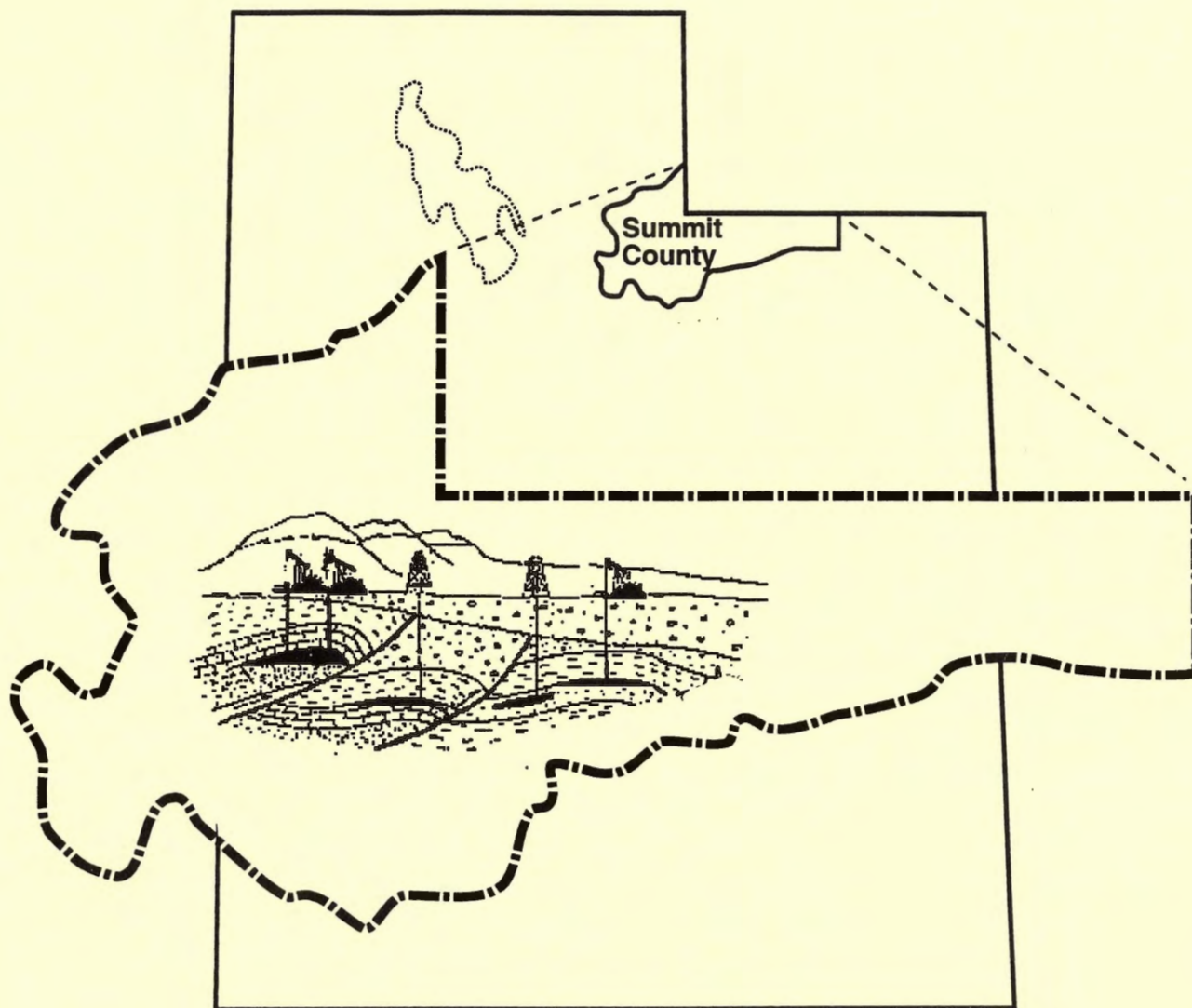


PETROLEUM PLAYS IN SUMMIT COUNTY, UTAH

by
Thomas C. Chidsey, Jr.
Utah Geological Survey



OPEN-FILE REPORT 321 June 1995
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES



This open-file report makes information available to the public which may not appear in another published form but is considered to be of value. It may not conform to UGS policy, technical review, or editorial standards, and therefore it may be premature for an individual or group to take action based on the contents of this report.

PETROLEUM PLAYS IN SUMMIT COUNTY, UTAH

by
Thomas C. Chidsey, Jr.
Utah Geological Survey

OPEN-FILE REPORT 321 **June 1995**
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES

This open-file report release makes information available to the public which may not appear in another published form but is considered to be of value. It may not conform to UGS policy, technical review, or editorial standards, and therefore it may be premature for an individual or group to take action based on the contents of this report.

STATE OF UTAH

Michael O. Leavitt, Governor

DEPARTMENT OF NATURAL RESOURCES

Ted Stewart, Executive Director

UTAH GEOLOGICAL SURVEY

M. Lee Allison, Director

UGS Board

Member	Representing
Russell C. Babcock, Jr. (chairman)	Mineral Industry
D. Cary Smith	Mineral Industry
Richard R. Kennedy.....	Civil Engineering
E.H. Deedee O'Brien	Public-at-Large
C. William Berge.....	Mineral Industry
Jerry Golden.....	Mineral Industry
Milton E. Wadsworth.....	Economics-Business/Scientific
Scott Hirschi, Director, Trust Lands Administration	<i>Ex officio member</i>

UGS Editorial Staff

J. Stringfellow	Editor
Vicky Clarke, Sharon Hamre.....	Graphic Artists
Patricia H. Speranza, James W. Parker, Lori Douglas.....	Cartographers

UTAH GEOLOGICAL SURVEY

The UTAH GEOLOGICAL SURVEY is organized into three geologic programs with Administration, Editorial, and Computer Resources providing necessary support to the programs. The ECONOMIC GEOLOGY PROGRAM undertakes studies to identify coal, geothermal, uranium, hydrocarbon, and industrial and metallic resources; to initiate detailed studies of the above resources including mining district and field studies; to develop computerized resource data bases, to answer state, federal, and industry requests for information; and to encourage the prudent development of Utah's geologic resources. The APPLIED GEOLOGY PROGRAM responds to requests from local and state governmental entities for engineering geologic investigations; and identifies, documents, and interprets Utah's geologic hazards. The GEOLOGIC MAPPING PROGRAM maps the bedrock and surficial geology of the state at a regional scale by county and at a more detailed scale by quadrangle. The Geologic Extension Service answers inquiries from the public and provides information about Utah's geology in a non-technical format. The Paleontology and Paleoecology Section maintains and publishes records of Utah's fossil resources, provides paleontological recovery services to state and local governments, and conducts studies of environmental change to aid resource management.

The UGS Library is open to the public and contains many reference works on Utah geology and many unpublished documents on aspects of Utah geology by UGS staff and others. The UGS has several computer data bases with information on mineral and energy resources, geologic hazards, stratigraphic sections, and bibliographic references. Most files may be viewed by using the UGS Library. The UGS also manages a sample library which contains core, cuttings, and soil samples from mineral and petroleum drill holes and engineering geology investigations. Samples may be viewed at the Sample Library or requested as a loan for outside study.

The UGS publishes the results of its investigations in the form of maps, reports, and compilations of data that are accessible to the public. For information of UGS publications, contact the Sales Office, 2363 South Foothill Drive, Salt Lake City, Utah 84109-1497, (801) 467-0401.

The Utah Department of Natural Resources receives federal aid and prohibits discrimination on the basis of race, color, sex, age, national origin, or handicap. For information or complaints regarding discrimination, contact Executive Director, Utah Department of Natural Resources, 1636 West North Temple #316, Salt Lake City, UT 84116-3193 or Office of Equal Opportunity, U.S. Department of the Interior, Washington, DC 20240.



Printed on recycled paper

CONTENTS

ABSTRACT	1
INTRODUCTION	2
REGIONAL GEOLOGY	5
PETROLEUM PLAYS	6
Green River Basin - Moxa Arch	7
North Flank Subthrust - Green River Basin	9
North Flank Subthrust - Hogsback Thrust	11
Hogsback Subthrust	11
True Duplexes - Hogsback and Absaroka Thrust Plates	13
Absaroka Thrust - Cretaceous	13
Absaroka Plate - Bridger Hill Thrust	15
Absaroka Thrust - Mesozoic-Cored Structures	16
Absaroka Thrust - Paleozoic-Cored Structures	18
Absaroka Thrust - Broad, Subtle Folds	19
SUMMARY	20
ACKNOWLEDGMENTS	21
REFERENCES	22

FIGURES

Figure 1. Oil and gas fields of the Utah/Wyoming salient of the thrust belt	3
Figure 2. Maximum extent of hydrocarbon potential in Summit County, Utah based on petroleum play areas ...	4
Figure 3. Schematic cross section of traps in the Green River basin - Moxa arch play	8
Figure 4. Schematic cross section of traps in the North Flank subthrust - Green River basin play	9
Figure 5. Schematic cross section of traps in the North Flank subthrust - Hogsback thrust play	10
Figure 6. Schematic cross section of traps in the Hogsback subthrust play	12
Figure 7. Schematic cross section of traps in the true duplexes - Hogsback and Absaroka thrust plates play	14
Figure 8. Schematic cross section of traps in the Absaroka thrust - Cretaceous play	14
Figure 9. Schematic cross section of traps in the Absaroka plate - Bridger Hill thrust play	16
Figure 10. Schematic cross section of traps in the Absaroka thrust - Mesozoic-cored structures play	17
Figure 11. Schematic cross section of traps in the Absaroka thrust - Paleozoic-cored structures play	19
Figure 12. Schematic cross section of traps in the Absaroka thrust - broad, subtle folds play	20

TABLES

Table 1. Cumulative oil, gas, and water production from Summit County fields as of January 1, 1995	4
Table 2. Wildcat well density and size of Summit County play areas	7

PLATES (in pocket)

Plate 1. Green River basin - Moxa arch play map
Plate 2. North Flank subthrust - Green River basin play map
Plate 3. North Flank subthrust - Hogsback thrust play map
Plate 4. Hogsback subthrust play map
Plate 5. True duplexes - Hogsback and Absaroka thrust plates play map
Plate 6. Absaroka thrust - Cretaceous play map
Plate 7. Absaroka plate - Bridger Hill thrust play map
Plate 8. Absaroka thrust - Mesozoic-cored structures play map
Plate 9. Absaroka thrust - Paleozoic-cored structures play map
Plate 10. Absaroka thrust - broad, subtle folds play map

ABSTRACT

Over 159 million barrels of oil and 2 trillion cubic feet of gas have been produced from oil and gas fields in the Cordilleran thrust belt and southern Green River basin in Summit County, Utah. However, the county still contains large, promising areas that are virtually unexplored. Potential prospects are within the economic and technical capabilities of both major and independent operators. These potential prospects are structurally and stratigraphically analogous to producing fields in the county or elsewhere in the Rocky Mountain region. Prospects are grouped into petroleum plays to aid petroleum companies in determining exploration and land acquisition strategies. Each play area is shown on a separate plate. These petroleum plays also serve as an informational or planning guide to pipeline companies, petroleum engineers, landowners, investors, government agencies, and other groups or individuals who have a vested interest in the prudent development of Summit County's hydrocarbon resources.

Summit County, Utah contains at least ten major petroleum plays which contain drilling targets grouped by common geologic parameters such as structural setting, depositional environment, or petroleum trapping mechanism. These plays represent the maximum extent of petroleum potential in a geographical area as defined by producing reservoirs, hydrocarbon shows, and untested hypotheses. Most plays have multiple potential reservoirs which range in age from Ordovician to Cretaceous. Several plays overlap to create areas with numerous vertically stacked traps and reservoirs. Oil companies will use seismic reflection methods, well control, dipmeter information, high-quality surface geologic maps, and detailed analyses of structural geometry and petroleum migration history to select specific drilling targets within these plays. Wildcat well density in these play areas is relatively sparse, averaging 10.5 square miles per well, leaving large portions of the county unexplored.

The attractiveness of the petroleum plays in Summit County to the petroleum industry varies depending on the chance of success, reserve potential, pipeline access, drilling costs, and environmental concerns associated with the individual plays. When evaluating these criteria, certain plays fit into the exploration guidelines for major companies while other plays fit into the guidelines of small independent companies. The use of horizontal-drilling techniques and the completion of a sour-gas pipeline in the county have greatly increased the potential for both exploration and development in several plays. As a result, Summit County promises to be a major producer of oil and gas for many years to come.

INTRODUCTION

After the 1975 discovery of oil and gas at Pineview field in Summit County, Utah the Cordilleran thrust belt of southwestern Wyoming and north-central Utah was the site of major petroleum exploration and development activities. Eight new oil and gas field discoveries were added to the only existing oil field in the county, Bridger Lake, located in the southernmost part of the Green River basin (figure 1). Productive reservoirs in the county range in age from Cretaceous to Mississippian. Over 159 million barrels of oil (25 million m³ of oil) and 2 trillion cubic feet of gas (57 billion m³ of gas) have been produced from these Summit County fields (table 1). With the collapse of oil prices in 1986 and a nationwide oversupply of natural gas, drilling activity has been greatly reduced in comparison to the levels of the late 1970s and early 1980s. However, the county still contains large, promising areas that are virtually unexplored. The completion of Union Pacific Resources Company's sour gas pipeline (Wahsatch Gathering System) and the successful application of horizontal drilling techniques to two subcommercial oil fields in the county (Elkhorn Ridge and Lodgepole, figure 1), add greatly to the future of the petroleum industry in the county. Development of potential prospects is within the economic and technical capabilities of both major and independent operators. These potential prospects are structurally and stratigraphically analogous to many producing fields in the thrust belt and other areas of the Rocky Mountain region.

To assist with the exploration and development efforts in Summit County by the petroleum industry, the Utah Geological Survey has identified and delineated ten petroleum plays. They are the: (1) Green River basin - Moxa arch, (2) North Flank subthrust - Green River basin, (3) North Flank subthrust - Hogsback thrust, (4) Hogsback subthrust, (5) true duplexes - Hogsback and Absaroka thrust plates, (6) Absaroka thrust - Cretaceous, (7) Absaroka plate - Bridger Hill thrust, (8) Absaroka thrust - Mesozoic-cored structures, (9) Absaroka thrust - Paleozoic-cored structures, and (10) Absaroka thrust - broad, subtle folds plays. The mapped play areas represent the maximum extent of potential based on common geological characteristics, producing reservoirs, hydrocarbon shows in wells within the areas, and even untested hypotheses. Within each of these ten areas one or more distinct structural and/or stratigraphic traps with multiple reservoirs may be targeted for drilling. Many of the play areas overlap and when combined, they cover approximately 616,320 acres (249,425 ha) in Summit County (figure 2). Wildcat density remains relatively sparse, averaging 10.5 square miles per well (16.8 km² per well). However, the overall success rate for the Utah thrust belt wildcats is 6 percent (8.8 percent in Summit County); a good success rate considered good for the depths, structural complexities, and sparse well density in the region.

The goal of this report and the accompanying play maps is to provide a quick but accurate understanding of the petroleum potential in Summit County for both petroleum exploration and development geologists. This will help guide petroleum companies, especially those new to the region, in planning exploration and land acquisition strategies. The maps will also aid pipeline companies and gas processors plan future facilities and pipeline extensions such as the location of additional sour-gas pipelines. Other users of the play maps may include petroleum engineers, petroleum landmen, landowners in the county, bankers and investors, economists, utility companies, manufacturers, Summit County planners, and numerous government agencies.

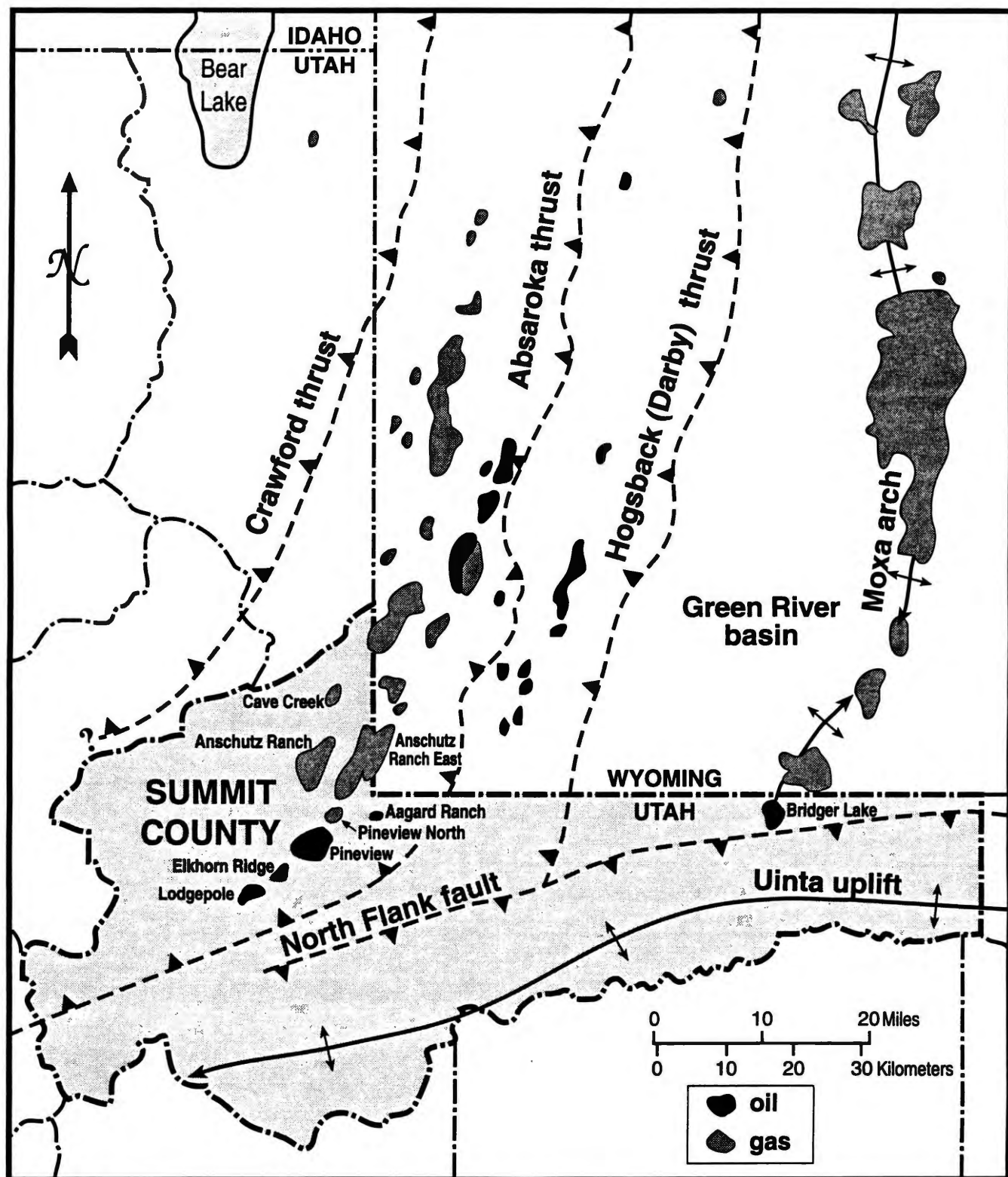


Figure 1. Oil and gas fields, uplifts, and major thrust faults (saw teeth on upper plate) in the Utah/Wyoming salient of the thrust belt and the southern portion of the Green River basin (modified after Chidsey, 1993). Names of Summit County, Utah oil and gas fields are shown.

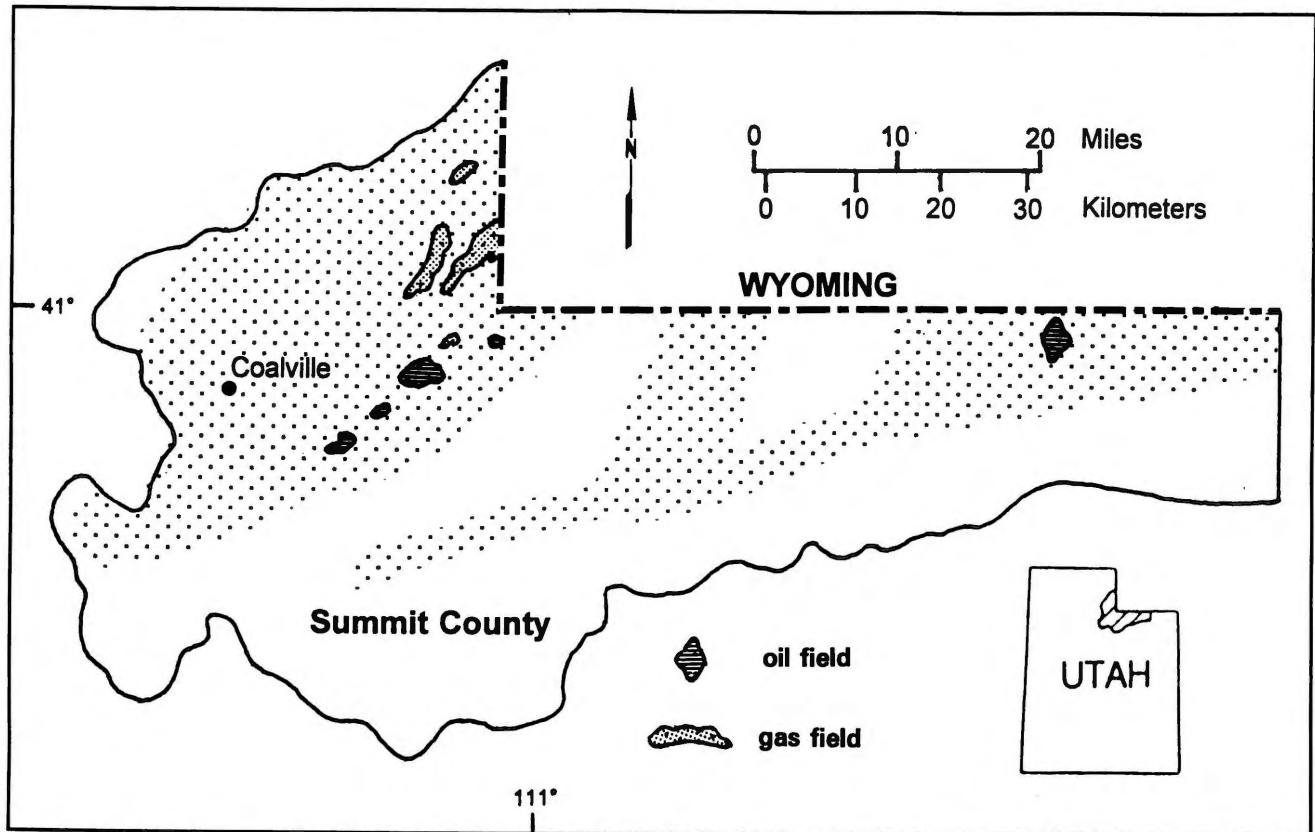


Figure 2. Maximum extent of hydrocarbon potential (stippled) in Summit County, Utah based on play concept maps. Refer to figure 1 for names of oil and gas fields.

Table 1. Cumulative oil, gas, and water production from Summit County fields as of January 1, 1995 (Utah Division of Oil, Gas and Mining, 1995).

Field	Discovery Date	Active Wells	Cumulative Production		
			Oil ¹ (Bbls)	Gas (Mcf)	Water (Bbls)
Aagard Ranch	1982	2	66,254	253,469	131,654
Anschutz Ranch	1979	14	974,559	60,857,388	1,445,367
Anschutz Ranch East ²	1979	33	113,321,832	1,990,969,574 ³	11,414,827
Bridger Lake	1966	6	12,732,799	66,686,143 ³	2,854,801
Cave Creek	1979	4	143,257	10,364,224	7,903
Elkhorn Ridge	1977	2	1,080,256	434,908	705,396
Lodgepole	1977	6	1,629,969	663,415	4,037,875
Pineview North	1982	2	653,986	7,408,929	1,045,420
Pineview	1975	16	28,904,602	35,555,510	64,515,597
Total	-----	85	159,507,514	2,173,193,560	86,158,840

¹ and/or condensate ² Utah portion only ³ includes cycled gas

REGIONAL GEOLOGY

The Utah-Wyoming-Idaho salient of the Cordilleran thrust belt is defined as the region north of the Uinta Mountains of northeastern Utah and south of the Snake River Plain of Idaho, with the Green River basin of Wyoming forming the eastern boundary. Thrusting extends westward into the Great Basin for more than 100 miles (161 km). Two major thrusts are present in Summit County: the Absaroka and Hogsback (Darby) thrusts (figure 1). They represent detached (not involving basement rock), compressional styles of deformation. The Absaroka thrust moved in late Cretaceous time (pre-mid-Santonian to pre-Campanian-Maestrichtian according to Royse and others [1975]). The Hogsback (Darby) thrust represents the youngest and easternmost advance of the Cordilleran thrust belt in Utah. Movement took place in late Paleocene to early Eocene time (Royse and others, 1975). The thrusts generally trend in a north-northeast direction. The leading edges of these faults are listric in form and structurally complex with numerous folds and thrust splays.

Petroleum traps in the thrust belt are long, narrow, doubly plunging, thrust anticlines. These anticlines are typically asymmetric, overturned to the east, with axes trending north to northeast (Royse and others, 1975; Conner and Covlin, 1977; Petroleum Information, 1981; Dixon, 1982; Lamerson, 1982; Bruce, 1988; Chidsey, 1990; Chidsey, 1993; Sprinkel and Chidsey, 1993). Hydrocarbons in both Mesozoic and Paleozoic reservoirs were generated from subthrust Cretaceous source rocks (Warner, 1982). These include organic-rich units in the Bear River, Aspen (Mowry equivalent), and Frontier formations. The source rocks began to mature after being overridden by thrust plates. Hydrocarbons were then generated, expelled, and subsequently migrated into overlying traps, primarily along fault planes.

The Green River basin (sometimes referred to as the Bridger basin) is defined as the region north of the Uinta Mountains and southwest of the Wind River Range in Wyoming, with the thrust belt to the west and the Rock Springs uplift to the east. The Moxa arch is a broad, gently folded basement uplift which trends north-south through the center of the Green River basin. The basin developed during the Late Cretaceous through Early Tertiary (Laramide time). Basin subsidence resulted from tectonic loading by surrounding basement-involved Laramide uplifts such as the Wind River Range and the Uinta Mountains (Hagen and others, 1985). The basin was filled with nearly 10,000 feet (3,050 m) of sediments shed off the surrounding uplifts. During the Cretaceous, the area of the Green River basin was part of the north-south-trending Western Interior seaway where two significant hydrocarbon-bearing formations were deposited: the Dakota Sandstone and the Frontier Formation; Lower and Upper Cretaceous in age respectively. The Dakota Sandstone was deposited as a widespread fluvial braided-delta system sourced from the south (Mullen and Barlow & Haun, Inc., 1993a). The Frontier Formation was deposited as a fluvial- to wave-dominated deltaic system sourced from Sevier highlands to the west.

Petroleum traps in the Green River basin are typically stratigraphic and structural combinations. Subsidiary closures are common along the Moxa arch. Fluvial sandstones of the Dakota Sandstone and Frontier Formation generally trend in northwestern and eastern directions respectively across these closures. In the Dakota Sandstone, hydrocarbons are produced from discontinuous point bars, longitudinal bars, and sheet-like, braided deltaic deposits (Reisser and Blanke, 1989; Doelger and others, 1993b; Mullen and Barlow & Haun, Inc., 1993a). In the Frontier Formation, hydrocarbons are produced from distributary channel, distributary-mouth bar, upper shoreface, and foreshore deposits (Moslow and Tillman, 1984, 1989; Dutton and Hamlin, 1991; Doelger and others, 1993a; Montgomery, 1994). Hydrocarbons in Cretaceous reservoirs of the Green River basin were generated and expelled from source rocks in the Cretaceous Mowry Shale located stratigraphically between the Dakota Sandstone and Frontier Formation (Nixon, 1973).

The Precambrian-cored Uinta uplift trends east-west through southern Summit County. The Uinta uplift is the largest Laramide structure in Utah and resulted from regional basement compression. Uplift began in Late Cretaceous and ended in Eocene (Hintze, 1988). The trend of the Utah thrust belt changes from north-south to west-southwest near the Uinta uplift. This change in trend was likely a response to the contemporaneous movement of the Uinta uplift which deflected thrusting. The north flank of the Uinta uplift is bounded by a major basinward, basement-involved, high-angle reverse fault, the North Flank fault. Several fault slivers are associated with basement-involved faults such as this. A small portion of the Hogsback thrust plate and Green River basin was overridden by the North Flank fault during the later stages of the Laramide orogeny.

Seismically-defined petroleum traps are deep, subtle structural closures below and masked by the Precambrian on the hanging wall of the North Flank fault. To date, no production has been found on these structures in Utah. Analogous features elsewhere in Rocky Mountain foreland basins have proved to be productive and because they are deep these features are gas rich (Doelger and others, 1993c; Mullen and others, 1993a). The basement-involved faults provide both the seal and the migration pathway for hydrocarbons. As in other areas of Summit County, the likely sources of potential hydrocarbons beneath the North Flank fault are organic-rich units in the Cretaceous Bear River, Aspen, Mowry, and Frontier formations, and possibly in the Triassic Thaynes Limestone, Permian Phosphoria Formation, and Pennsylvanian Amsden/Morgan Formation.

PETROLEUM PLAYS

The petroleum plays are ideas concerning favorable petroleum potential in geographic areas due to combinations of source rock, migration paths, and reservoir rock characteristics. Play areas having similar geologic parameters are shown on plates 1-10. These parameters may include a common structural setting, hydrocarbon-trapping mechanism, stratigraphic unit, rock type, or depositional environment. Hydrocarbon potential was identified from production out of various reservoirs in large or small oil and gas fields, encouraging hydrocarbon shows in wells, or delineation of untested traps. Play areas represent the maximum extent of the potential in that particular play and may contain multiple potential reservoirs or traps. Traps include stratigraphic, structural, and combination. Table 2 summarizes the size of play areas in acres, number of wildcat wells drilled to date, and the square miles per wildcat well for each play area.

Several of the thrust belt plays cover more than just Summit County. They extend into Uinta and Lincoln Counties, Wyoming, with one play partially in Rich and Morgan Counties, Utah. Green River basin plays extend into Daggett County, Utah and most of southwestern Wyoming.

Table 2. Wildcat well density and size of Summit County play areas.

Play Concept	Play Area Size (acres)	No. of Wildcats	Square Miles/Well
Green River Basin - Moxa Arch	66,560	12	7
North Flank Subthrust - Green River Basin	88,960	1	39
North Flank Subthrust - Hogsback Thrust	34,560	none	N/A*
Hogsback Subthrust	49,920	1	78
True Duplexes - Hogsback Thrust Plate	24,320	6 (penetrating objective section)	6.3
Absaroka Thrust Plate	196,480	37 (penetrating objective section)	8.3
Absaroka Thrust - Cretaceous	35,840	10	5.6
Absaroka Plate - Bridger Hill Thrust	118,400	26	7.1
Absaroka Thrust - Mesozoic-cored Structures	104,320	21	7.8
Absaroka Thrust - Paleozoic-cored Structures	57,600	10	9
Absaroka Thrust - Broad Subtle Folds	161,280	4	63

*N/A=not applicable

Green River Basin - Moxa Arch

The Green River basin - Moxa arch play is located in the northeastern part of Summit County (plate 1) and covers approximately 66,560 acres (26,940 ha) (table 2). The play continues to the east into Daggett County, Utah and north into Uinta, Lincoln, Sublette, and Sweetwater Counties, Wyoming. New interpretation of seismic data and geophysical well logs suggests that the Moxa arch, which trends north-south in Wyoming, extends southwesterly into Utah paralleling the leading edge of the Hogsback (Darby) thrust. Drilling targets are delineated using geophysical well logs and seismic stratigraphy methods. The Green River basin - Moxa arch play area does not include that portion of the basin beneath the North Flank fault of the Uinta uplift because exploring there would involve: (1) considerable seismic acquisition, (2) expensive well-site preparation, road construction, and drilling operations, and (3) major environmental and related permitting problems. Therefore the Green River basin beneath the North Flank fault has been placed in a separate play.

Potential petroleum trapping mechanisms in the Green River - Moxa arch play consist of: (1) combination structural and stratigraphic traps where fluvial- and braided-deltaic sandstones trend over subsidiary closures on the Moxa arch, (2) stratigraphic pinchouts on the flanks of the Moxa arch and other areas of the Green River basin, and (3) broad anticlines in the deep Paleozoic section along the Moxa arch (figure 3). Potential reservoirs in the Green River - Moxa arch play include the Cretaceous Frontier Formation, Dakota Sandstone, and Muddy Sandstone, Pennsylvanian Morgan Formation, and Mississippian Madison Limestone. Exploratory well density is sparse in the play area averaging 7 square

miles per well (MPW) (16.8 km² per well [KPW]) (table 2).

There are numerous fields in the Green River - Moxa arch play; but only one in Utah. The Bridger Lake field (figure 1 and plate 1) in T. 3 N., R. 14 E., Summit County, is a combination structural/stratigraphic trap with production from the Dakota Sandstone reservoir. This field is located in the center of the play area and was discovered in 1966. Cumulative production was over 12 million barrels of oil (MMBO) (1.9 million m³ of oil [MMCMO]) and 66 billion cubic feet of gas (BCFG) (1.9 billion m³ of gas [BCMCG]) as of January 1, 1995 (table 1) (Utah Division of Oil, Gas and Mining, 1995). The Dakota Sandstone and Frontier Formation are productive in many fields along the length of the Moxa arch north for 120 miles (190 km), such as Bruff, Church Buttes, and Lincoln Road fields. Sour gas (gas containing hydrogen sulfide [H₂S]) is produced from the Morgan Formation on deep, broad anticlines in the Church Buttes and Butcher Knife Springs fields along the Moxa arch, Uinta County, Wyoming. Carbon dioxide is produced from the Madison Limestone on deep anticlines in the Greater Big Piney/La Barge field complex in the northern part of the Moxa arch, Sublette County, Wyoming (Doelger and others, 1993).

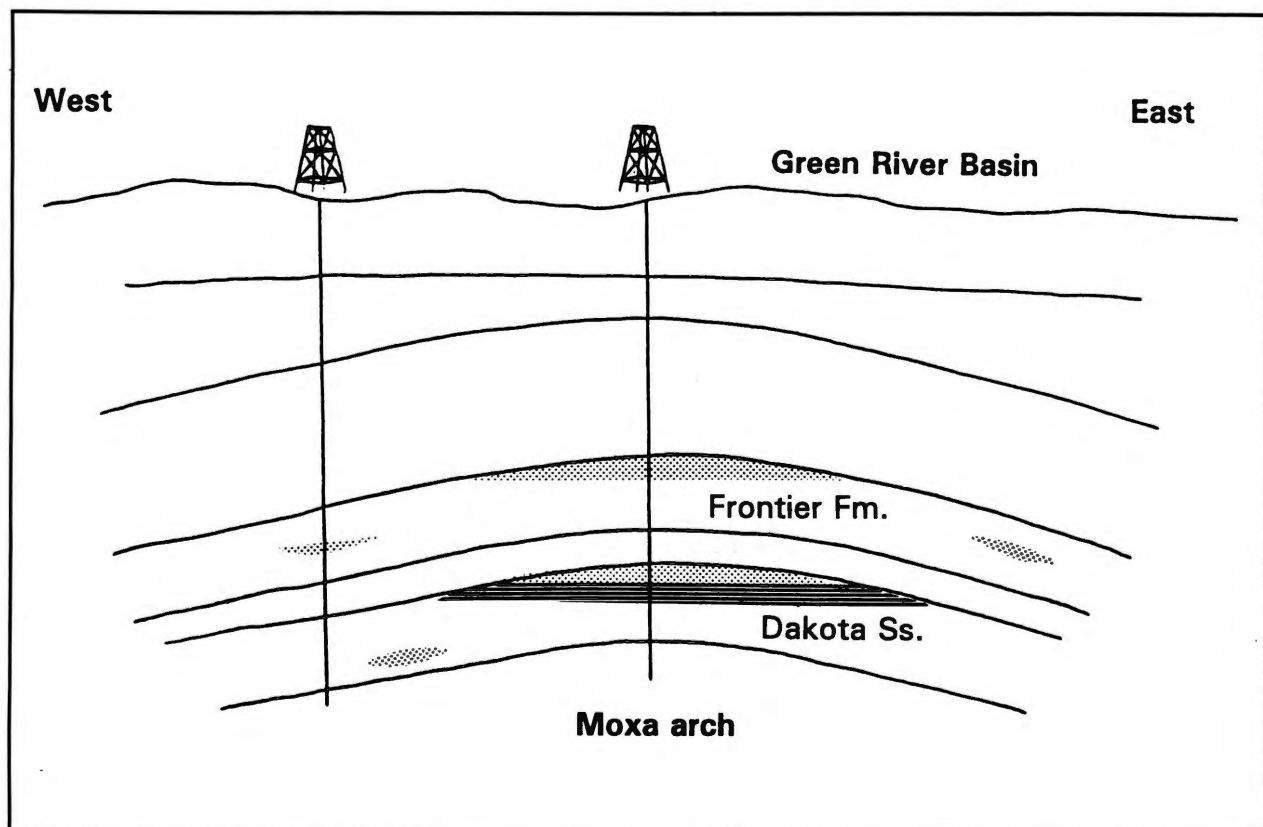


Figure 3. Schematic cross section of traps in the Green River basin - Moxa arch play. Oil deposits are shaded dark gray; gas deposits are shaded light gray.

North Flank Subthrust - Green River Basin

The North Flank subthrust - Green River basin play is located in the central part of the eastern half of Summit County (plate 2) and covers approximately 88,960 acres (36,000 ha) (table 2). This play represents that portion of the Green River basin overridden by the North Flank fault of the Uinta uplift (figure 4). The northern boundary of the play is defined by the surface trace of the North Flank fault. The southern boundary is defined by the cutoff of the deepest potential reservoir by the North Flank fault. Hydrocarbon potential exists in a 3 mile- (4.8 km-) wide band between these boundaries. The play continues east along the north flank of the Uinta uplift into Daggett County, Utah. In the western portion of the play area, the potential Green River basin drilling targets lie beneath both the North Flank fault and the Hogsback (Darby) thrust plate (figure 5). All drilling targets in the play area must be delineated using seismic reflection methods. Attendant velocity correction problems must be addressed such as pull-ups of time events in the footwall caused by high-velocity Precambrian rocks in the hanging wall.

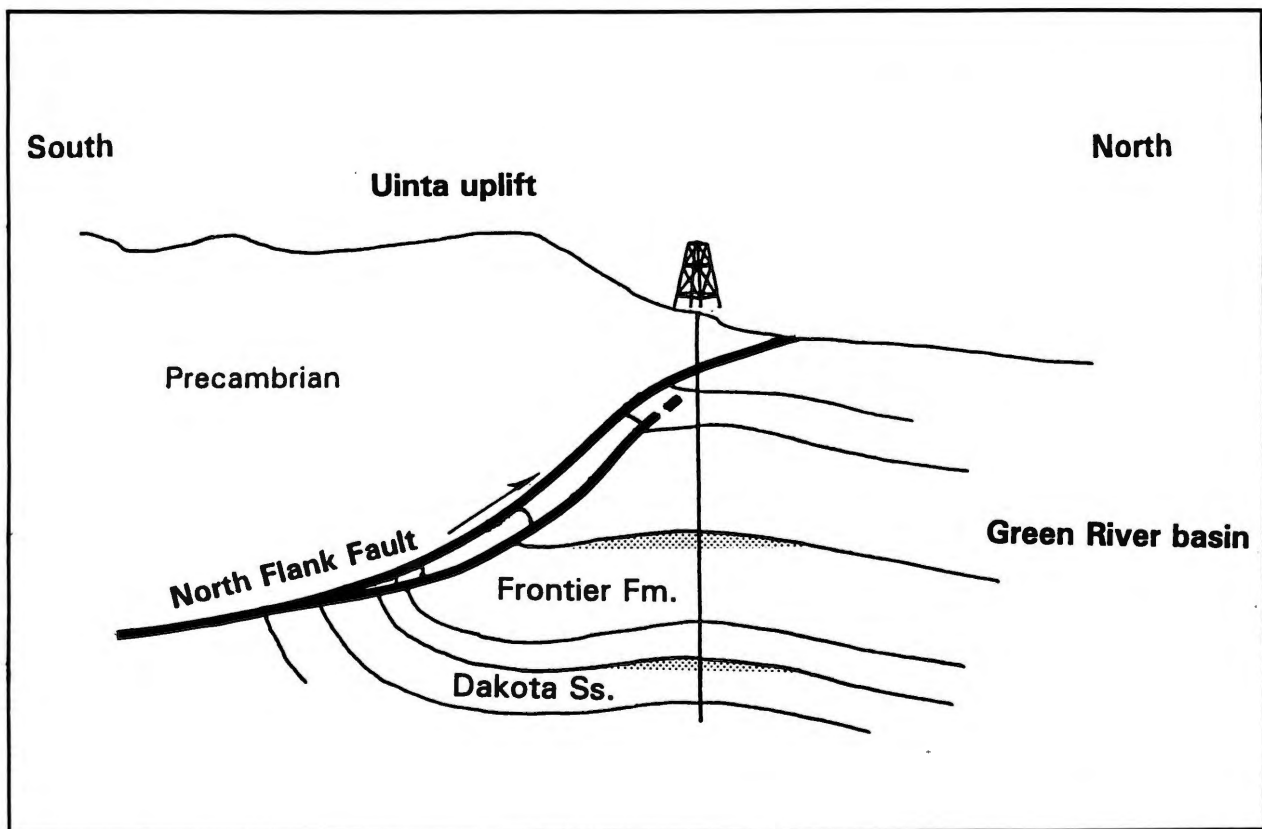


Figure 4. Schematic cross section of traps in the North Flank subthrust - Green River basin play. Gas deposits are shaded light gray.

Petroleum trapping mechanisms in the North Flank subthrust - Green River basin play consist of: (1) simple, independent anticlines (figure 4), (2) basement-involved, ramp anticlines, and (3) drag of beds between fault slivers of the North Flank fault. The possible southern continuation of the Moxa arch beneath the North Flank fault is a major exploratory target. Combination structural and stratigraphic traps where fluvial- and braid-deltaic sandstones trend over subsidiary closures on the arch may be present like the Green River basin - Moxa arch play to the north, through at greater depths. Potential reservoirs in the North Flank subthrust - Green River basin play include the Cretaceous Frontier Formation and Dakota Sandstone, Pennsylvanian Morgan Formation, and Mississippian Madison Limestone. Only one exploratory well has been drilled in the play area, the Shell Oil 21X-9 Dahlgreen Creek Unit Government well (Sec. 9, T. 2 N., R. 14 E.) completed as a 17,100-foot (5,181-m) dry hole to the Jurassic Morrison Formation in 1968. As a result exploratory drilling density is an average of 39 MPW (63 KPW) for the play (table 2).

There are few fields in the Rocky Mountain region analogous to the targets in the North Flank subthrust - Green River basin play. One such field, however, is Tepee Flats field located in the Wind River basin (Sec. 16, T. 37 N., R. 86 W.), Natrona County, Wyoming. The trap is a deep anticline below the Owl Creek thrust and Precambrian rocks of the overlying Casper arch on the northeast flank of the basin. The principal reservoir is the Cretaceous Lakota Formation which has produced over 5.8 BCFG (0.2 BCMG) as of January 1, 1995. The overlying Frontier Formation in the fault sliver has produced minor amounts of oil. Another subthrust discovery, Barrett's 1 Cave Gulch-Federal (Sec. 31, T. 37 N., R. 86 W.), was made 3 miles (4.8 km) to the southwest in September, 1994. That well was completed in the Upper Cretaceous Lance Formation flowing 9.7 million cubic feet of gas per day (MMCFGPD) (0.3 million m³ of gas per day [MMCMGPD]) and 116 barrels of oil per day (18.4 m³ of oil per day) (Petroleum Information, 1994).

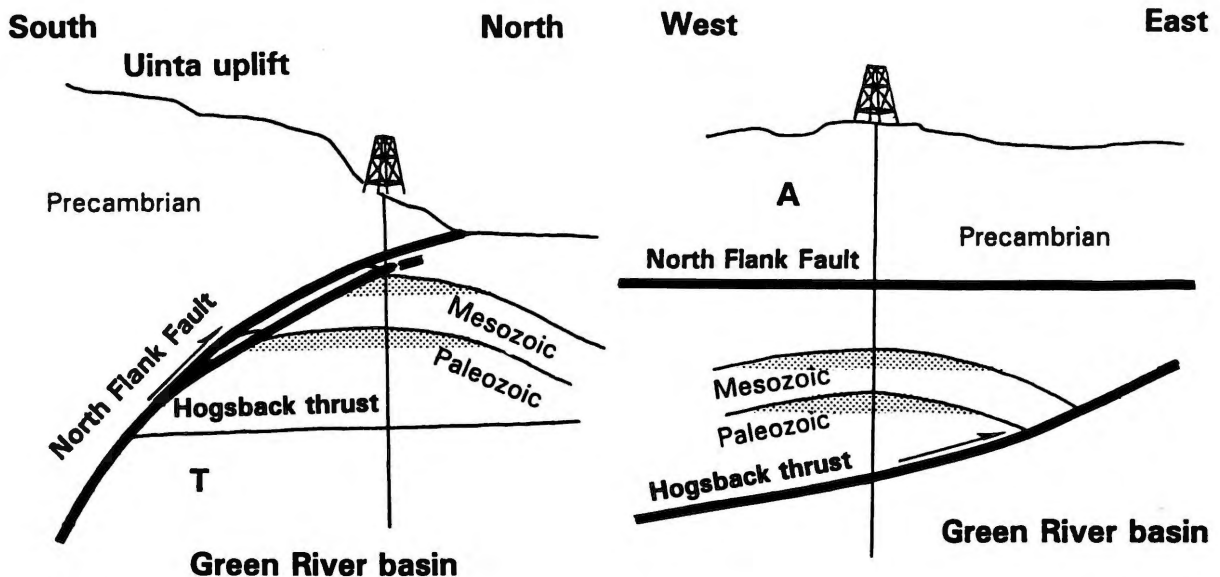


Figure 5. Schematic cross section of traps in the North Flank subthrust - Hogsback thrust play. Gas deposits are shaded light gray. T = block moving toward viewer; A = block moving away from the viewer.

North Flank Subthrust - Hogsback Thrust

The North Flank subthrust - Hogsback thrust play is located in and confined to the central part of Summit County (plate 3) and covers approximately 34,560 acres (14,000 ha) (table 2). This play represents that portion of the Hogsback (Darby) thrust plate overridden by the North Flank fault of the Uinta uplift (figure 5). The northern boundary of the play is defined by the surface trace of the North Flank fault. The southern boundary is defined by the cutoff of the deepest potential reservoir on the Hogsback thrust plate by the North Flank fault. Hydrocarbon potential exists in a 2 to 2.5 mile- (3.2-4 km-) wide band between these boundaries. The easternmost part of the play area overlaps approximately 7,360 acres (2,980 ha) of the North Flank subthrust - Green River basin play. This overlapping area represents 21 percent of the North Flank subthrust - Hogsback thrust play and constitutes an excellent location where multiple exploratory drilling targets may be encountered. All drilling targets in the play area must be delineated by using seismic reflection methods. Seismic reflection data for the footwall must be corrected for the effect of high-velocity Precambrian rocks in the hanging wall.

Petroleum trapping mechanisms in the North Flank subthrust - Hogsback thrust play consist of: (1) ramp anticlines where potential reservoirs and hydrocarbon seals dip into the Hogsback thrust or associated thrust splays (figure 5), and (2) drag of beds on the Hogsback thrust plate between fault slivers of the North Flank fault. Potential reservoirs in the North Flank subthrust - Hogsback thrust play include the Jurassic Twin Creek Limestone and Nugget Sandstone, Triassic Thaynes Limestone, Permian Phosphoria Formation, Pennsylvanian Weber Sandstone and Amsden Formation, Mississippian Madison Group (the Madison is elevated to Group status in the Utah-Wyoming thrust belt [DeBruin and Sprinkel, 1993 sheet 2]), and Devonian Darby Formation. Most of these formations are major oil and gas producers in the main thrust belt producing fairway of Utah and Wyoming. However, to date no exploratory wells have been drilled in the play area (table 2).

There are no fields or exploratory wells in the Rocky Mountain region analogous to the targets in the North Flank subthrust - Hogsback thrust play. However, two wells have been proposed in the play area though never drilled. In 1985, Amoco staked a 19,000-foot (5,790-m) Nugget test in Section 21, T. 1 N., R. 10 E., the 1 Federal Amoco-A well located in the eastern part of the play area (Chidsey, 1990). In 1993, Chevron USA proposed a 17,000-foot (5,180-m) Dakota test in Section 16, T. 1 N., R. 10 E., the 1 Tabletop-Federal well. Both wildcats were designed to test structures beneath the North Flank fault on the Hogsback thrust plate and in the Green River basin. Major environmental and related permitting problems resulted in the curtailing of the drilling of these wells.

Hogsback Subthrust

The Hogsback subthrust play is located in the north-central part of Summit County (plate 4) and covers approximately 49,920 acres (20,200 ha) (table 2). This play represents that portion of the Green River basin overridden by the Hogsback (Darby) thrust plate but excluding that which lies beneath the North Flank fault (figure 6). The eastern and southern boundaries of the play are defined by the surface traces of the Hogsback thrust and North Flank fault respectively. The western boundary is defined by the cutoff of the deepest potential reservoir by the Hogsback thrust. The play continues north as a 7 to 8 mile- (11-13 km-) wide band along the Hogsback thrust through Uinta, Lincoln, and Sublette Counties, Wyoming. All drilling targets in the play area must be delineated primarily by using seismic reflection methods. Seismic reflection data for the footwall must be corrected for the effect of high-velocity Paleozoic rocks in the

hanging wall.

Petroleum trapping mechanisms in the Hogsback subthrust play consist of: (1) ramp anticlines along minor detached thrusts (figure 6), basement-involved thrusts, or backthrusts, and (2) simple, independent anticlines. Backthrusts have not been documented in the Utah portion of the Green River basin along the leading edge of the Hogsback thrust but are present in Sublette County, Wyoming. Backthrusts may be an indication of potential structures below as well as creating important traps (Webel, 1987). Potential reservoirs in the Hogsback subthrust play include the Cretaceous Frontier Formation, Muddy Sandstone, and Dakota Sandstone, Jurassic Nugget Sandstone, and Mississippian Madison Limestone. Only one exploratory well has been drilled in the play area, the American Quasar Petroleum 1 Cow Hollow well (Sec. 17, T. 2 N., R. 11 E.) completed in 1975 as a 18,922-foot (5,767-m) dry hole to the Jurassic Morrison Formation. As a result, exploratory drilling density is an average of 78 MPW (126 KPW) for the play (table 2).

There are several fields in the Greater Big Piney/La Barge platform area, Sublette and Lincoln Counties (the northwestern part of the Green River basin), Wyoming, which are placed in the northern Hogsback subthrust play. Dry Piney, Hogsback, and Tip Top fields produce oil and gas from ramp anticlines beneath the Hogsback thrust (referred to as the Darby thrust in that area) (Blackstone, 1979). All of these fields are major producer of oil and gas from the Frontier, Muddy, Dakota, and Nugget formations (Golden, 1979; Carlson, 1979; Webel, 1979). Dry Piney field (T. 27 N., R. 114 W., Sublette County), for example, has produced over 15.6 MMBO (2.5 MMCMO) from the Frontier Formation and 125.8 BCFG (3.6 BCMG) from the Dakota Sandstone as of January 1, 1995. Carbon dioxide is produced from the Madison Limestone on deep anticlines below the Darby thrust in Graphite, Lake Ridge, and Fogarty Creek fields, Sublette County, Wyoming (Doelger and others, 1993).

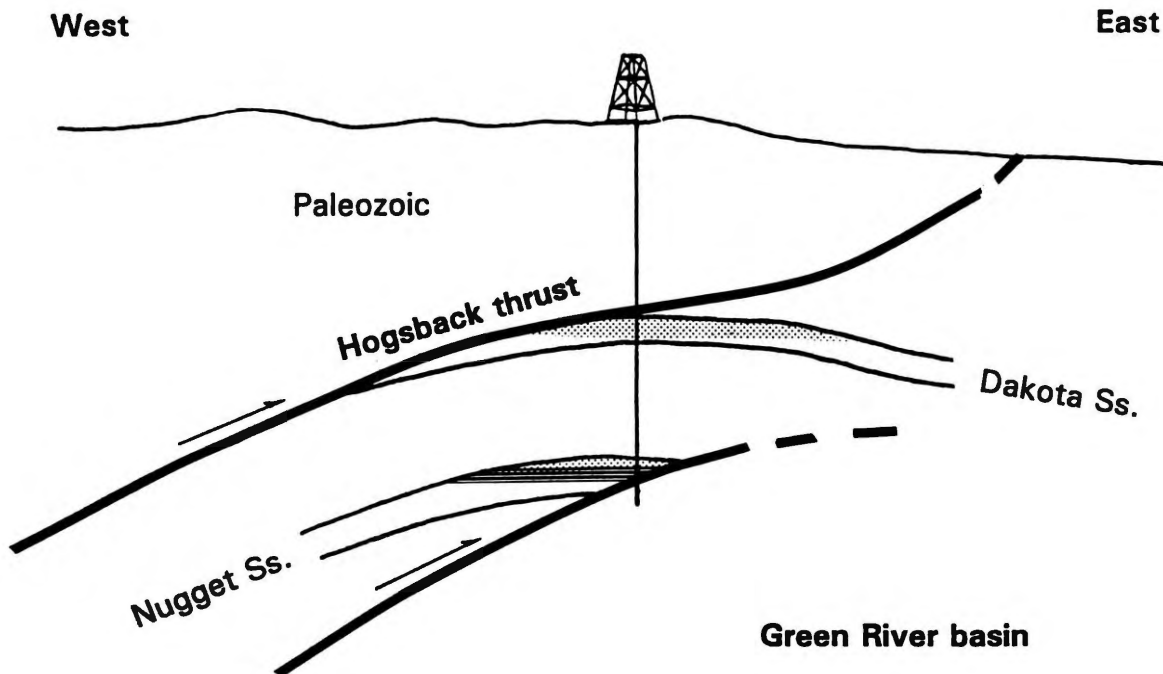


Figure 6. Schematic cross section of traps in the Hogsback subthrust play. Oil deposits are shaded dark gray; gas deposits are shaded light gray.

True Duplexes - Hogsback And Absaroka Thrust Plates

The true duplexes - Hogsback and Absaroka thrust plates play are located in the central and western parts of Summit County (plate 5). The play covers approximately 220,800 acres (89,360 ha); 24,320 acres (9,840 ha) on the Hogsback plate and 196,480 acres (79,520 ha) on the Absaroka plate (table 2). The play is defined as that area of the Absaroka and Hogsback thrusts where imbricate thrust faults or stacked imbricate faults form complex structural targets. The eastern boundaries of the play are set back 1 to 6 miles (1.6-9.7 km) from the surface traces of the Hogsback and Absaroka thrusts. The western boundary is defined as the area of the respective thrust plates where complex imbrication is not present or rare. The southern boundary on the Hogsback thrust is the surface trace of the North Flank fault of the Uinta uplift. The southern portion of the Absaroka thrust trends southwest toward the Wasatch Mountains where the play area terminates. The play extends north through Uinta and Lincoln Counties, Wyoming. The play area overlaps with one or more other Summit County plays and thus there is the likelihood of multiple drilling targets. Prospective drilling targets in the play must be delineated using seismic reflection methods, identification of faults from geophysical well log evaluation, and the construction of balanced structural cross sections.

Potential petroleum trapping mechanisms in the true duplexes - Hogsback and Absaroka thrust plates play consist of: (1) true duplexes where the targeted structure is the horse bounded by roof and floor thrusts (figure 7), (2) overlapping ramp anticlines, (3) hybrid duplexes, and (4) subtle fault-propagation folds (Mitra, 1986; Sprinkel and Chidsey, 1993). These traps may be developed along secondary fault-propagation folds, along backlimb thrust faults, or between imbricate splays on the forelimb of anticlines (Mitra, 1986, 1990). Potential reservoirs in the true duplexes - Hogsback and Absaroka thrust plates play include the Jurassic Nugget Sandstone, Triassic Thaynes Limestone, Permian Phosphoria Formation, Pennsylvanian Weber Sandstone and Amsden Formation, Mississippian Madison Group, Devonian Darby Formation, and Ordovician Bighorn Dolomite. Exploratory well density is relatively sparse in the play area averaging 6.3 MPW (10.1 KPW) on the Hogsback plate and 8.3 MPW (13.4 KPW) on the Absaroka plate (table 2).

There is only one field in the true duplexes - Hogsback and Absaroka thrust plates play; Horse Trap field (T. 23 N., R. 115 W.), Lincoln County, Wyoming. Horse Trap is also the only significant gas field located on the Hogsback thrust plate. The trap is a true duplex where the producing reservoir in the horse, the Amsden Formation, is sealed by low-permeable units also of the Amsden above the roof thrust (Lamerson, 1982, plate 6; Chidsey, 1990). The field has produced over 1.6 BCFG (0.05 BCMG) and 6,200 barrels (986 m³) of oil as of January 1, 1995. The produced gas is sweet; the only sweet gas production from Paleozoic reservoirs in the thrust belt.

Absaroka Thrust - Cretaceous

The Absaroka thrust - Cretaceous play is located in the west-central part of Summit County (plate 6) and covers approximately 35,840 acres (14,500 ha) (table 2). This play represents that portion of the Absaroka thrust plate which corresponds to a structural low (depression) located to the west between two broad structural highs (culminations) (Lamerson, 1982), and where drilling targets are relatively shallow (4,500 to 6,500 feet [1,372-1,981 m]). The play is defined on the west by the truncation at depth of the Jurassic Nugget Sandstone against the leading edge of the Absaroka thrust. The eastern boundary is defined by the surface trace of the Absaroka thrust. The play area wedges out to the southwest as the fault

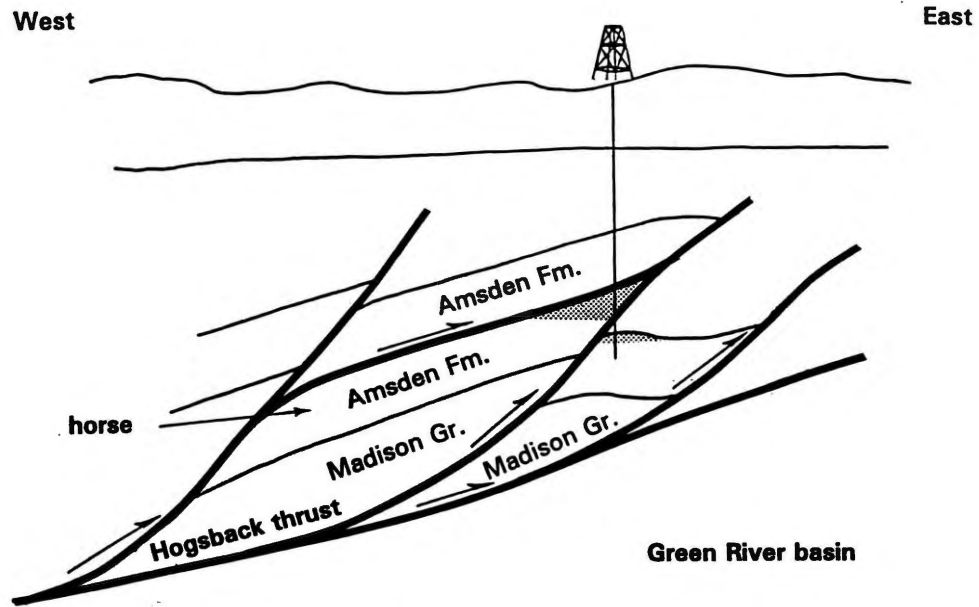


Figure 7. Schematic cross section of traps in the true duplexes - Hogsback and Absaroka thrust plates play. Gas deposits are shaded light gray.

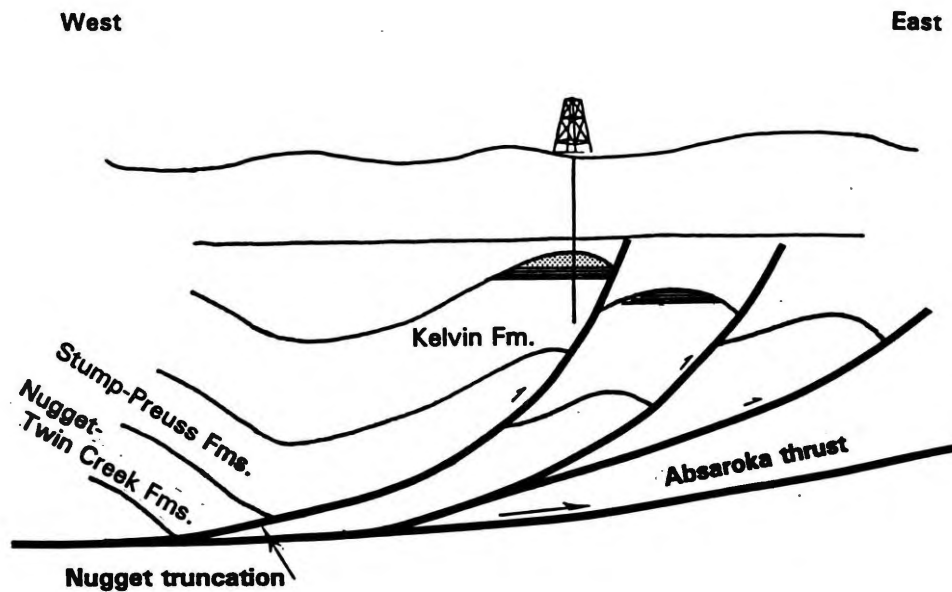


Figure 8. Schematic cross section of traps in the Absaroka thrust - Cretaceous play. Oil deposits are shaded dark gray; gas deposits are shaded light gray.

plane of the Absaroka thrust steepens and the distance between the Nugget truncation and the surface trace of the thrust lessens. The play continues north into the southern part of Uinta County, Wyoming. Prospective drilling targets in the play are delineated using seismic reflection methods, identification of faults and dip directions from geophysical well log evaluation, and the construction of balanced structural cross sections.

Potential petroleum trapping mechanisms in the Absaroka thrust - Cretaceous play consist of: (1) small, thrust ramp anticlines where potential reservoirs and hydrocarbon seals dip into the Absaroka thrust or associated thrust splays (figure 8), and (2) updip stratigraphic pinchouts. These traps involve only uppermost Jurassic through Cretaceous as older rocks are not present in this part of the Absaroka thrust plate. The east limbs of ramp anticlines in the play are commonly overturned to the west. Bedding plane faults within the folds further complicate the structural picture. Potential reservoirs in the Absaroka thrust - Cretaceous play are the Cretaceous Frontier and Kelvin Formations which consist of fluvial to fluvial-deltaic deposits. Exploratory well density in the play area averages 5.6 MPW (9 KPW) (table 2).

There is only one field in the Absaroka thrust - Cretaceous play; Aagard Ranch field (T. 3 N., R. 8 E.), Summit County (figure 1). The trap for Aagard Ranch field is a small ramp anticline developed along a splay off the Absaroka thrust. Oil and gas production is from fluvial sandstones in the Kelvin Formation. This field is located in the northwest part of the play area and was discovered in 1982. Cumulative production was over 66,000 barrels (10,500 m³) of oil and 253,000 cubic feet of gas (253 MCFG [7,165 m³ of gas]) as of January 1, 1995 (table 1) (Utah Division of Oil, Gas and Mining, 1995).

Absaroka Plate - Bridger Hill Thrust

The Absaroka plate - Bridger Hill thrust play is located in the western part of Summit County (plate 7) and covers approximately 118,400 acres (47,920 ha) (table 2). The play represents that area of the Absaroka thrust plate where imbricate faults off the Bridger Hill thrust are common. The Bridger Hill thrust is primarily a bedding plane fault developed in basal salt beds of the Jurassic Pruess Formation (Lamerson, 1982, plate 5). Drilling targets in most of the play area are relatively shallow (4,000 to 8,000 feet [1,200-2,440 m]). The eastern boundary of the play is defined by the leading edge of the Bridger Hill thrust (usually covered). The western boundary is that point at which the Bridger Hill thrust cuts down-section through competent rocks eventually merging with the Absaroka thrust. The southern portion of the Bridger Hill thrust plate trends southwest toward the Wasatch Mountains where the play area terminates. The play extends north as a 6-mile- (9.7-km-) wide band through Uinta County, Wyoming. The play area overlaps with two other Summit County plays, presenting multiple drilling targets. Prospective drilling targets in the play are delineated using seismic reflection methods, identification of faults and dip directions from geophysical well log evaluation, and the construction of balanced structural cross sections.

Potential petroleum trapping mechanisms in the Absaroka plate - Bridger Hill thrust play consist of: (1) small, thrust ramp anticlines where potential reservoirs and hydrocarbon seals dip into the Absaroka thrust or associated thrust splays (figure 9), and (2) updip stratigraphic pinchouts of lenticular sand bodies. Thrust splays and associated folds in the hanging wall typically stack up over larger structures in the footwall (Lamerson, 1982; Chidsey, 1990). The overall dip direction of rocks on the Bridger Hill thrust plate in Summit County is to the west. Potential reservoirs in the Absaroka plate - Bridger Hill thrust play are the Cretaceous Kelvin Formation and the Jurassic Stump Formation. Exploratory well density in the play area averages 7.1 MPW (11.4 KPW) (table 2). However, most of the wells drilled in the play area targeted deeper structures and reservoirs, often overlooking the shallow potential on the Bridger Hill plate.

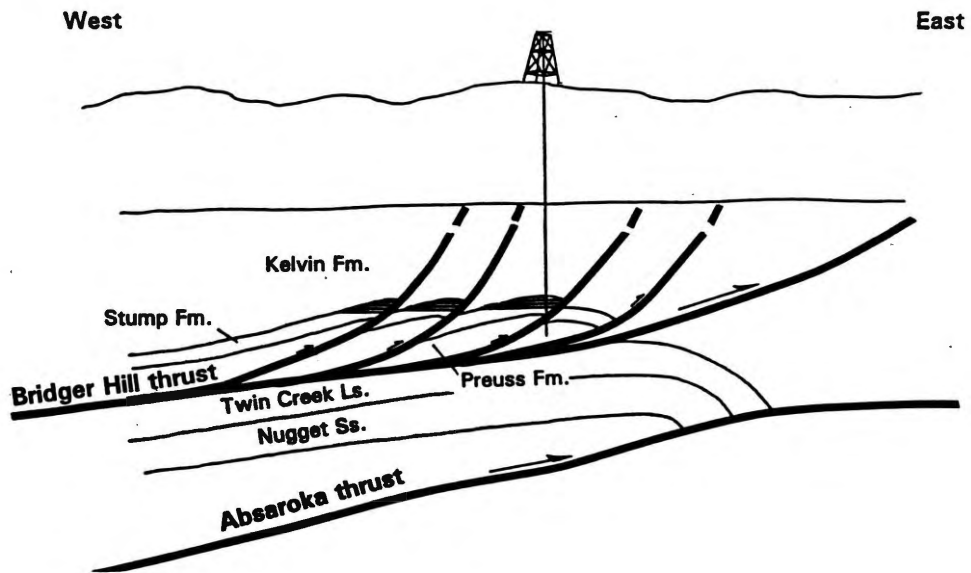


Figure 9. Schematic cross section of traps in the Absaroka plate - Bridger Hill thrust play. Oil deposits are shaded dark gray.

There is only one field in the Absaroka plate - Bridger Hill thrust play; Pineview field (T. 2-3 N., R. 7 E.), Summit County (figure 1). The Stump and Kelvin Formations produce from small, shallow ramp anticlines developed on splays off the Bridger Hill thrust. The oil and gas in the Kelvin Formation accumulated in a combination structural and stratigraphic trap; a sandstone lens emplaced against a fault. The discovery of these productive reservoirs came three and seven years respectively after the main reservoirs below the Bridger Hill thrust in Pineview field were discovered. Cumulative production for the Stump Formation is 906,084 barrels (144,067 m³) of oil and 1.2 BCFG (0.034 BCMG). However, no Stump production was reported during 1994 (Utah Division of Oil, Gas and Mining, 1995). The Kelvin Formation produced 14,116 barrels (2,244 m³) of oil and 27.4 MCFG (0.8 thousand m³ of gas) from one well before the zone was temporarily abandoned in 1984 (Petroleum Information, 1984). The lenticular nature of the sandstone units (limited reservoir size) accounts for the low productivity from the Kelvin Formation in the field.

Absaroka Thrust - Mesozoic-Cored Structures

The Absaroka thrust - Mesozoic-cored structures play is located in the western part of Summit County (plate 8) and covers approximately 104,320 acres (42,220 ha) (table 2). The play represents a linear hanging wall, Mesozoic-cored ramp anticline parallel to the leading edge of the Absaroka thrust. This ramp anticline can be divided into a broad structural high (culmination) and a structural low (depression) within the play area. The culmination is present in the southern part of the play and related to the proximity of a transverse ramp associated with the Uinta uplift (Lamerson, 1982; Chidsey, 1993). The depression is located in the northernmost part of the play area in Summit County between the culmination to the south and another culmination related to the Muddy Creek transverse ramp to the north in Lincoln County, Wyoming (Lamerson, 1982; Chidsey, 1993). The eastern boundary of the play is defined by the

truncation of the Jurassic Twin Creek Limestone against the leading edge of the Absaroka thrust. The western boundary is defined by a large imbricate thrust off the Absaroka thrust, referred to as the Tunp thrust. The southern portion of the Absaroka thrust plate trends southwest toward the Wasatch Mountains where the play area terminates. The play extends north as a 5-mile- (8-km-) wide band through Uinta and into Lincoln Counties, Wyoming. Prospective drilling targets in the play are delineated using seismic reflection methods, well control, dipmeter information, high-quality surface geologic maps, and detailed analyses of structural geometry and petroleum migration history.

Potential petroleum trapping mechanisms in the Absaroka thrust - Mesozoic-cored structures play consist of long, narrow, doubly plunging anticlines that trend north to northeast (figure 10) (Royce and others, 1975; Conner and Covlin, 1977; Dixon, 1982; Lamerson, 1982). These anticlines are asymmetric, overturned to the east, and often develop en echelon structures along the leading edge of the Absaroka thrust. Traps form on discrete subsidiary closures along major ramp anticlines. Traps on culminations typically produce oil and associated gas while traps in the structural depression produce nonassociated gas and retrograde condensate. Potential reservoirs in the Absaroka thrust - Mesozoic-cored structures play include the Jurassic Twin Creek Limestone and Nugget Sandstone, and the Triassic Thaynes Limestone and Ankareh Formation. Exploratory well density in the play area averages 7.8 MPW (12.6 KPW) (table 2).

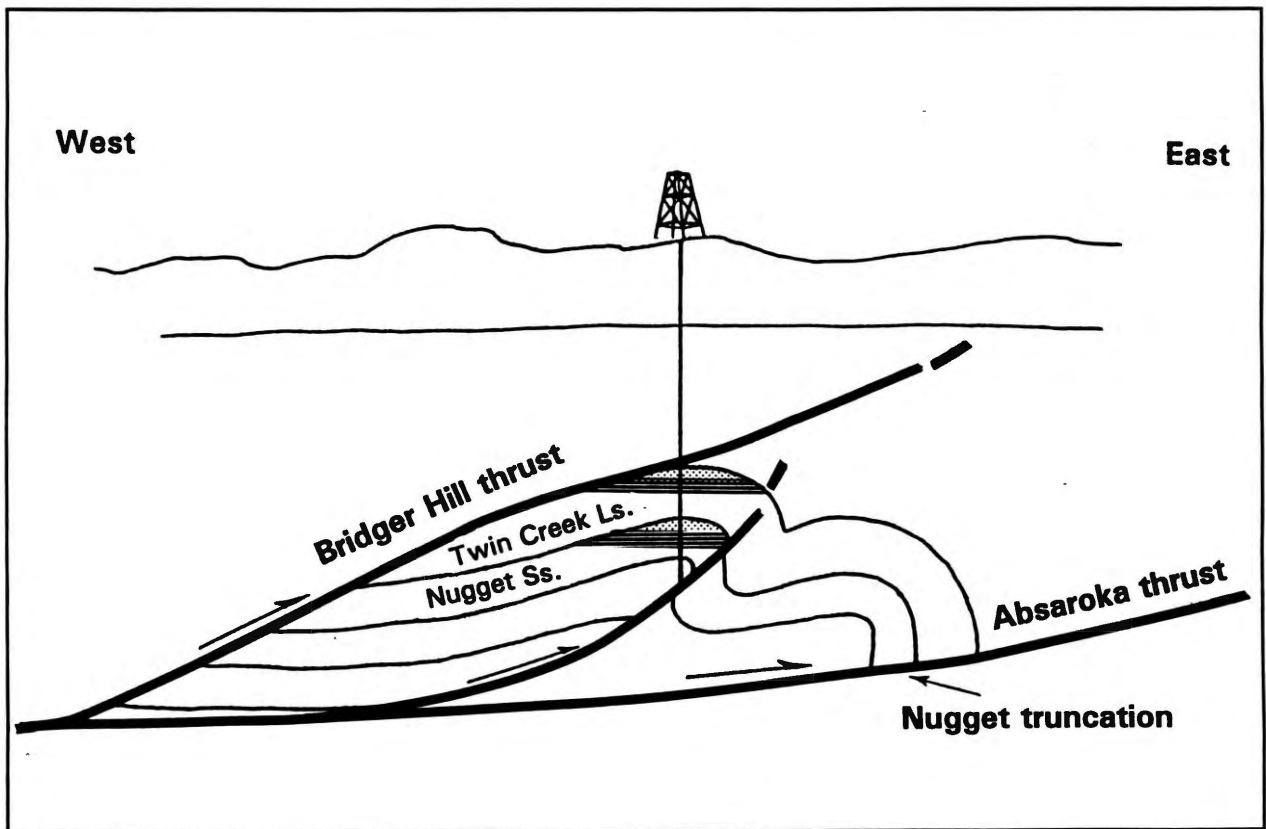


Figure 10. Schematic cross section of traps in the Absaroka thrust - Mesozoic-cored structures play. Oil deposits are shaded dark gray; gas deposits are shaded light gray.

There are numerous fields in the Absaroka thrust - Mesozoic-cored structures play. For example the Anschutz Ranch East field (figure 1) in T. 3-4 N., R. 7-8 E., Summit County (part of the field is in Uinta County, Wyoming), consists of two narrow, elongate anticlines overturned to the east (Lelek, 1982). This field is located in the structural depression part of the play area (as is Pineview North field [figure 1]) and was discovered in 1979. Anschutz Ranch East has the largest reserves in the Utah thrust belt with cumulative production from the Nugget Sandstone of over 113 million barrels of retrograde condensate (18 million m³ of condensate) and 1,990 BCFG (56.4 BCMG) as of January 1, 1995 (table 1) (Utah Division of Oil, Gas and Mining, 1995). Pineview, Elkhorn Ridge, and Lodgepole fields (figure 1) are located on the culmination part of the play area and combined have produced over 30.7 MMBO (4.9 MMCMO) and 35.5 BCFG (1 BCMG) from the Twin Creek Limestone and Nugget Sandstone as of January 1, 1995 (Utah Division of Oil, Gas and Mining, 1995). The Twin Creek Limestone is a fractured reservoir currently being successfully exploited using horizontal drilling techniques in the Elkhorn Ridge and Lodgepole fields.

Absaroka Thrust - Paleozoic-Cored Structures

The Absaroka thrust - Paleozoic-cored structures play is located in the northwestern part of Summit County (plate 9) and covers approximately 57,600 acres (23,310 ha) (table 2). The play represents a very continuous and linear hanging wall, Paleozoic-cored ramp anticline parallel to the leading edge of the Absaroka thrust. The eastern boundary of the play is defined by the truncation of the Jurassic Twin Creek Limestone against the Tump thrust and the truncation of the Paleozoic section against the Absaroka thrust. The western boundary is defined as the point at which the dips on the west flank of the ramp anticline begin to flatten out. The southern portion of this ramp anticline trends southwest toward the Wasatch Mountains where the play area terminates. The play extends north as a 3-mile- (4.8-km-) wide band through Uinta and into Lincoln Counties, Wyoming where it terminates against the Muddy Creek transverse ramp. Like other plays in Summit County, prospective drilling targets in this play are delineated using seismic reflection methods, well control, dipmeter information, high-quality surface geologic maps, and detailed analyses of structural geometry and petroleum migration history.

Potential petroleum trapping mechanisms in the Absaroka thrust - Paleozoic-cored structures play consist of long, narrow, doubly plunging anticlines that trend north to northeast (figure 11) (Royce and others, 1975; Conner and Covlin, 1977; Petroleum Information, 1981; Dixon, 1982; Lamerson, 1982; Bruce, 1988). These anticlines are asymmetric, overturned to the east, and form on discrete subsidiary closures along the major ramp anticline. Splay faults within the deeper part of the anticlinal axes are common, complicating drilling operations and compartmentalizing productive zones. Potential reservoirs in the Absaroka thrust - Paleozoic-cored structures play include the Jurassic Twin Creek Limestone and Nugget Sandstone, Permian Phosphoria Formation, Pennsylvanian Weber Sandstone, Mississippian Madison Group, Devonian Darby Formation, and Ordovician Bighorn Dolomite. Current production consists of nonassociated gas and condensate from both Paleozoic and Mesozoic reservoirs. Gas produced from Paleozoic reservoirs in the thrust belt producing fairway is sour, varying from as low as 0.6 percent to as high as 21.4 percent H₂S (Mullen and Barlow & Haun, Inc., 1993b, 1993c; Mullen and others, 1993b). In Summit County, sour gas must be transported via the Wahsatch Gathering System to the Whitney Canyon Processing Plant 25 miles (40 km) to the northeast in Wyoming, where the H₂S is removed. Exploratory well density in the play area averages 9 MPW (14.5 KPW) (table 2).

There are numerous fields in the Absaroka thrust - Paleozoic-cored structures play. For example the Anschutz Ranch field (figure 1) in T. 3-4 N., R. 7 E., Summit County, consists of a large, elongate anticline with over 7,100 feet (2,164 m) of structural closure involving Jurassic through Ordovician rocks (Chidsey,

1993). This field was discovered in 1978 and has produced over 974,000 barrels (154,000 m³) of condensate and 60.9 BCFG (1.7 BCMG) from the Nugget Sandstone and Twin Creek Limestone as of January 1, 1995, (table 1) (Utah Division of Oil, Gas and Mining, 1995). Cave Creek field (T. 5 N., R. 7-8 E.), 4 miles (6 km) north of Anschutz Ranch field, also produces from the Twin Creek Limestone and tested sour gas (8 to 14 percent H₂S) from the Phosphoria, Weber, and Madison reservoirs. Respective flow rates from these reservoirs were 25 MMCFGPD (0.7 MMCMGPD) with 500 barrels of condensate per day (BCPD) (80 m³ of condensate per day [CMCPD]), 12.5 MMCFGPD (0.4 MMCMGPD) with 206 BCPD (33 CMCPD), and 2.4 MMCFGPD (0.1 MMCMGPD) with 78 BCPD (12 CMCPD) (Petroleum Information, 1984). Cave Creek field has been tied to the Wahsatch Gathering System and production from the Phosphoria Formation began in August, 1994.

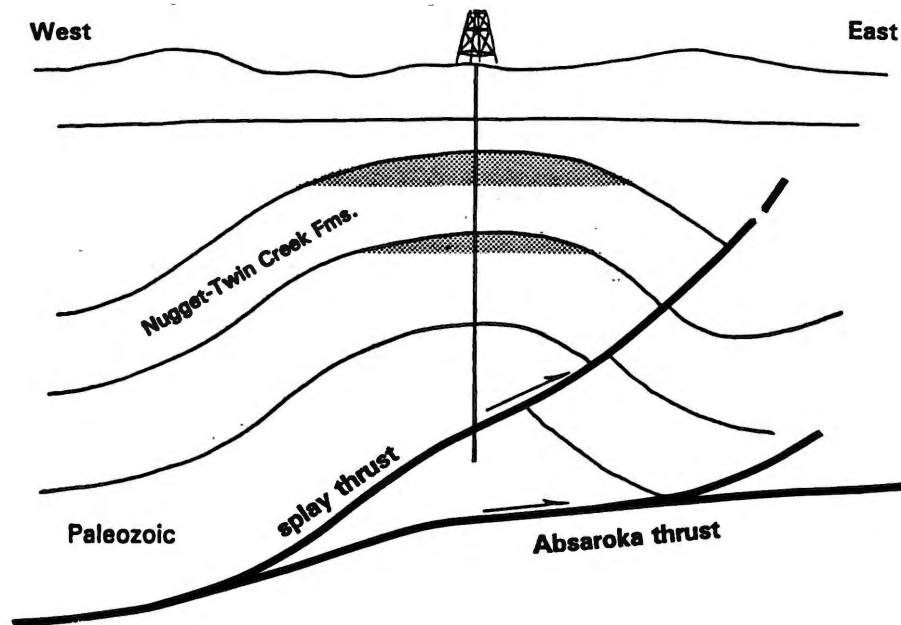


Figure 11. Schematic cross section of traps in the Absaroka thrust - Paleozoic-cored structures play. Gas deposits are shaded light gray.

Absaroka Thrust - Broad, Subtle Folds

The Absaroka thrust - broad, subtle folds play is located in the northwest part of Summit County (plate 10) and covers approximately 161,280 acres (76,320 ha) (table 1). The play represents that portion of the Absaroka thrust plate where the Paleozoic and Mesozoic section dips gently west, and imbricate thrust faulting and complex structures are absent. The eastern boundary is defined as the point at which the dips steepen to form the west flank of the ramp anticline along the leading edge of the Absaroka thrust. The western boundary is defined by the cutoff of the deepest potential reservoir against the Crawford thrust (see figure 1 for the location of the Crawford thrust). The southern portion of the Absaroka plate trends southwest toward the Wasatch Mountains where the play area terminates. The play extends north as a 6 to 11-mile- (10-18-km-) wide band into parts of Morgan and Rich Counties, Utah, and through Uinta and Lincoln Counties, Wyoming where it terminates against the Muddy Creek transverse ramp. Drilling targets in the play area must be delineated primarily by using seismic reflection methods.

Potential petroleum trapping mechanisms in the Absaroka thrust - broad, subtle folds play are large, non-faulted anticlines or domes with gentle dips on the flanks (figure 12) (Lamerson, 1982; Chidsey, 1990). Potential reservoirs include the Mississippian Madison Group and Ordovician Bighorn Dolomite. Exploratory well density in the play area averages 63 MPW (101 KPW) (table 2).

There are two fields in the Absaroka thrust - broad, subtle folds play; Session Mountain (T. 18 N., R. 120 W.) and Woodruff Narrows (T. 17-18 N., R. 120 W.), Uinta County, Wyoming. Production consists of nonassociated sour gas and condensate. For example, Session Mountain field has produced over 78,900 barrels (12,545 m³) of condensate and 6.8 BCFG (0.2 BCMG) from the Madison Group and Bighorn Dolomite as of January 1, 1995. With the completion of the Wahsatch Gathering System in Summit County, Utah prospects which have been on hold because of sour gas potential may now be drilled.

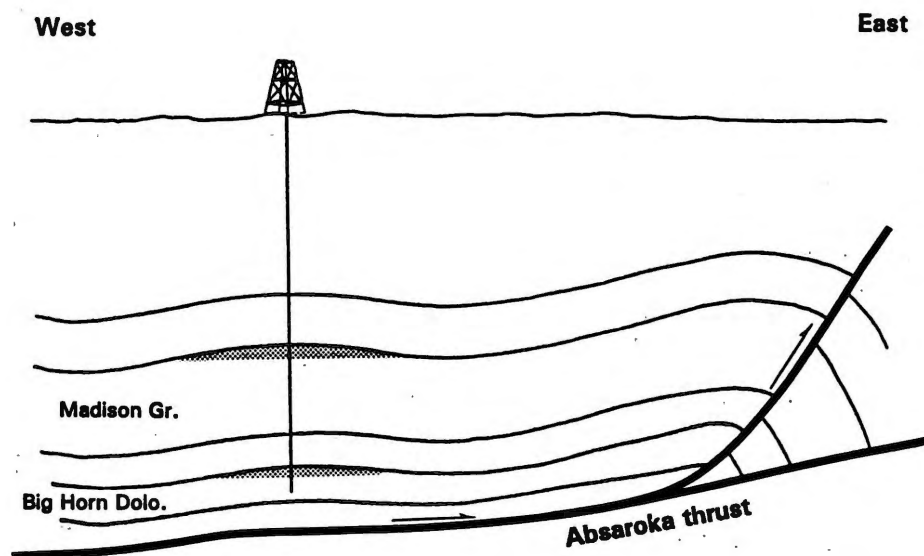


Figure 12. Schematic cross section of traps in the Absaroka thrust - broad, subtle folds play. Gas deposits are shaded light gray.

SUMMARY

The primary goal of this study was to identify the petroleum plays in Summit County, Utah. This included describing the concept which defined these plays, the areal extent, exploration methods required for delineation of drilling targets, petroleum trapping mechanisms, potential reservoirs, exploratory drilling density, and identifying fields already in the play or analogous fields elsewhere in the Rocky Mountain region. At least ten petroleum plays are present in Summit County. The attractiveness of these plays to the petroleum industry varies depending on the chance of success, reserve potential, pipeline access, drilling costs, and environmental concerns.

Analysis of the ten petroleum plays in Summit County indicates certain plays have considerably higher exploration risk than others but greater reserve potential. For example, the highest risk area is the overlapping portions of the North Flank subthrust - Green River basin and Hogsback thrust plays.

Exploration and drilling costs in the area will be great due to the depths of potential reservoirs and site access problems which must address environmental concerns. Such high costs would eliminate most small operators from pursuing these plays. However, this area has the largest reserve potential due to large, multiple traps (stacked) and multiple reservoirs. No pipeline exists in the area and therefore presents an additional problem in this environmentally sensitive region (see Oil and Gas Pipeline Map of Utah [Chidsey and Anderson, 1994] for pipeline locations in Summit County).

Drilling targets within the economic reach of small exploration companies may be found in the Absaroka thrust - Cretaceous and Absaroka plate - Bridger Hill thrust plays. Pipelines are available, drilling depths relatively shallow, and environmental concerns minimal (these plays cover fee acreage). However, reserve potential is small due to limited trap size and reservoirs which are thin. Larger companies may find success pursuing drilling targets in the Absaroka thrust - broad subtle folds and Paleozoic-cored structures plays. Although drilling targets are deep and gas is production likely sour, reserve potential from multiple reservoirs is large. The close proximity of the Wahsatch Gathering System will allow for production of sour gas from successful wells. Many of the obvious structures have been tested in the Mesozoic-cored structures play. The application of horizontal drilling techniques to maturing or subcommercial fractured reservoirs, such as the Twin Creek Limestone in Elkhorn Ridge and Lodgepole fields, can result in a two- to four-fold increase in initial flowing potential and ultimate recovery at the same time requiring fewer wells to exploit the reserves.

Summit County, Utah has been a major contributor to the state of Utah's hydrocarbon production since 1975. As domestic reserves of oil and gas continue to decrease, both large and small exploration and production companies can continue to focus on the variety of petroleum plays in Summit County. By applying new technology and exploration methods to these plays, and with the availability of pipelines to expanding markets in Utah, Summit County will continue to be a major producer of hydrocarbons well into the next century.

ACKNOWLEDGMENTS

This study was supported by the county government for Summit County, Utah, under the project entitled "Petroleum Products for Summit County", contract No. 93-2539. The author thanks the following individuals: Sheldon D. Richins, James Soter, and Thomas E. Flinders, Summit County Commissioners; and Robert W. Adkins, Summit County Attorney. Michael D. Laine, Utah Geological Survey, is thanked for assistance with the assembly of play concept maps and other important data. Craig D. Morgan, Utah Geological Survey, provided a dry hole and hydrocarbon show map. I also thank Bryce T. Tripp and Robert W. Gloyn, Utah Geological Survey, for their critical review and comments on the maps and manuscript.

REFERENCES

- Blackstone, D.L., Jr., 1979, Geometry of the Prospect-Darby and La Barge faults at their junction with the La Barge platform, Lincoln and Sublette Counties, Wyoming: The Geological Survey of Wyoming Report of Investigation 18, 34 p.
- Bruce, C.L., 1988, Jurassic Twin Creek Formation: a fractured limestone reservoir in the overthrust belt, Wyoming and Utah, *in* Goolsby, S.M., and Longman, M.W., editors, Occurrence and petrophysical properties of carbonate reservoirs in the Rocky Mountain region: Denver, Colorado, Rocky Mountain Association of Geologists, p. 105-120.
- Carlson, C.E., 1979, Hogsback unit, *in* Greater Green River basin: Wyoming Geological Association, Wyoming Oil and Gas Fields Symposium, p. 194-196.
- Chidsey, T.C., Jr., 1990, Exploration highlights and activity in the Utah overthrust belt during the 1980s, *in* Allison, M.L., editor, Energy and mineral resources of Utah: Utah Geological Association Publication 18, p. 1-26.
- _____, 1993, TB-3. Jurassic-Triassic Nugget Sandstone, *in* Hjellming, C.A., editor, Atlas of major Rocky Mountain gas reservoirs: New Mexico Bureau of Mines and Mineral Resources, p. 77-79.
- Chidsey, T.C., Jr., and Anderson, P.B., 1994, Oil and gas pipeline map of Utah: Utah Geological Survey Public Information Series 22, scale 1:1,000,000.
- Conner, D.C., and Covlin, R.J., 1977, Development geology of Pineview field, Summit County, Utah, *in* Heisey, E.L., Lawson, D.E., Norwood, E.R., Wach, P.H., and Hale, L.A., editors, Rocky Mountain thrust belt geology and resources: Wyoming Geological Association, 29th Annual Field Conference, p. 639-650.
- DeBruin, R.H., and Sprinkel, D.A., 1993, Stratigraphic correlation chart of major gas-producing basins and uplifts, *in* Hjellming, C.A., editor, Atlas of major Rocky Mountain gas reservoirs: New Mexico Bureau of Mines and Mineral Resources, sheet 2.
- Dixon, J.S., 1982, Regional structural synthesis, Wyoming salient of western overthrust belt: American Association of Petroleum Geologists Bulletin, v. 66, no. 10, p. 1560-1580.
- Doelger, M.J., Barlow, J.A., Jr., and Barlow & Haun, Inc., 1993, LBTU-WY. Low -BTU gas in Wyoming, *in* Hjellming, C.A., editor, Atlas of major Rocky Mountain gas reservoirs: New Mexico Bureau of Mines and Mineral Resources, p. 170.
- Doelger, M.J., Mullen, D.M., and Barlow & Haun, Inc., 1993a, KU-5. Frontier Formation, *in* Hjellming, C.A., editor, Atlas of major Rocky Mountain gas reservoirs: New Mexico Bureau of Mines and Mineral Resources, p. 50-53.
- _____, 1993b, Lower Cretaceous [KL] plays - overview, *in* Hjellming, C.A., editor, Atlas of major Rocky

Mountain gas reservoirs: New Mexico Bureau of Mines and Mineral Resources, p. 56-57.

_____, 1993c, Rocky Mountain foreland structure [FS] plays - overview, *in* Hjellming, C.A., editor, Atlas of major Rocky Mountain gas reservoirs: New Mexico Bureau of Mines and Mineral Resources, p. 69.

Dutton, S.P., and Hamlin, H.S., 1991, Geologic controls on reservoir properties of Frontier Formation low-permeability gas reservoirs, Moxa arch, Wyoming: Society of Petroleum Engineers Paper 21851, p. 479-488.

Golden, J.B., 1979, Dry Piney, *in* Greater Green River basin: Wyoming Geological Association, Wyoming Oil and Gas Fields Symposium, p. 134-135.

Hagen, E.S., Schuster, M.W., and Furlong, K.P., 1985, Tectonic loading and subsidence of intermontane basins, Wyoming foreland province: *Geology*, v. 13, p. 585-592.

Hintze, L.F., 1988, Geologic history of Utah: Provo, Utah, Brigham Young University Geology Studies Special Publication 7, p. 99-101.

Lamerson, P.R., 1982, The Fossil basin area and its relationship to the Absaroka thrust fault system, *in* Powers, R.B., editor, Geologic studies of the Cordilleran thrust belt: Rocky Mountain Association of Geologists, v. 1, p. 279-340.

Lelek, J.J., 1982, Anschutz Ranch East field, northeast Utah and southwest Wyoming, *in* Powers, R.B., editor, Geologic studies of the Cordilleran thrust belt: Denver, Colorado, Rocky Mountain Association of Geologists, v. 2, p. 619-631.

Mitra, Shankar, 1986, Duplex structures and imbricate thrust systems: Geometry, structural position, and hydrocarbon potential: American Association of Petroleum Geologists Bulletin, v. 70, no. 9, p. 1087-1112.

_____, 1990, Fault-propagation folds: Geometry, kinematics, and hydrocarbon traps: American Association of Petroleum Geologists Bulletin, v. 74, no. 6, p. 921-945.

Montgomery, Scott, 1994, Moxa arch Frontier Formation: revitalization of a gas province: Denver, Colorado, Petroleum Information Corporation, Petroleum Frontiers, 71 p.

Moslow, T.F., and Tillman, R.W., 1984, Sedimentary facies and reservoir characteristics of the Frontier Formation sandstones, southwestern Wyoming: American Association of Petroleum Geologists Studies in Geology 24, p. 271-295.

_____, 1989, Characterization, distribution of Frontier Formation reservoir facies of Wyoming fields: Oil and Gas Journal, v. 87, no. 22, p. 95-104.

Mullen, D.M., and Barlow & Haun, Inc., 1993a, KL-3. Dakota/Fall River Sandstone, *in* Hjellming, C.A., editor, Atlas of major Rocky Mountain gas reservoirs: New Mexico Bureau of Mines and Mineral

Resources, p. 66.

_____, 1993b, TB-5. Pennsylvanian Weber Sandstone, *in* Hjellming, C.A., editor, Atlas of major Rocky Mountain gas reservoirs: New Mexico Bureau of Mines and Mineral Resources, p. 81.

_____, 1993c, TB-6. Mississippian Madison/Mission Canyon Limestone, *in* Hjellming, C.A., editor, Atlas of major Rocky Mountain gas reservoirs: New Mexico Bureau of Mines and Mineral Resources, p. 82.

Mullen, D.M., Doelger, M.J., and Barlow & Haun, Inc., 1993a, FS-3. Greater Green River basin, *in* Hjellming, C.A., editor, Atlas of major Rocky Mountain gas reservoirs: New Mexico Bureau of Mines and Mineral Resources, p. 73.

_____, 1993b, TB-7. Ordovician Bighorn Dolomite, *in* Hjellming, C.A., editor, Atlas of major Rocky Mountain gas reservoirs: New Mexico Bureau of Mines and Mineral Resources, p. 82.

Nixon R.P., 1973, Oil source beds in the Cretaceous Mowry Shale of northwestern interior United States: American Association of Petroleum Geologists Bulletin, v. 57, no. 1, p. 136-157.

Petroleum Information, 1981, The overthrust belt-1981: Denver, Colorado, Petroleum Information Corporation, 251 p.

_____, 1984, Overthrust Belt field summaries: Denver, Colorado, Petroleum Information Corporation, 99 p.

_____, 1994, Rocky Mountain region report - northern addition: Denver, Colorado, Petroleum Information Corporation, v. 67, no. 243, p. 2.

Reisser, K.D., and Blanke, S.J., 1989, Paleostuctural control of Dakota hydrocarbon accumulations on the southern Moxa arch, southwest Wyoming and northeast Utah, *in* Petrogenesis and petrophysics of selected sandstone reservoirs of the Rocky Mountain region: Denver, Colorado, Rocky Mountain Association of Geologists, p. 135-148.

Royce, Frank, Jr., Warner, M.A., and Reese, D.L., 1975, Thrust belt structural geometry and related stratigraphic problems, Wyoming-Idaho-Northern Utah, *in* Bolyard, D.W., editor, Symposium on deep drilling frontiers of the central Rocky Mountains: Denver, Colorado, Rocky Mountain Association of Geologists, p. 41-54.

Sprinkel, D.A., and Chidsey, T.C., Jr., 1993, TB-2. Jurassic Twin Creek Limestone, *in* Hjellming, C.A., editor, Atlas of major Rocky Mountain gas reservoirs: New Mexico Bureau of Mines and Mineral Resources, p. 76.

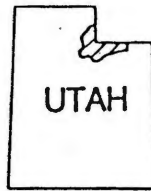
Utah Division of Oil, Gas and Mining, 1995, December 1994 oil and gas production report: Utah Department of Natural Resources Division of Oil, Gas and Mining, not paginated.

Warner, M.A., 1982, Source and time of generation of hydrocarbons in the Fossil basin, western Wyoming

thrust belt, *in* Powers, R.B., editor, *Geologic studies of the Cordilleran thrust belt*: Denver, Colorado, Rocky Mountain Association of Geologists, v. 2, p. 805-815.

Webel, Suzanne, 1979, *Tip Top*, *in* *Greater Green River basin*: Wyoming Geological Association, Wyoming Oil and Gas Fields Symposium, p. 388-389.

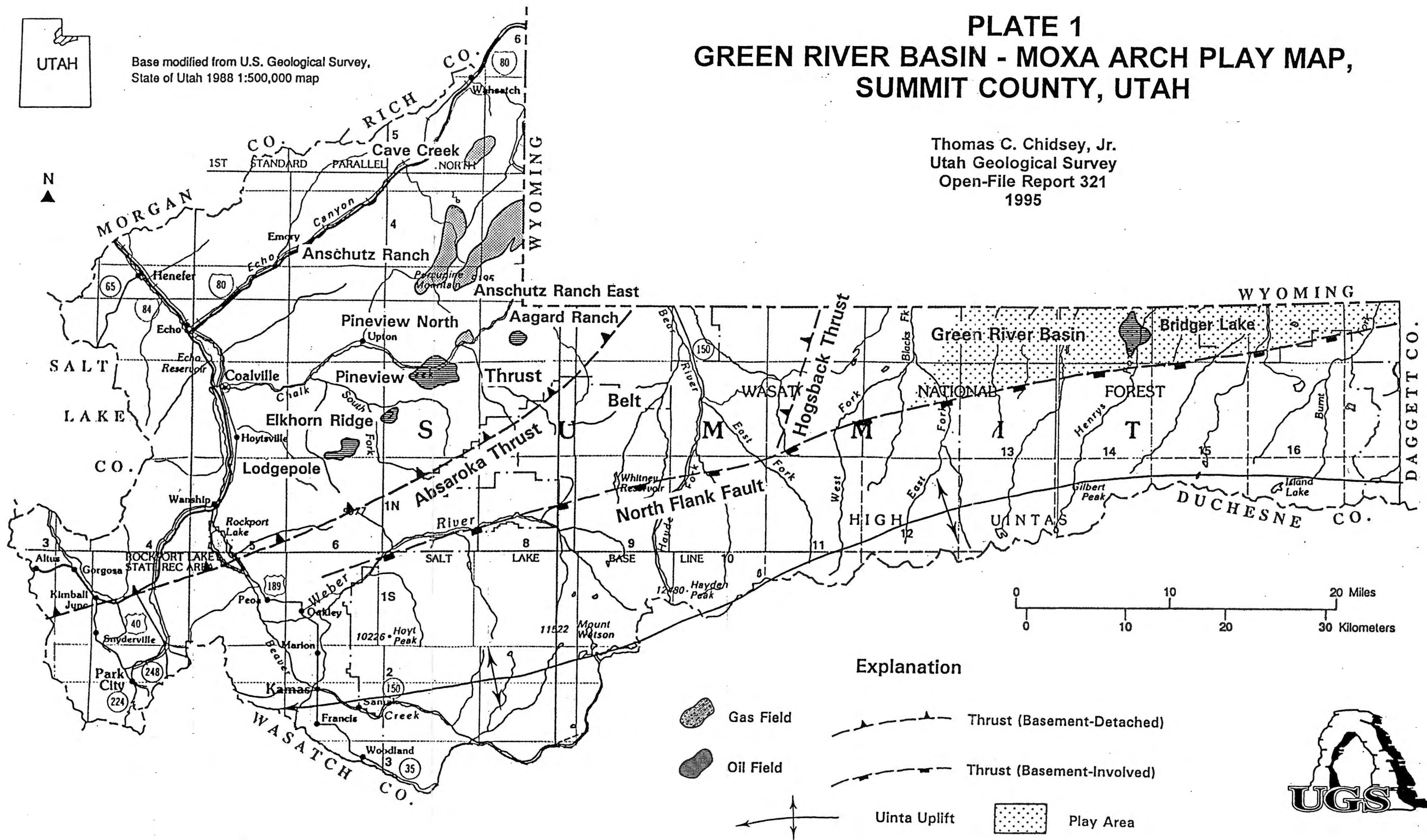
_____, 1987, *Significance of backthrusting in the Rocky Mountain thrust belt*, *in* Miller, W.R., editor, *The thrust belt revisited*: Wyoming Geological Association Thirty Eighth Field Conference Guidebook, p. 37-53.

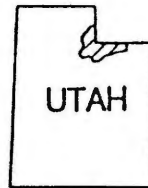


Base modified from U.S. Geological Survey,
State of Utah 1988 1:500,000 map

PLATE 1 GREEN RIVER BASIN - MOXA ARCH PLAY MAP, SUMMIT COUNTY, UTAH

Thomas C. Chidsey, Jr.
Utah Geological Survey
Open-File Report 321
1995

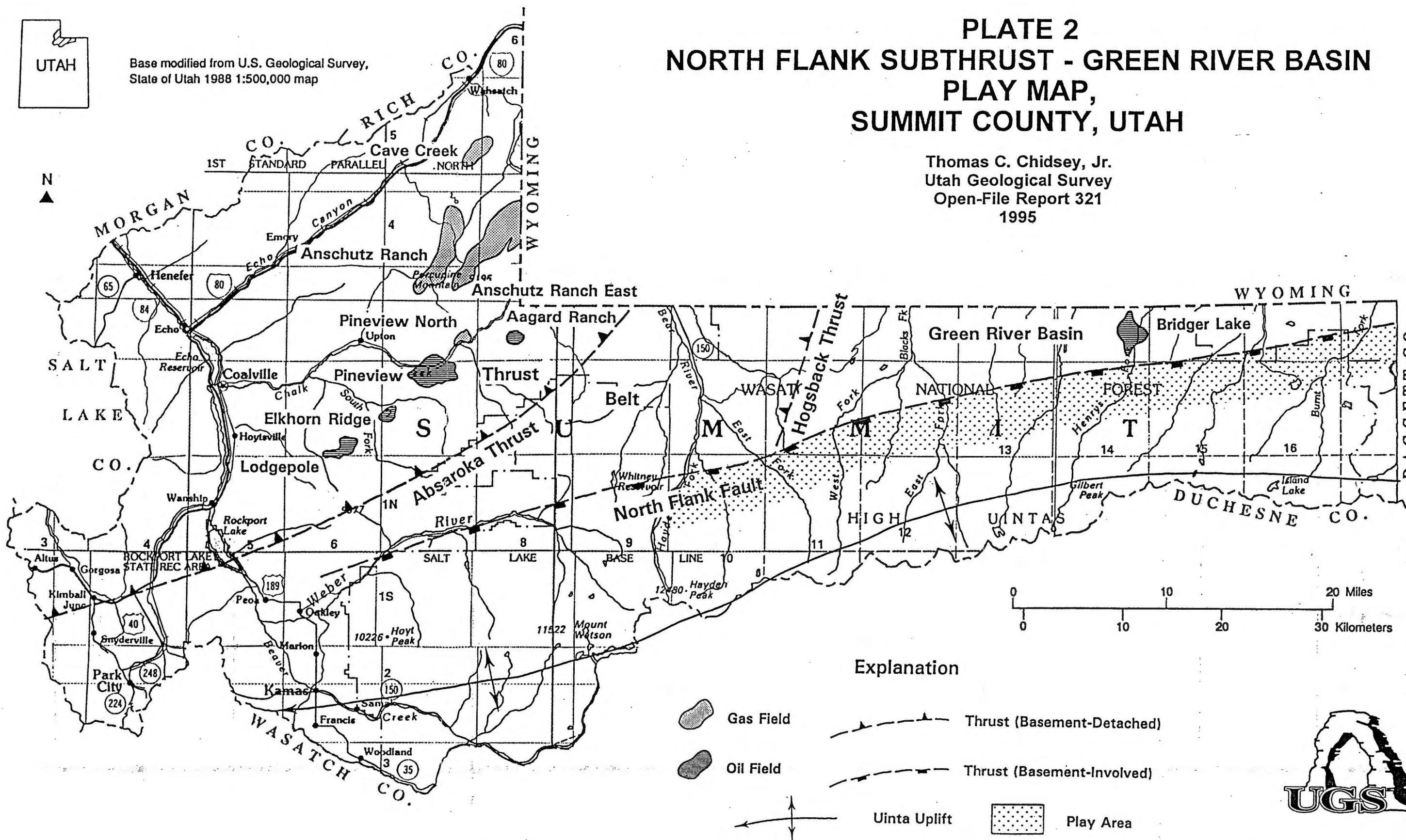


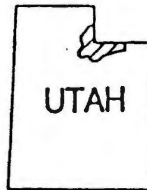


Base modified from U.S. Geological Survey,
State of Utah 1988 1:500,000 map

PLATE 2 NORTH FLANK SUBTHRUST - GREEN RIVER BASIN PLAY MAP, SUMMIT COUNTY, UTAH

Thomas C. Chidsey, Jr.
Utah Geological Survey
Open-File Report 321
1995

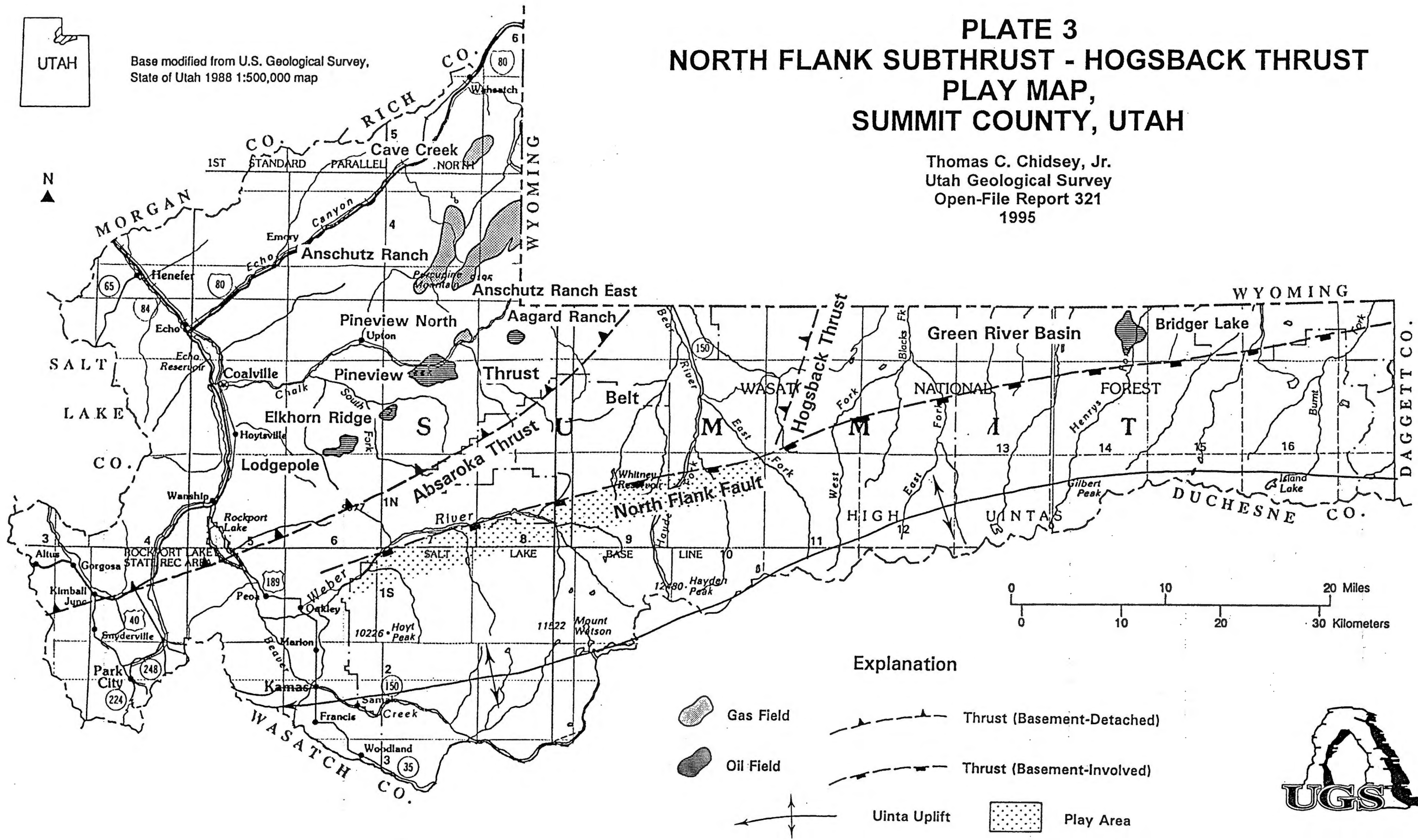


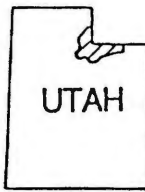


Base modified from U.S. Geological Survey, State of Utah 1988 1:500,000 map

PLATE 3 NORTH FLANK SUBTHRUST - HOGSBACK THRUST PLAY MAP, SUMMIT COUNTY, UTAH

Thomas C. Chidsey, Jr.
Utah Geological Survey
Open-File Report 321
1995

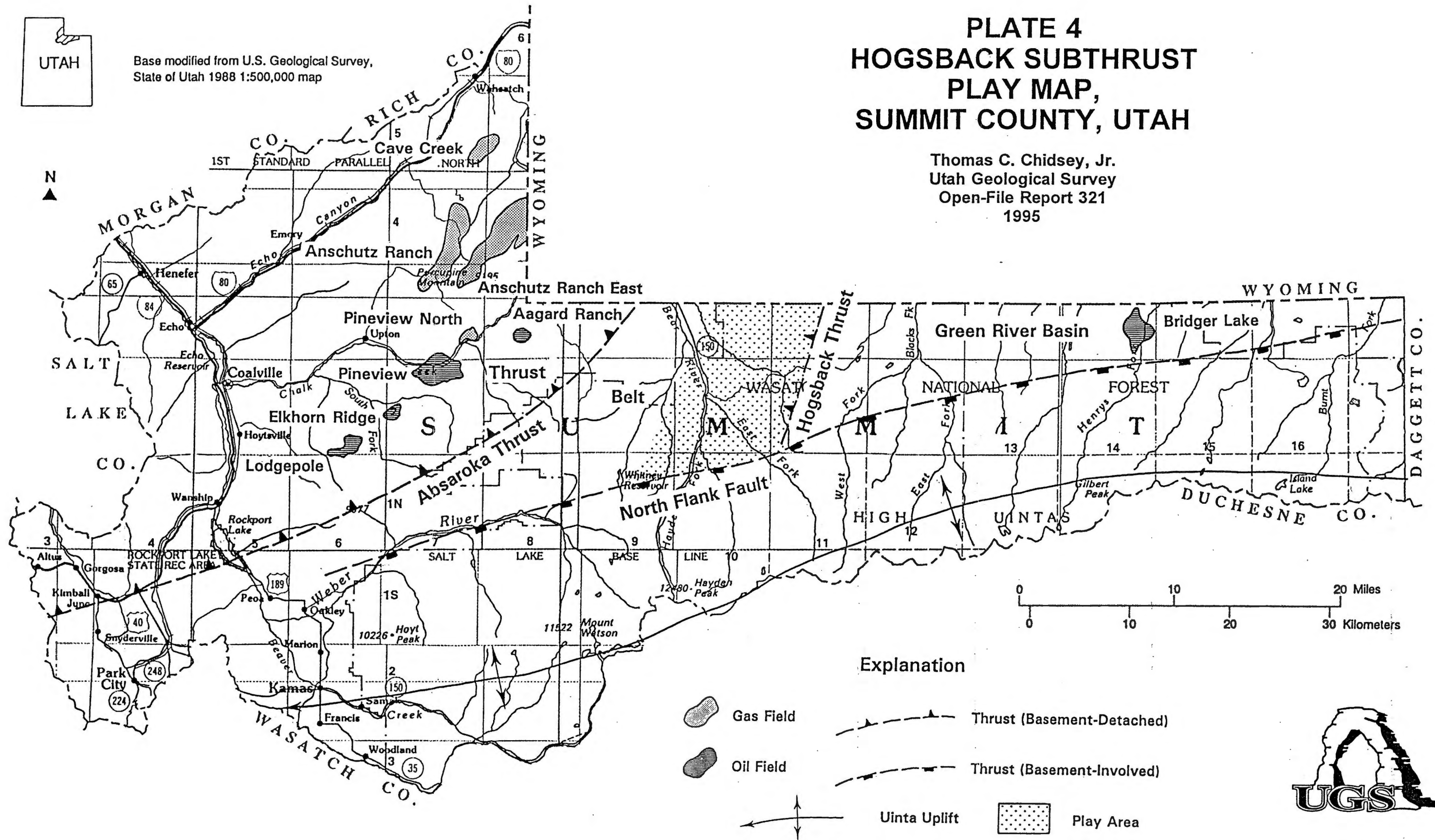


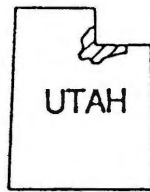


Base modified from U.S. Geological Survey,
State of Utah 1988 1:500,000 map

PLATE 4 HOGSBACK SUBTHRUST PLAY MAP, SUMMIT COUNTY, UTAH

Thomas C. Chidsey, Jr.
Utah Geological Survey
Open-File Report 321
1995

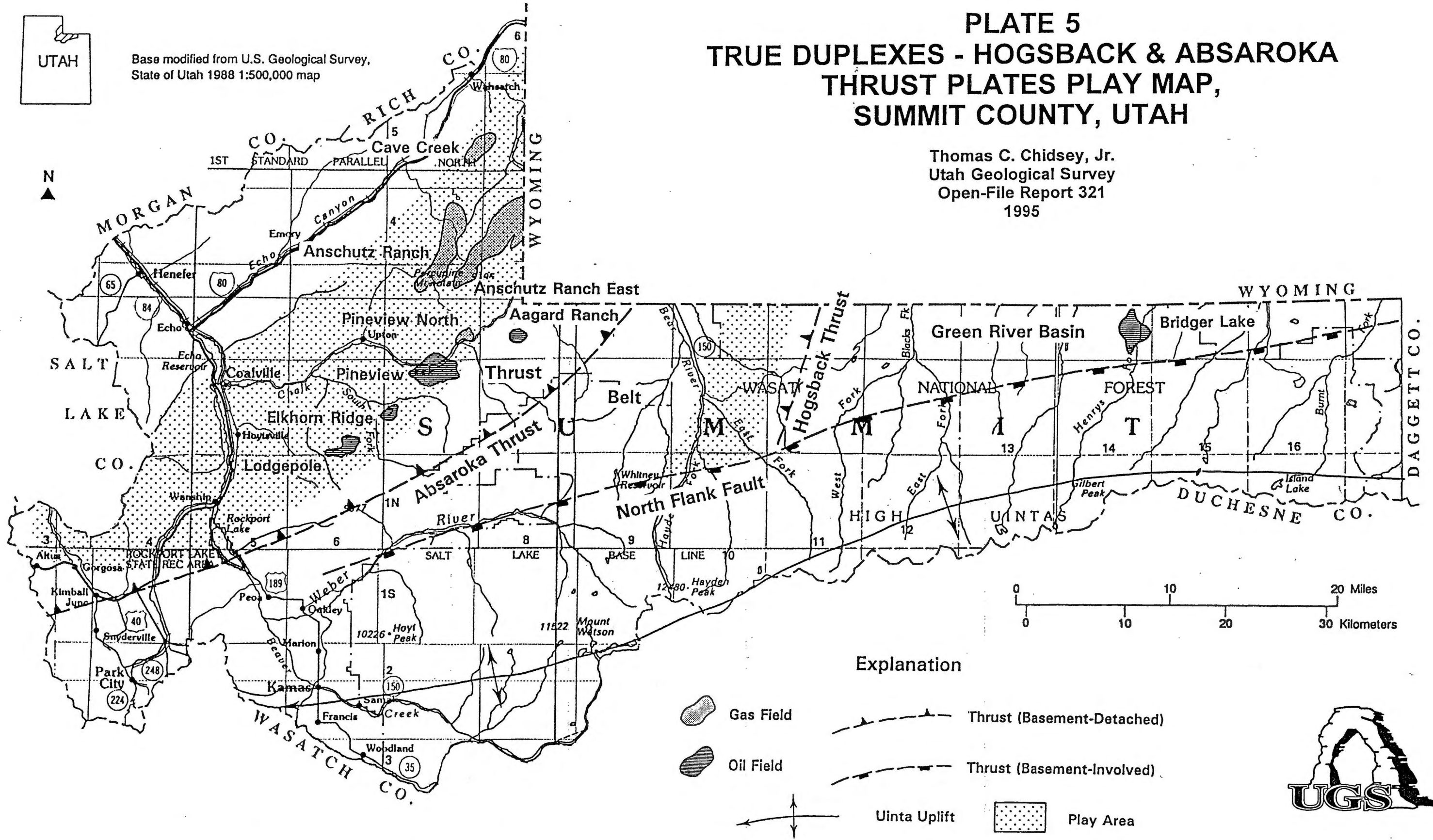






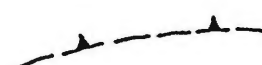



Base modified from U.S. Geological Survey, State of Utah 1988 1:500,000 map

PLATE 5 TRUE DUPLEXES - HOGSBACK & ABSAROKA THRUST PLATES PLAY MAP, SUMMIT COUNTY, UTAH

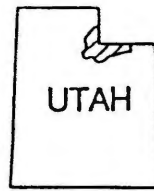
Thomas C. Chidsey, Jr.
Utah Geological Survey
Open-File Report 321
1995



Explanation

-  Gas Field
-  Oil Field
-  Thrust (Basement-Detached)
-  Thrust (Basement-Involved)
-  Uinta Uplift
-  Play Area

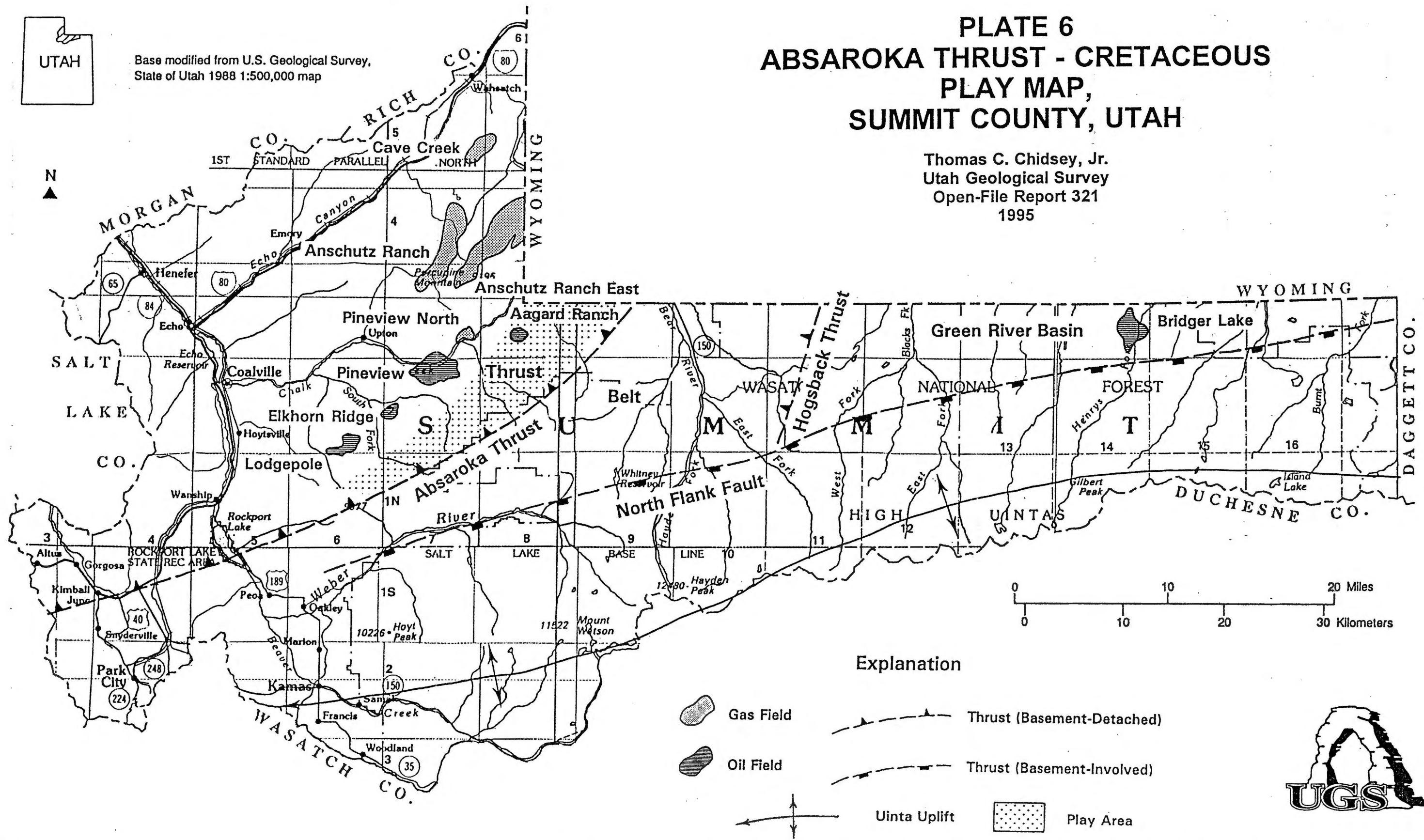










Base modified from U.S. Geological Survey,
State of Utah 1988 1:500,000 map

PLATE 6 ABSAROKA THRUST - CRETACEOUS PLAY MAP, SUMMIT COUNTY, UTAH

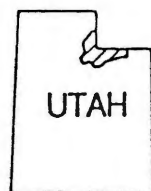
Thomas C. Chidsey, Jr.
Utah Geological Survey
Open-File Report 321
1995



Explanation

-  Gas Field
-  Oil Field
-  Thrust (Basement-Detached)
-  Thrust (Basement-Involved)
-  Uinta Uplift
-  Play Area

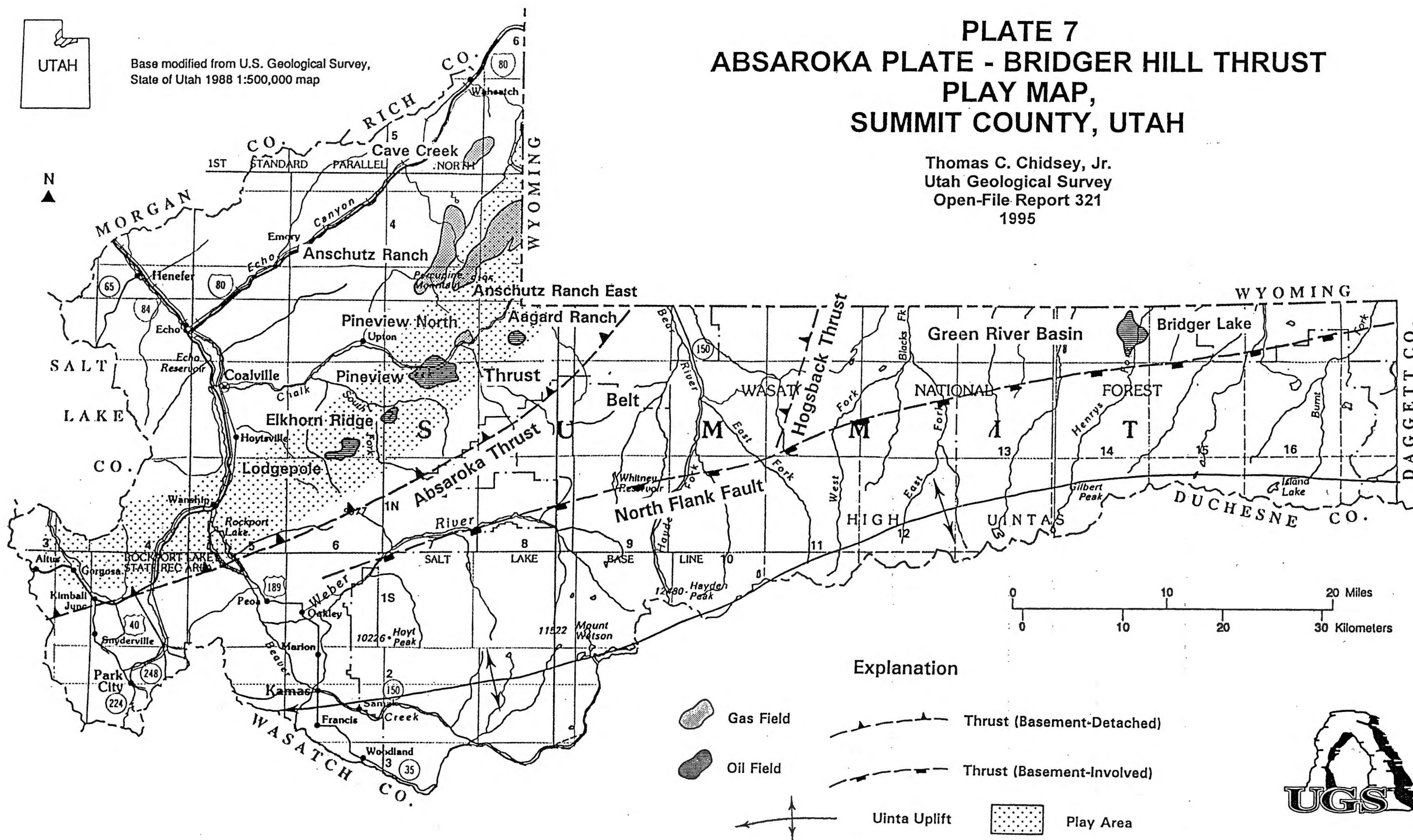


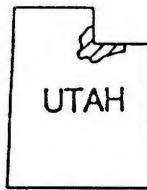


Base modified from U.S. Geological Survey,
State of Utah 1988 1:500,000 map

PLATE 7 ABSAROKA PLATE - BRIDGER HILL THRUST PLAY MAP, SUMMIT COUNTY, UTAH

Thomas C. Chidsey, Jr.
Utah Geological Survey
Open-File Report 321
1995

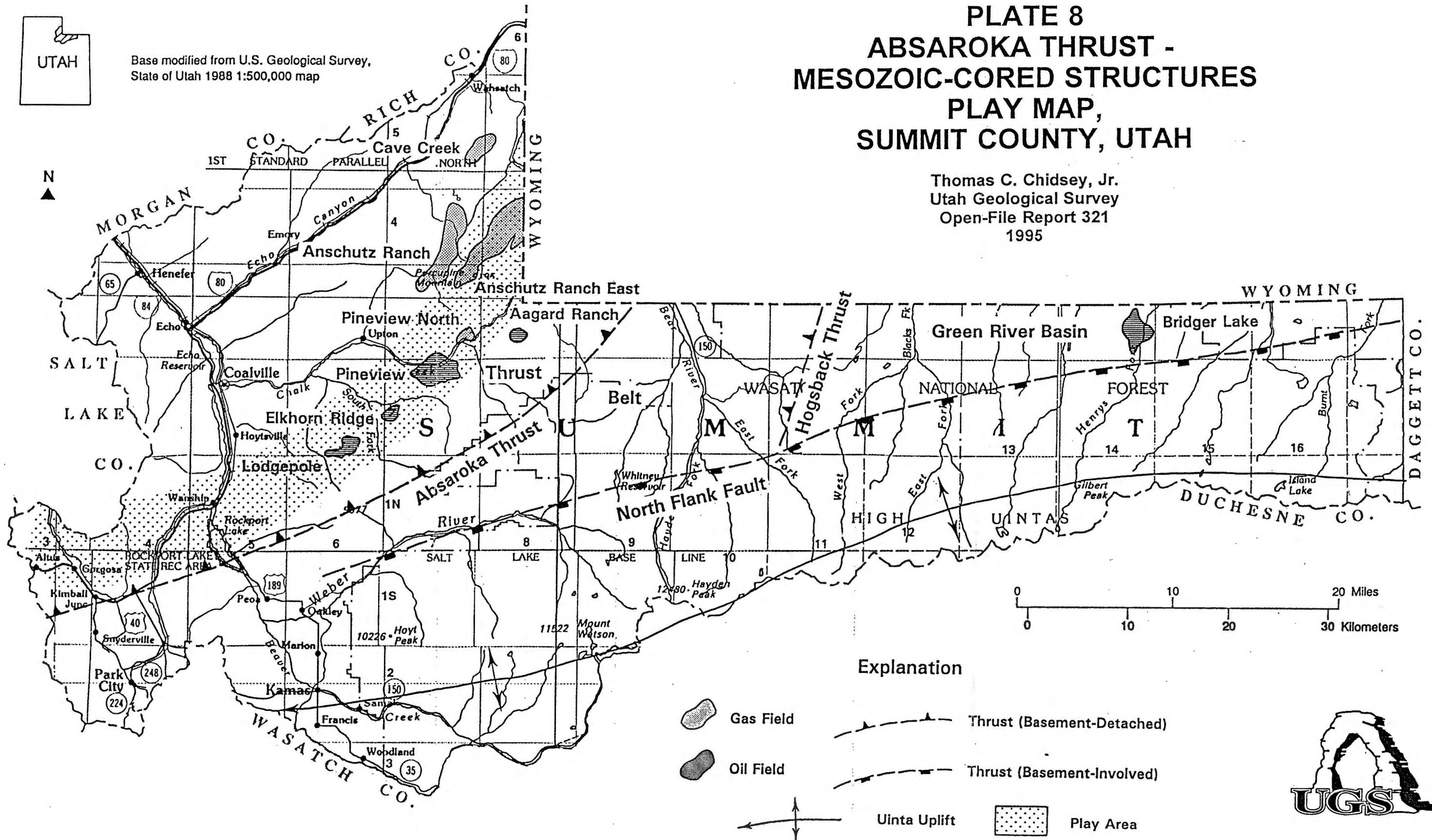


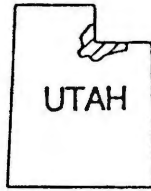


Base modified from U.S. Geological Survey,
State of Utah 1988 1:500,000 map

PLATE 8 ABSAROKA THRUST - MESOZOIC-CORED STRUCTURES PLAY MAP, SUMMIT COUNTY, UTAH

Thomas C. Chidsey, Jr.
Utah Geological Survey
Open-File Report 321
1995

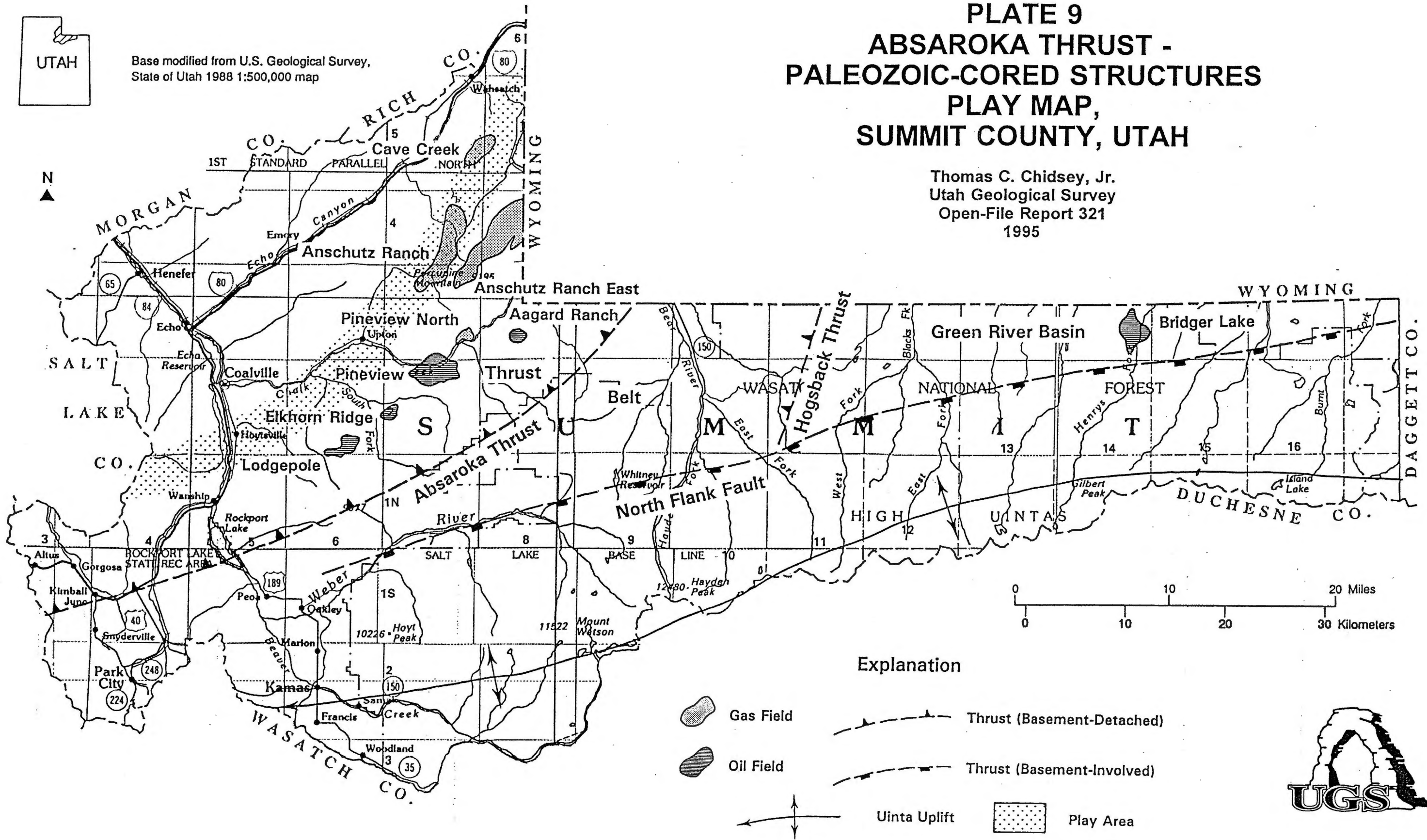


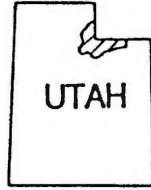


Base modified from U.S. Geological Survey,
State of Utah 1988 1:500,000 map

PLATE 9 ABSAROKA THRUST - PALEOZOIC-CORED STRUCTURES PLAY MAP, SUMMIT COUNTY, UTAH

Thomas C. Chidsey, Jr.
Utah Geological Survey
Open-File Report 321
1995





Base modified from U.S. Geological Survey, State of Utah 1988 1:500,000 map

PLATE 10 ABSAROKA THRUST - BROAD, SUBTLE FOLDS PLAY MAP, SUMMIT COUNTY, UTAH

Thomas C. Chidsey, Jr.
Utah Geological Survey
Open-File Report 321
1995

