bitter cress *Cardamine constancei*	Wallowa primrose *Primula cusickiana*	(unnamed) pussy-toes *Antennaria arcuata*	Aase onion *Allium aaseae*
Davis' peppergrass *Lepidium davisii*	(n.c.n.) *Tofieldia glutinosa* ssp. *absona*	(unnamed) fleabane *Erigeron latus*	Clearwater phlox *Phlox idahonis*
(n.c.n.)[a] *Silene spaldingii*	MacFarlane's four-o-clock *Mirabilis macfarlanei*	(unnamed) goldenweed *Haplopappus radiatus*	(unnamed) Indian paintbrush *Castilleja christii*
Indian Valley sedge *Carex aboriginum*		(n.c.n.)[a] *Dasynotus daubenmirei*	Wavy-leaf thelypody *Thelypodium repandum*
(unnamed) milkvetch *Astragalus amnisamissi* *Astragalus purshii* *Astragalus sterilis*		Davis' stickseed *Hackelia davisii*	(unnamed) evening primrose *Oenothera psammophi*
		Montana	
	(n.c.n.)[a] *Silene spaldingi* *Trisetum orthochaetum*	(unnamed) phlox *Phlox missoulensis*	
		Washington	
Douglas' thistle milkvetch *Astragalus kentrophyta var. douglasii*	Bluegrass seacliff *Poa pachypholis*	Sukodorf's desert-parsley *Lomatium sukadorfii*	(unnamed) scorpionweed *Phacelia lenta*
Pamper milkvetch *Astragalus misellus var. pauper*	Chelan rockmat *Petrophytum cinerascens*	Hoover's desert parsley *Lomatium tuberosum*	Blue mountain onion *Allium dictuon*
Whited milkvetch *Astragalus sinuatus*	Kotzebue's grass-of-parnassus *Parnassia kotzebuei var. pumila*	Basalt daisy *Erigeron basalticus*	Alaska rein-orchid *Platanthera unalascensis* ssp. *maritima*
Thompson's clover *Trifolium thompsonii*		(n.c.n.)[a] *Silene spaldingii*	(n.c.n.)[a] *Tauschia hooveri*
Thompson's waterleaf ballhead *Hydrophyllum capitatum var. thompsonii*		Columbia milkvetch *Astragalus columbianus*	Showy stickseed *Hackelia venusta*

[a](n.c.n.) = no common name.

Table B.2. Threatened and Endangered Terrestrial Plant Species in the State, of the Western Great Plains Region

Kansas	Montana	Wyoming	Colorado	North Dakota	South Dakota	Nebraska
Mead's milkweed *Asclepias meadii*	See Table B.1	See Table B.3	See Table B.4	No species were listed for these three states		

Table B.3. Threatened and Endangered Terrestrial Plant Species in the States of the Wyoming Basin Region

Wyoming	Montana	Colorado
(unnamed) pussy-toes *Antennaria arcuata*	See Table B.1	See Table B.4
(unnamed) rockcress *Arabis fructicosa*		
Fremont's bladderpod *Lesquerella fremontii*		
(unnamed) bladderpod *Lesquerella macrocarpa*		
(unnamed) milkvetch *Astragalus proimanthus*		
(n.c.n.)[a] *Gaura neomexicana*		
(unnamed) goldenweed *Haplopappus contractus*		
(unnamed) feverfew *Parthenium ligulatum*		

[a](n.c.n.) = no common name.

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Table B.4. Threatened and Endangered Terrestrial Plant Species in the States of the Southern Rocky Mountains Region

Colorado

(unnamed) milkvetch
Astragalus deterior
Astragalus detritalis
Astragalus humillimus
Astragalus linifolius
Astragalus microcymbus
Astragalus naturitensis

Osterhout's milkvetch
Astragalus osterhoutii

Schmoll's milkvetch
Astragalus schmollae

(unnamed) scorpionweed
Phacelia formosula

(n.c.n.)[a]
Gaura neomexicana

(unnamed) fescue
Festuca dasyclada

(unnamed) wild buckwheat
Eriogonum ephedroides
Eriogonum pelinophilum

(unnamed) goldenweed
Haplopappus fremontii ssp. *monocephalus*

Porter's groundsel
Senecio porteri

(unnamed) catseye
Cryptantha aperta

Weber's catseye
Cryptantha weberi

(unnamed) rockcress
Arabis oxylobula

(n.c.n.)[a]
Draba humilis ssp. *ventosa*
Eutrema penlandii

(unnamed) bladderpod
Lesquerella pruinosa

(n.c.n.)[a]
Pediocactus knowltonii
Sclerocactus glaucus
Sclerocactus mesaeverdae

(unnamed) chickweed
Stellaria irrigua

(unnamed) wild columbine
Aquilegi micrantha

(unnamed) feverfew
Parthenium ligulatum

Spineless hedgehog cactus
Echinocereus triglochidiatus var. *inermis*

(unnamed) saltbrush
Atriplex pleiantha

(unnamed) scorpionweed
Phacelia submutica

(unnamed) beardtongue
Penstemon retrorus

(Unnamed) rockcress
Arabis beweri var. *pencuniari*

Wyoming

See Table B.3.

New Mexico

See Table B.5.

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[a](n.c.n.) = no common name.

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Table B.5. Threatened and Endangered Terrestrial Plant Species in the States of the Colorado Plateau Region

Arizona

(n.c.n.)[a]
Agave toumeyana var. bella

Kearney's sumac
Rhus kearneyi

Jones' dogbane
Apocynum jonesii

(unnamed) fleabane
Erigeron eriophyllus
Erigeron kuschei

(n.c.n.)[a]
Galinsoga semicalva var. percalva
Greenella discoidea

(unnamed) goldenweed
Haplopappus salicinus

(n.c.n.)[a]
Machaeranthera arizonica

Rusby's fetid-marigold
Pectis rusbyi

(unnamed) rock-daisy
Perityle gilenesis var. salensis

Eriogonum [illegible] vii
Eriogonu[illegible] [illegible]lium var. eric[illegible]lium
Eriogonum mortonianum
Eriogonum thompsonae var. atwoodii
Eriogonum zionis var. coccineum

(unnamed) dock
Rumex orthoneurus

(unnamed) buttercup
Ranunculus inamoenus var. subaffinis

(unnamed) cliff-rose
Cowania subintegra

(n.c.n.)[a]
Echeveria collomae
Echeveria rusbyi

(unnamed) sedge
Carex specuicola

Beath's milkvetch
Astragalus beathii

(unnamed) milkvetch
Astragalus cremnophylax

(unnamed) locoweed
Astragalus lentiginosis var. maricopae

(unnamed) milkvetch
Astragalus striatiflorus
Astragalus xiphoides

(unnamed) scuff pea
Psoralea epipsila

(n.c.n.)[a]
Sophora formosa

(unnamed) scorpionweed
Phacelia filiformis
Phacelia welshii

(n.c.n.)[a]
Plummera ambigens

San Francisco Peaks groundsel
Senecio franciscanus

Schott's wire-lettuce
Stephanomeria schottii

(unnamed) barberry
Berberis harrisoniana

Atwood's catseye
Cryptantha atwoodii

(n.c.n.)[a]
Agave arizonica
Agave mckelveyana
Agave schottii

(unnamed) stickleaf
Metzelia nitens var. leptocaulis

(unnamed) globemallow
Spahaeralcea fendleri linermis var. albescens

(n.c.n.)[a]
Allionia cristata

Goodding's ash
Fraxinus gooddingii

(n.c.n.)[a]
Camissonia specuicola ssp. specuicola

(unnamed) desert poppy
Arctomecon humilis

(unnamed) dropseed
Sporobolous patens

(unnamed) wild buckwheat
Eriogonum capillare

(unnamed) bedstraw
Galium collomae

(unnamed) Indian paintbrush
Castilleja cruenta

(unnamed) mudwort
Limosella publiflora

(unnamed) beardtongue
Penstemon clutei
Penstemon discolor

(n.c.n.)[a]
Echinocactus horizonthalonius var. nicholii

(unnamed) hedgehog cactus
Echinocereus triglochidiatus var. arizonicus

Bakersfield beavertail cactus
Opuntia basilaris

(n.c.n.)[a]
Pediocartus bradyi
Pediocactus peeblesianus var. peeblesianus
Pediocactus sileri
Silene rectiramea

Griffith's saltbrush
Atriplex griffilhsii

(unnamed) morning-glory
Ipomea egregia

Lemmon's morning-glory
Ipomea lemmonii

(n.c.n.)[a]
Draba asprella var. asprella
Sisymbrium kearneyi

Lemmon's jewelflower
Streptanthus lemmonii

Table B.5. Continued

Utah

Warner's dodder
Cuscuta warneri

(unnamed) milkvetch
Astragalus deserticus

(unnamed) wild buckwheat
Eriogonum cronquistii
Eriogonum ephedroides
Eriogonum humivagans
Eriogonum hylophilum
Eriogonum intermontanum
Eriogonum lancifolium
Eriogonum loganum
Eriogonum zionis var. *zionis*

(unnamed) Indian paintbrush
Castilleja aquariensis
Castilleja reveolii

(unnamed) beardtongue
Penstemon concinnus
Penstemon grahamii

Garrett's beardtongue
Penstemon garretii

Sharp buttercup
Ranunculus acriformis var. aestivalis

(unnamed) milkvetch
Astragalus lentiginosus var. ursinus

(unnamed) deathcamus
Zigadenus vaginatus

Hamilton's milkvetch
Astragalus hamiltonii

Harrison's milkvetch
Astragalus harrisonii

(unnamed) milkvetch
Astragalus iselyi
Astragalus loanus
Astragalus perianus
Astragalus saurinus
Astragalus serpens
Astragalus striatiflorus

(unnamed) scorpionweed
Phacelia argillacea
Phacelia indecomma
Phacelia mammillarensis

Passey's onion
Allium passeyi

(n.c.n.)[a]
Hermidium alipes var. pallidum
Camissonia megalantha

(unnamed) wild buckwheat
Eriogonum corymbosum var. revealionum
Eriogonum smithii

(unnamed) milkvetch
Astragalus detritalis

Cronquist's milkvetch
Astragalus cronquistii

(unnamed) desert-poppy
Arctomecon humilis

(unnamed) fescue
Festuca dasyclada

(n.c.n.)[a]
Gilia caespitosa

(unnamed) wild buckwheat
Eriogonum ammophilum
Eriogonum aretioides

Corymbed wild buckwheat
Eriogonum corymbosum var. davidsei

(n.c.n.)[a]
Cymopterus minimus

(n.c.n.)[a]
Cycladenia jonesii

(unnamed) fleabane
Erigeron flagellaris
Erigeron kachinensis
Erigeron maguirei
Erigeron religiosus
Erigeron sionis

Jones' telegraph plant
Heterotheca jonesii

(n.c.n.)[a]
Lygodesmia grandiflora var. stricta

(unnamed) feverfew
Parthenium ligulatum

Yellow blanket flower
Gaillardia flava

(n.c.n.)[a]
Townsendia aprica

(unnamed) catseye
Cryptantha breviflora
Cryptantha ochroleuca

(n.c.n.)[a]
Glaucocarpum suffrutescens

Barneby's peppergrass
Lepidium barnebyanum

(unnamed) bladderpod
Lesquerella tumulosa

Graham's twinpod
Physaria grahamii

Engelmann's purple hedgehog cactus
Echinocereus engelmannii var. purpureus

(n.c.n.)[a]
Sclerocactus glaucus
Sclerocactus wrightiae

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Table B.5. Continued

New Mexico

(n.c.n.)[a]
Coryphantha sneedii var. *leei*
Coryphantha sneedii var. *sneedii*

(unnamed) fleabane
Erigeron rhizomatus

(unnamed) sunflower
Helianthus paradoxus

Golden bladderpod
Lesquerella aurea

(unnamed) bladderpod
Lesquerella lata
Lesquerella valida
Lesquerella aurea

(unnamed) milkvetch
Astragalus siliceus

(unnamed) prairie clover
Petalostemum scariosum

(unnamed) prickley-poppy
Argemone pleiacantha ssp. *pinnatisecta*

(n.c.n.)[a]
Polygala rimulicola

(unnamed) wild buckwheat
Eriogonum gypsophilum

(unnamed) wild columbine
Aquilegia chaplinei

(unnamed) figwort
Scrophularia coccineas

Hempel's hedgehog cactus
Echinocereus hempelii

Lloyd's hedgehog cactus
Echinocereus lloydii

(n.c.n.)[a]
Pediocactus knowltonii
Sclerocactus mesae-verdae
Silene plankii

Castetter's milkvetch
Astragalus castetteri

Colorado

See Table B.4

[a](n.c.n.) = no common name.

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Table B.6. Threatened and Endangered Terrestrial Plant Species of the Texas Coastal Plains Region[a]

(n.c.n.)[b]
Frankenia johnstonii

Texas screwstem
Bartonia texana

(unnamed) scorpion-weed
Phacelia pallida

Rock quillwart
Isoetets lithophylla

(n.c.n.)[b]
Brazoria pulcherrima

Old blue pennyroyal
Hendeoma pilosum

Corell's false dragon head
Physostegia correllii

(n.c.n.)[b]
Polianthes runyonii

(unnamed) sunnybell
Schoenolirion texanum

Texas poppy-mallow
Callirhoe scabriuscula

(n.c.n.)[b]
Machaeranthera aurea

(unnamed) rock-daisy
Perityle bisetosa var. *bisetosa*
Perityle bisetosa var. *scalaris*
Perityle cinerea
Perityle lindheimeri var. *halmifolia*
Perityle rotundata
Perityle vitreomontana

Field golden-eye
Viguiera ludens

Golden glade cress
Leavenworthia aurea

(unnamed) wild columbine
Aquilegia chaplinei

Hinckley's wild columbine
Aquilegia hinckleyana

Kerr crowfoot
Ranunculus fascicularis var. *cuneiformis*

Comal snakewood
Colubrina stricta

(unnamed) dewberry
Rubus duplaris

Shinners tickle-tongue
Zanthoxylum parvum

Goat Mt. cottonwood
Populus hinckleyana

(unnamed) Indian paintbrush
Castilleja ciliata

(n.c.n.)[b]
Slymeria harvardii
Nephropetalum pringlei

(unnamed) silver-bells
Styrax platanifolia var. *stellata*

(unnamed) ortiguilla
Urtica chamaedryoides var. *runyonii*

(n.c.n.)[b]
Coryphantha sneedii var. *sneedii*

(n.c.n.)[b]
Hechtia texensis

(unnamed) bladder-pod
Lesquerella valida

(n.c.n.)[b]
Selenia jonesii

Sparsely flowered jewel-flower
Streptanthus sparsiflorus

(unnamed) thelypody
Thelypodium tenue

(n.c.n.)[b]
Ancistrocactus tobuschii
Coryphantha minima
Coryphantha ramillosa
Coryphantha scheeri var. *uncinata*
Coryphantha strobiliformis var. *durispina*

(unnamed) hedgehog cactus
Echinocereus chloranthus var. *neocapillis*

Kleberg's saltbrush
Atriplex klebergorum

Hardtoe seepweed
Suaeda duripes

(unnamed) pinweed
Lechea mensalis

(unnamed) stonecrop
Lenophyllum texanum

Cylinder spikerush
Eleocharis cylindrica

(unnamed) pipewort
Eriocaulon kornickianum

(n.c.n.)[b]
Andrachne arida

(unnamed) wild mercury
Argythamnia aphorcides
Argythamnia argyraea

(unnamed) spurge
Euphorbia fendleri var. *triligulata*
Euphorbia gorlondrina

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Table B.6. Continued

(n.c.n.)[b] *Manihot walkerae* *Acacia emoryana* *Brongniartia minutifolia* *Calliandra biflora*	Neches River rose-mallow *Hibiscus dasycalyx*	(unnamed) wildbuckwheat *Eriogonum nealleyi* *Eriogonum suffruticosum*	(n.c.n.)[b] *Gaya violacea*	Lloyd's hedgehog cactus *Echinocereus lloydii*
(n.c.n.)[b] *Genistidium dumosum*	Navasot ladies'-tresses *Spiranthes parksii*	(unnamed) jointweed *Polygonella parksii*	Plateau milkvine *Matelea edwardsensis*	(unnamed) hedgehog cactus *Echinocereus reichenbachii var. albertii* *Echinocereus russanthus*
Slender rush-pea *Hoffmannseggia tenella*	(unnamed) muhly *Muhlenbergia villosa*	(unnamed) knotweed *Polygoneum texense*	(unnamed) ragweed *Ambrosia cheiranthifolia*	Davis' green pitaya *Echinocereus viridiflorus var. davisii*
(unnamed) prairie clover *Petalostemum reverchonii*	Big Bend blue grass *Poa involuta*	(unnamed) pondweed *Patamogenton clystacarpus*	(n.c.n.)[b] *Brickellia viejensis*	(n.c.n.)[b] *Neolloydia gautii* *Neolloydia mariposensis*
Sabinal prairie clover *Petalostemum sabinale*	Texas wild rice *Zizania texana*	Livermore sandwort *Arenaria livermorensis*	(unnamed) tick seed *Coreopsis intermedia*	(unnamed) prickly pear *Opuntia strigil*
Hairy pod vetch *Vicia reverchonii*	(unnamed) phlox *Phlox nivalis ssp. texiensis*	Clawson's mouse-ear chickweed *Cerastium clawsonii*	(n.c.n.)[b] *Dyssodia tephroleuca*	Texas sea purslane *Sesuvium trianthemoides*
Slender oak *Quercus graciliformis*	(unnamed) Jacob's ladder *Polemonium pauciflorum ssp. hinckleyi*	(unnamed) whitlow-wart *Paronychia congestra*	(unnamed) fleabane *Erigeron geiseri var. calcicola*	Texas snowbells *Styrax texana*
Hinckley's oak *Quercus hinckleyi*	(n.c.n.)[b] *Polygala maravillasensis* *Polygala rimulicola*	McCart's whitlow-wart *Paronychia maccartii*	(unnamed) gumweed *Grindelia oolepis*	
		(n.c.n.)[b] *Silene plankii*	(unnamed) sunflower *Helianthus paradoxus*	
			Texas bitterweed *Hymenoxys texana*	

[a]The Texas Coastal Plains Region consists of a part of south central Texas.

[b](n.c.n.) = no common name.

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APPENDIX C. FEDERALLY LISTED ENDANGERED AND THREATENED FISHES*

Arizona

- Humpback Chub (*Gila cypha*)
- Colorado River Squawfish (*Ptychocheilus lucius*)
- Gila Topminnow (*Poeciliopsis occidentalis occidentalis*)
- Arizona Trout (*Salmo apache*)

Colorado

- Colorado River Squawfish (*Ptychocheilus lucius*)
- Greenback Cutthroat Trout (*Salmo clarki stomiae*)

New Mexico

- Gila Trout (*Salmo gilae*)

Texas

- Fountain Darter (*Etheostoma fonticola*)
- Big Bend Gambusia (*Gambusia gaigei*)
- Clear Creek Gambusia (*Gambusia heterochir*)
- Pecos Gambusia (*Gambusia nobilis*)
- Comanche Springs Pupfish (*Cyprinodon elegans*)

Utah

- Humpback Chub (*Gila cypha*)
- Colorado River Squawfish (*Ptychocheilus lucius*)
- Woundfin (*Plagopterus argentissimus*)

Wyoming

- Humpback Chub (*Gila cypha*)
- Kendall Warm Springs Dace (*Rhinichthys osculus thermalis*)

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*Modified from: "List, by State, of Endangered and Threatened Animal Species and Subspecies of U.S., Puerto Rico, Virgin Islands, American Samoa, Guam, and Trust Territory," National Wildlife Federation, January 1977.

APPENDIX D. GLOSSARY

In general this glossary is limited to words that are not commonly found in desk dictionaries, except for words that are used in an unusual technical sense or if there exists a possibility of confusion among various meanings given in the dictionary.

alaskite--a granite of medium or fine grain composed chiefly of quartz and alkali feldspars.
aldrin--a white crystalline insecticide consisting chiefly of a chlorinated tetracyclic derivative, $C_{12}H_8Cl_6$, of naphthalene.
amphibole--any of a group of minerals, $A_2B_5(Si,Al)_8O_{22}(OH)_2$, with like cry' ' structures usually containing three groups of metal ions.
arkose--a sandstone derived from the rapid disintegration of granite or gneiss and characterized by feldspar fragments.

blackbrush--a desert shrub of the southwestern United States with spiny twigs.
bristle grass--a grass with long bristles beneath the spikelets.

Cambrian--see Table D.1.
cenizo (or ceniza)--a variety of shrub with silver-grey foliage having a dense cluster of minute greenishflowers found in the western United States.
Cenozoic--see Table D.1.
Chara--a genus of plants common in freshwater lakes of limestone districts.
chlordane--a highly chlorinated liquid insecticide, $C_{10}H_6Cl_8$.
communities (ecological sense)--an interacting population of different kinds of individuals (as species) constituting a society or association or simply an aggregation of mutually related individuals in a given location.
coontail (hornwort)--a plant of the genus *Ceratophyllum*.
Cretaceous--see Table D.1.

dacite--an extrusive rock that is sometimes partly glassy, mainly composed of plagioclase and quartz.
DDD--an insecticide, $(ClC_6H_4)_2CHCHCl_2$, closely related chemically to DDT and similar in properties.
DDE--as DDD except formula is: $(ClC_6H_4)_2CCCl_2$.
DDT--a colorless, odorless, water-insoluble, crystalline insecticide, $(ClC_6H_4)_2CHCCl_3$.
Diazinon--a colorless oil, $C_{12}H_{21}O_3N_2PS$, used as an insecticide and nematocide.
dieldrin--a white crystalline insecticide consisting chiefly of the epoxide, $C_{12}H_8Cl_6O$, obtained by oxidation of aldrin.
distribution, joint frequency--a tabular array giving the frequency of occurrence of appropriate ranges of values for two variables.

elmid--a water beetle of the family Elmidae, found in riffle ponds.
Eocene--see Table D.1.

faulted--rock having a surface or zone of rock fracture along which there has been displacement.
block-faulted--crustal units of rock bounded by faults, either completely or in part.
thrust-faulted--rock faulted at an angle of 45° or less where one limb overrides the other along the plane of the fault.
Fayette prairie--a fairly dense prairie with medium-tall grasses dominated by little bluestem and buffalo grass.

horizon (geology)--a deposit corresponding to a particular time period, usually identified by distinctive fossils.
horizon (soil)--a reasonably distinct layer of soil.
horizon (cultural)--a level of development characterized by separated groups of artifacts.
hornfels--a fine-grained silicate rock produced by contact metamorphism.

junegrass--a tufted grass abundant on prairies and having narrow leaves and densely flowered terminal panicles like spikes.
Jurassic--see Table D.1.

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Laramide--of or relating to the mountain-making movements near the opening of the Cenozoic era (from Laramie mountains).
latite (basalt)--a lava that is the extrusive equivalent of monzonite.

Malathion--a thiophosphate insecticide, $C_{10}H_{19}O_6PS_2$.
Mesozoic--see Table D.1.
metamorphism (geology)--a pronounced change effected by pressure, heat, and water that results in a more compact and more highly crystalline condition.
metamorphosis (biology)--a marked and sometimes abrupt change in the form or structure of an animal occurring subsequent to birth or hatching.
Mollisols--dark-colored soils rich in calcium and magnesium.
monzonite--a granular igneous rock.

needlegrass--a type of grass of the western United States furnishing poor forage.
needle-and-thread--a needlegrass (*Stipa comata*).
NURE (Region)--National Uranium Resource Evaluation (Region).

Paleocene--see Table D.1.
Paleozoic--see Table D.1.
parathion--a thiophosphate insecticide, $C_{10}H_{14}NO_5PS$.
PCBs--polychlorinated biphenyls, $C_{12}H_xCl_{10-x}$.
phyllite--a foliated rock that is intermediate in composition and fabric between slate and schist.
pickleweed (iodine bush)--a shrub with fleshy jointed stems, leaves resembling scales, and flowers in crowded spikes that grows in moist soils in the southwestern United States and is used for winter grazing.
pine grass--a bunchgrass of Oregon and Washington where it forms valuable forage.
Pleistocene--see Table D.1.
pluton--a body of intrusive igneous rock of any size or shape.
Precambrian--see Table D.1.
province (physiographic)--an area throughout which geological history has been essentially the same or which is characterized by particular structural, petrographical, or physiographical features.

rabbitbrush--a widespread common shrub of western North America characterized by clusters of yellow flowers.
rift valley--an elongated valley formed by the depression of a block of the earth's crust between two faults or fault zones of approximately parallel strike.

sandreed (beach grass)--any of several tough, strongly rooted grasses that grow on exposed sandy shores.
shadscale--a scruffy grayish shrub of the western United States having a dense cluster of minute greenish flowers.
sill--a tabular body of igneous rock injected while molten between other rocks.
Silvex--a herbicide, $Cl_3C_6H_3OC_2H_4COOH$, used mainly to protect sugar cane, rice and allied crops.
stock--a body of igneous rock that is smaller than a batholith and intruded into older formations.
stratigraphy--the arrangement of strata (rock series are arranged in stratigraphic columns in Table D.1).
synusia--a structural unit of a major ecological community characterized by relative uniformity of life-form.

Tertiary--see Table D.1.
tobosa--a coarse range grass that is an important forage plant on semiarid plains and hills of the southwestern United States and adjacent Mexico.
Toxaphene--a chlorinated camphene used as a pesticide, $C_{10}H_{10}Cl_8$.
Triassic--see Table D.1.
2,4-D--a white crystalline compound, $C_8H_6Cl_2O_3$, used as a weed-killer.
2,4,5-T--a compound, $C_8H_5Cl_3O_3$, used in brush and weed control.

water moss--an aquatic plant (as various algae or liverworts) that suggests a moss in appearance or habit of growth.
wheatgrass--a grass of the genus *Agropyron* as (a) bearded wheatgrass, (b) western wheatgrass, (c) couch grass.
winter fat--a shrub that is common in parts of the southwestern United States and yields valuable forage to live stock.

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Table D.1. Geologic Time Table[a]

Era	Time Period or Rock System	Epoch	Rock Series	Estimated Duration, Years	Estimated Years Since Beginning
Cenozoic Era	Quaternary	Recent Epoch	Recent		10 to 25,000
		Pleistocene	Pleistocene	1 million	1 million
	Tertiary	Pliocene	Pliocene	12 million	13 million
		Miocene	Miocene	12 million	25 million
		Oligocene	Oligocene	11 million	36 million
		Eocene	Eocene	22 million	58 million
		Paleocene	Paleocene	5 million	63 million
Mesozoic Era	Cretaceous	Late Cretaceous	Upper Cretaceous	62 million	
		Early Cretaceous	Lower Cretaceous		135 million
	Jurassic	Late Jurassic	Upper Jurassic	46 million	
		Early Jurassic	Lower Jurassic		181 million
	Triassic	Late Triassic	Upper Triassic	49 million	
		Early Triassic	Lower Triassic		230 million
Paleozoic Era	Permian	Late Permian	Upper Permian	50 million	
		Early Permian	Lower Permian		280 million
	*Pennsylvanian	Late Pennsylvanian	Upper Pennsylvanian	65 million	
		Middle Pennsylvanian	Middle Pennsylvanian		
		Early Pennsylvanian	Lower Pennsylvanian		
	*Mississippian	Late Mississippian	Upper Mississippian		
		Early Mississippian	Lower Mississippian		345 million
	Devonian	Late Devonian	Upper Devonian	60 million	
		Middle Devonian	Middle Devonian		
		Early Devonian	Lower Devonian		405 million
	Silurian	Late Silurian	Upper Silurian	20 million	
		Middle Silurian	Middle Silurian		
		Early Silurian	Lower Silurian		425 million
	Ordovician	Late Ordovician	Upper Ordovician	75 million	
		Middle Ordovician	Middle Ordovician		
		Early Ordovician	Lower Ordovician		500 million
	Cambrian	Late Cambrian	Upper Cambrian	100 million	
		Middle Cambrian	Middle Cambrian		
		Early Cambrian	Lower Cambrian		600 million
Precambrian		Informal subdivisions used locally		Over 3 billion	

*Considered subdivisions of the Carboniferous Rock System.

[a]From "Ground Water and Wells," Johnson Division, UPO Inc., St. Paul, MN, 1975 (table reproduced with permission of the publisher).

NRC FORM 335 (7-77) U.S. NUCLEAR REGULATORY COMMISSION **BIBLIOGRAPHIC DATA SHEET**	1. REPORT NUMBER (Assigned by DDC) NUREG/CR-0597
4. TITLE AND SUBTITLE (Add Volume No., if appropriate) Descriptions of United States Uranium Resource Area	2. (Leave blank)
	3. RECIPIENT'S ACCESSION NO.
7. AUTHOR(S) G.L. Montet, P.A. Benioff, S. A. Curtis, et. al.	5. DATE REPORT COMPLETED MONTH May YEAR 1979
9. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code) Division of Environmental Impact Studies Argonne National Laboratory Argonne, Illinois 60439	DATE REPORT ISSUED MONTH June YEAR 1979
	6. (Leave blank)
	8. (Leave blank)
12. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code) Office of Nuclear Material Safety and Safeguards U.S. Nuclear Regulatory Commission Washington, D. C. 20555	10. PROJECT/TASK/WORK UNIT NO.
	11. CONTRACT NO. NRC FIN No. A2143
13. TYPE OF REPORT	PERIOD COVERED (Inclusive dates)
15. SUPPLEMENTARY NOTES	14. (Leave blank)

16. ABSTRACT (200 words or less)

Descriptive material on six uranium-producing regions of the United States is presented in this document. The six regions include parts of all of the physiographic provinces commonly designated as the Northern Rocky Mountains, the Western Great Plains, the Wyoming Basin, the Southern Rocky Mountains, the Colorado Plateau, and the Texas Coastal Plains. The document includes chapters on climate, topography, land resources and uses, geology and seismicity, mineral resources and uses, surface water resources and uses, groundwater resources and uses, soils, terrestrial biota, aquatic biota, demographic and economic profiles, social and cultural patterns, archeology and prehistory, esthetic and recreational resources, and radiological background. Lists of threatened, endangered, and rare species and a glossary of some technical terms used are presented in appendices.

17. KEY WORDS AND DOCUMENT ANALYSIS	17a. DESCRIPTORS
17b. IDENTIFIERS/OPEN-ENDED TERMS	

18. AVAILABILITY STATEMENT	19. SECURITY CLASS (This report)	21. NO. OF PAGES
Unlimited	Unclassified	
	20. SECURITY CLASS (This page)	22. PRICE $

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

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