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Geology and Hydrocarbon Assessment of the Blue Ridge, Province No. 132

By

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CONTENTS

ABSTRACT

The Blue Ridge belt (province No. 132) extends south and west for approximately 1,200 miles (1930 km) from the Canadian-Vermont border to central Alabama (north of Montgomery), where it is overlapped by late Mesozoic and Tertiary strata of the Gulf Coast. The belt includes parts of eleven States and ninety-two counties and covers an area of 41,081 square miles (26,291,840 acres).

Three areas were selected by the author as having a hydrocarbon potential because of: (1) oil and gas shows in play No. 1 and gas production to the northeast in the Quebec lowlands, (2) oil production in Virginia on the west flank of the Valley and Ridge for play 2A, and (3) favorable conodont alteration indices (CAI) in the Blue Ridge fensters in association with two key seismic profiles in Tennessee and North Carolina, in plays 2A and 2B.

Recent (1974-85) seismic surveys indicate that extensive thrust faulting moved crystalline rocks of the Blue Ridge and Piedmont westward hundreds of miles and buried a large section of Paleozoic sedimentary rocks of the eastern overthrust. This concealed segment of the overthrust belt extends eastward beneath the thrust-faulted crystalline rocks of the Blue Ridge and part of the Piedmont. If this wedge of Paleozoic strata is not thermally overmature, it is the most likely prospect for hydrocarbons in this still untested frontier area.

Because the entire Blue Ridge province is a frontier area without available drill data, play names could not be assigned, nor could conventional categories of data be discussed, such as traps, seals, migration, and timing. The author had access to three seismic lines for the analysis of province No. 132.

Introduction

Petroleum geologists have subdivided the Appalachian Mountain system into two main geographically parallel parts: the eastern overthrust belt and the western segment of the Appalachian plateaus. From east to west the eastern overthrust belt includes the Blue Ridge Mountains, a sequence of igneous and metamorphic rocks, the Valley and Ridge, a thrust-faulted and folded sequence of Paleozoic sedimentary rocks, and the eastern and central segments of the Appalachian plateaus, a less deformed sequence of Paleozoic strata (fig. 1). The western segment of the Appalachian plateaus, which lies west of the limit of Alleghenian thrusting, is structurally simple and exhibits a few extensional faults cutting the undeformed Paleozoic rocks.

Oil and gas have been extracted in quantity (more than 3 billion barrels of oil and 35 trillion cubic feet of gas) from the Paleozoic rocks of the Appalachian plateaus since the mid 1800's. The area is a well-developed mature petroleum province. In contrast, oil and gas were first produced from valley and ridge sedimentary rocks in the 1930's and 1940's. Little of the complexly faulted and folded area has been adequately explored for hydrocarbons. As yet, test wells have not been drilled through rocks of the Blue Ridge, which is by context a frontier area for petroleum exploration.

Recent (1974-85) seismic surveys indicate that extensive thrust faulting moved crystalline rocks of the Blue Ridge and Piedmont westward hundreds of miles, and buried a large section of Paleozoic sedimentary rocks of the eastern overthrust (Harris and Bayer, 1979a,b,c). This concealed segment of the overthrust belt ranges from 10,000 to more than 20,000 feet in thickness and extends eastward beneath the thrust faulted crystalline rocks of the Blue Ridge and part of the Piedmont (fig. 2).

Surface and subsurface data from the Valley and Ridge and seismic stratigraphic interpretations suggest that the buried segment includes Cambrian and Lower Ordovician shallow-shelf clastic and carbonate rocks. Thus, the concealed rocks beneath the Blue Ridge and Piedmont crystallines may be likely targets for hydrocarbons within this Appalachian frontier area.

Structural Setting

The Blue Ridge province (BRP) is a narrow elongate area extending from the Canadian-Vermont border (lat 45° N.), south 10° west, to the southeast corner of New York State. The strike changes abruptly to south 45° west and continues to central Alabama, where Blue Ridge rocks are overlapped by Late Mesozoic and Tertiary strata of the Gulf Coast (see special map "Generalized structural, lithologic and physiographic provinces in the fold and thrust belts of the United States," Bayer, 1984).

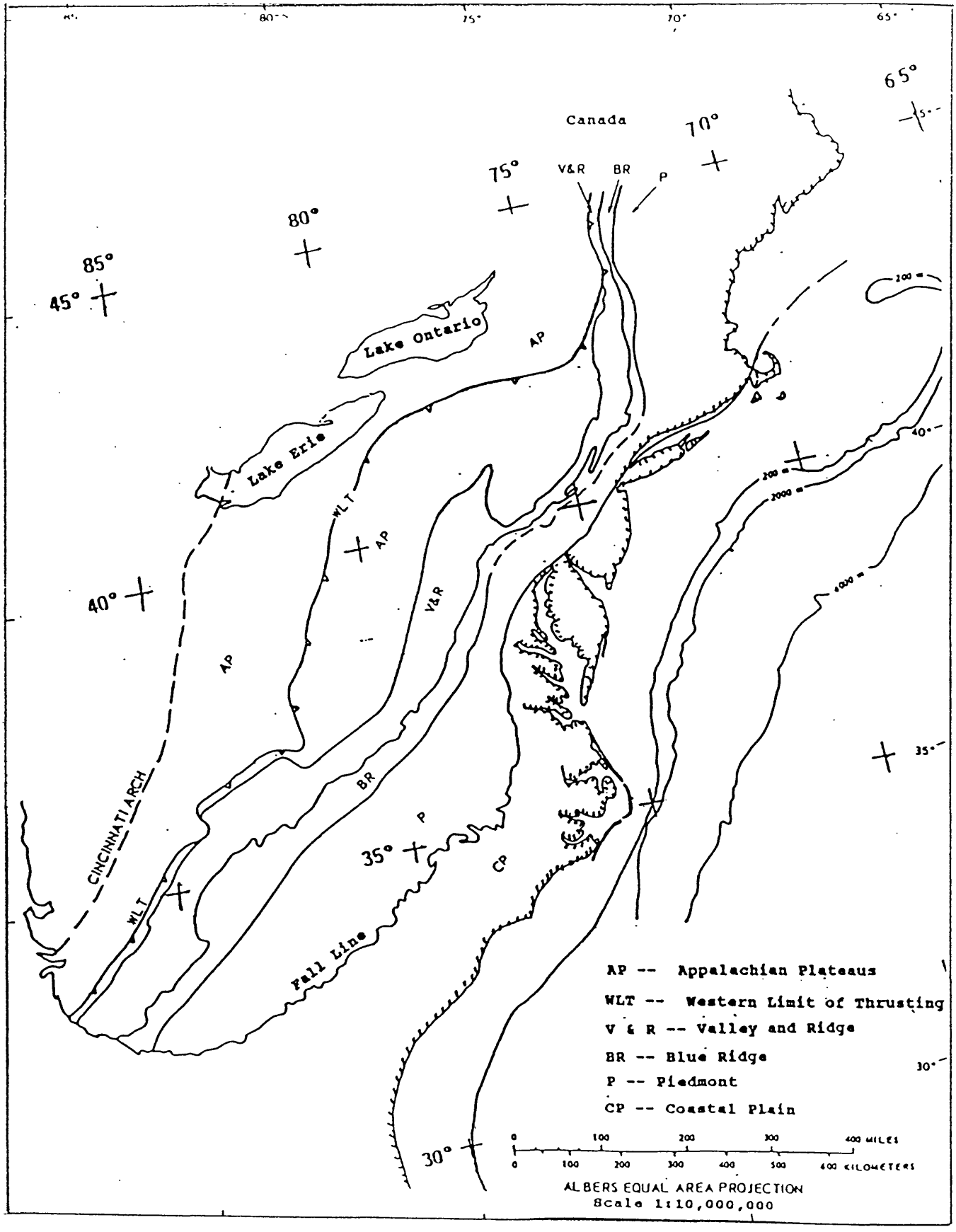

Figure 1. Appalachian provinces.

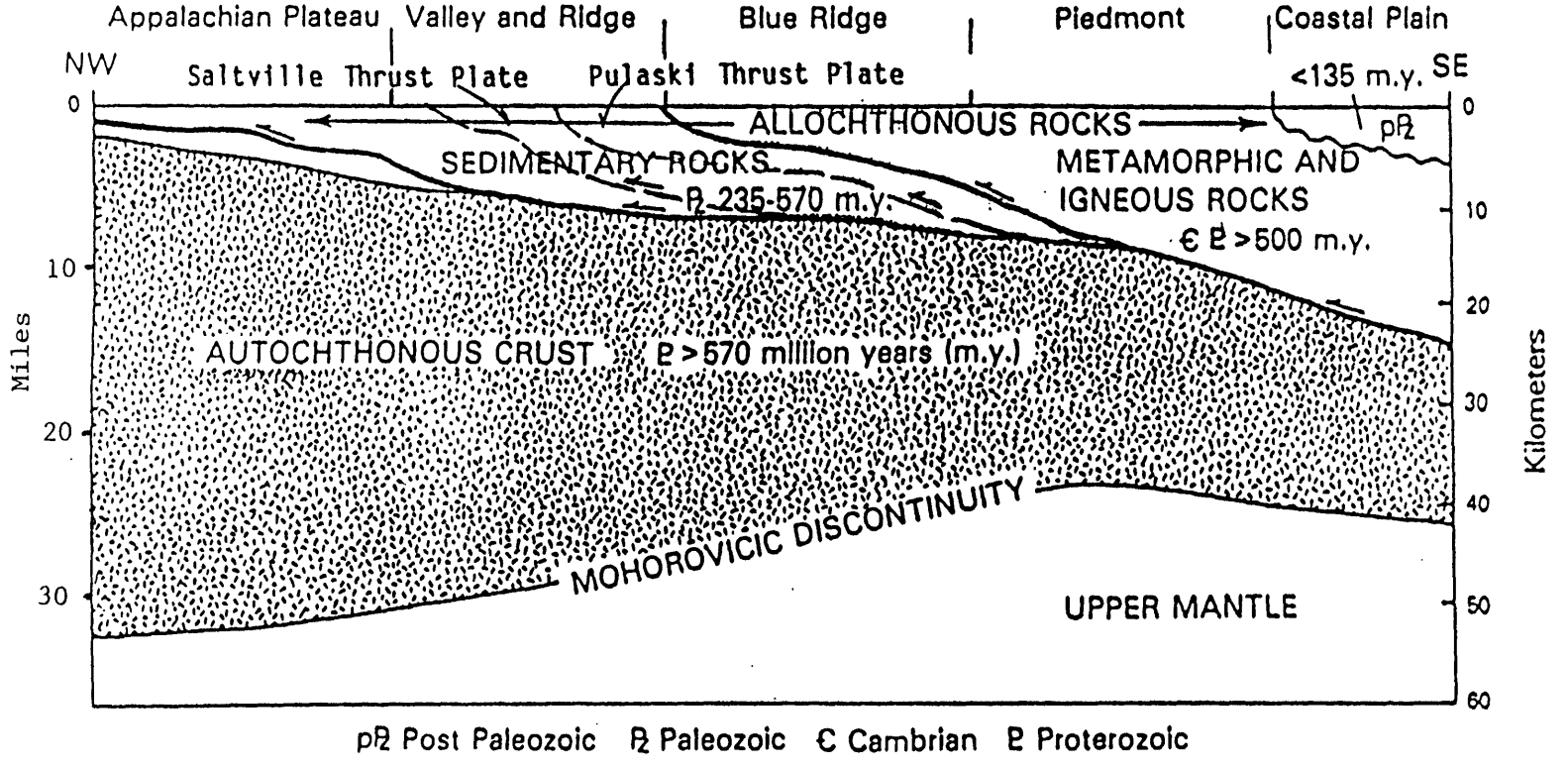

Figure 2. Idealized Appalachian thrust-belt model, showing sedimentary rocks of Paleozoic age, favorable for accumulation of oil and gas, under Blue Ridge and Piedmont crystalline rocks.

The Blue Ridge province No. 132, (see U. S. Geological Survey Open-File Report 88-373, page 19d, for province numbers) covers 41,081 square miles (26,291,840 acres) in parts of 11 eastern States, ninety-two counties, and one incorporated city (Lynchburg, Va). Triassic basins partially or totally within the BRP (Scottsville, Barboursville, Culpeper, Gettysburg, and Newark Basins) constitute a separate assessment report, Open-File Report 88-299, (Arthur P. Schultz, 1988). Additionally, province No. 134, the Adirondack and New England areas (fig. 3), in the author's opinion, did not meet the minimum parameters of recoverable accumulations equal to or greater than 1 million barrels of oil or 6 billion cubic feet of gas to justify a resource assessment at this time.

Discussion of Plays

(Figure 4, table 1)

Play No. 1.--The play area covers 215 square miles within a sedimentary basin of more than 500 square miles and extends westward to the Adirondack mountains and northward through Quebec's St. Lawrence lowlands. The play area is included in Chittenden, Franklin, and Grand Isle Counties of northwest Vermont (fig. 5).

A sequence of Cambrian and Ordovician clastics and carbonate rocks lies unconformably on Grenvillian rocks of the Precambrian craton. This sequence dips to the southeast. According to Robin J. Beiers (1976):

> In more geologic detail, there is a relatively complete sequence present from the Cambrian to Ordovician, either from outcrop or from wells.
>
> The Cambrian Potsdam Group is divided into two formations: the basal Covey Hill Formation and the overlying Chateauguay Formation, Table 1. The Covey Hill Formation, in general, lies unconformably on the Precambrian basement and is composed principally of feldspathic, poorly sorted, cemented, reddish sands deposited in a fresh water, beach or bay environment. The overlying Chateauguay Formation was deposited unconformably on the Covey Hill as a clean, generally well cemented, buff to white, quartz sand. In the upper part of the Chateauguay Formation, a marine influence is evident from an interbedding of carbonates and sandstones.

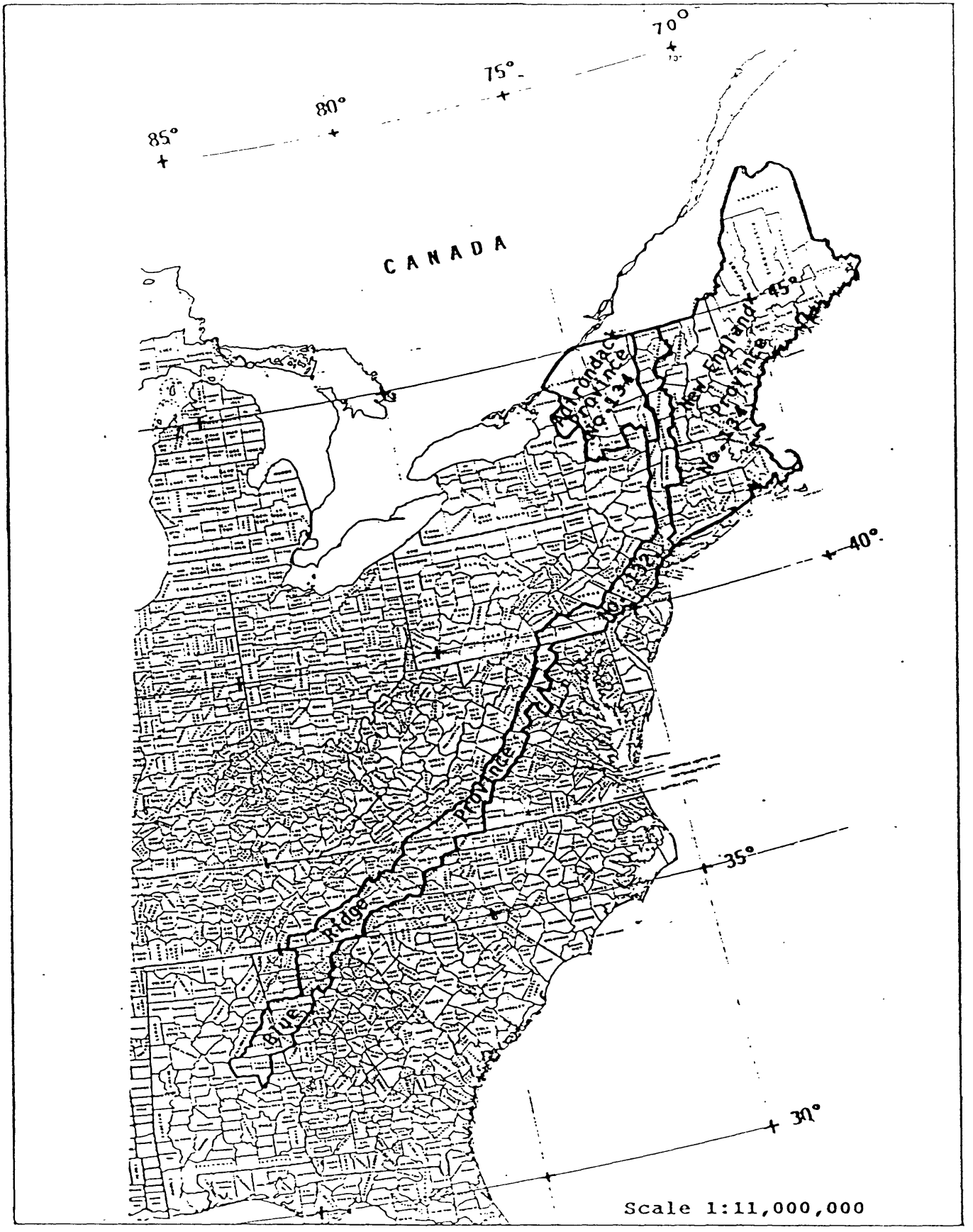

Figure 3. Location map. Adirondack, Blue Ridge and New England provinces.

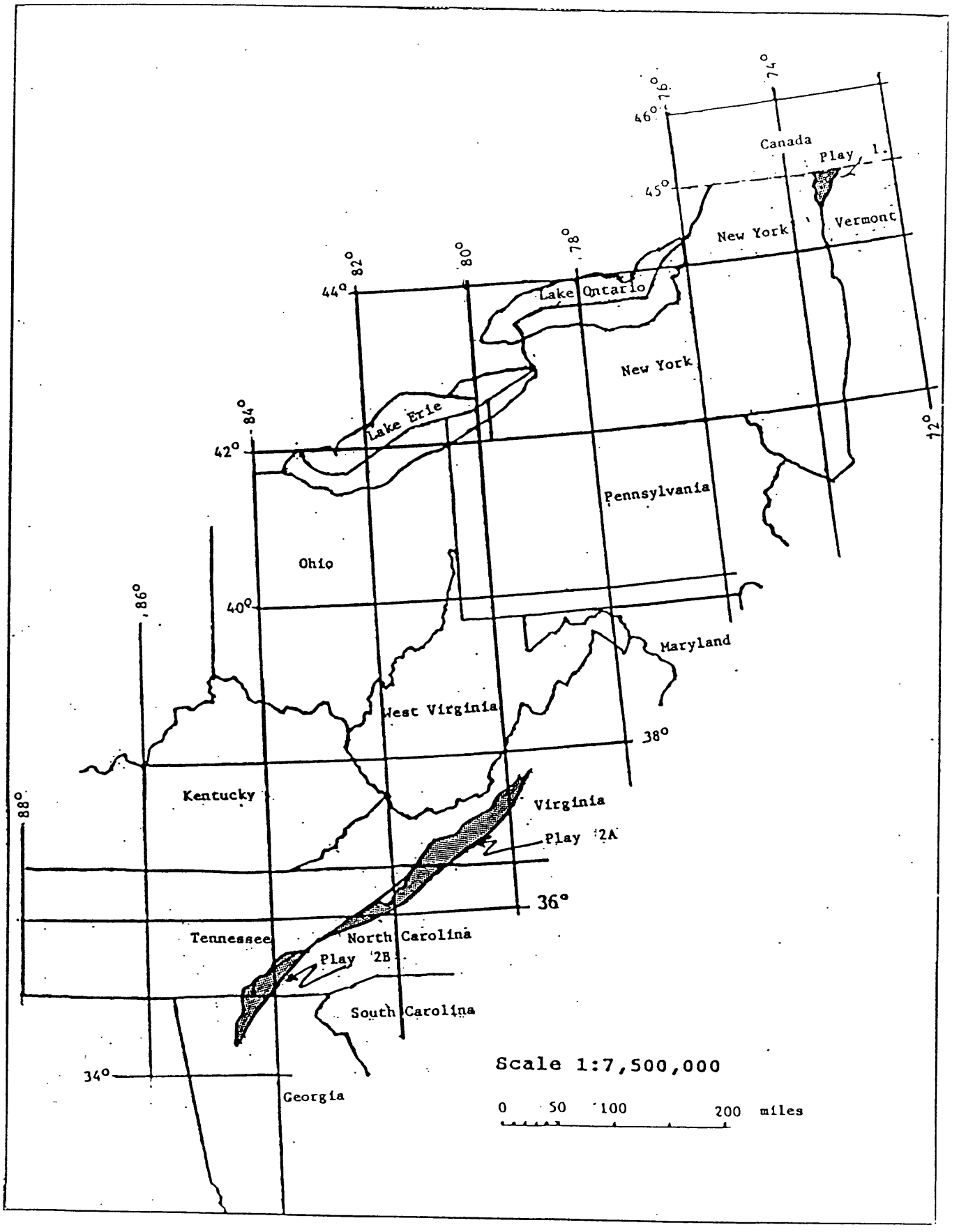

Figure 4. Blue Ridge Plays. Province No. 132.

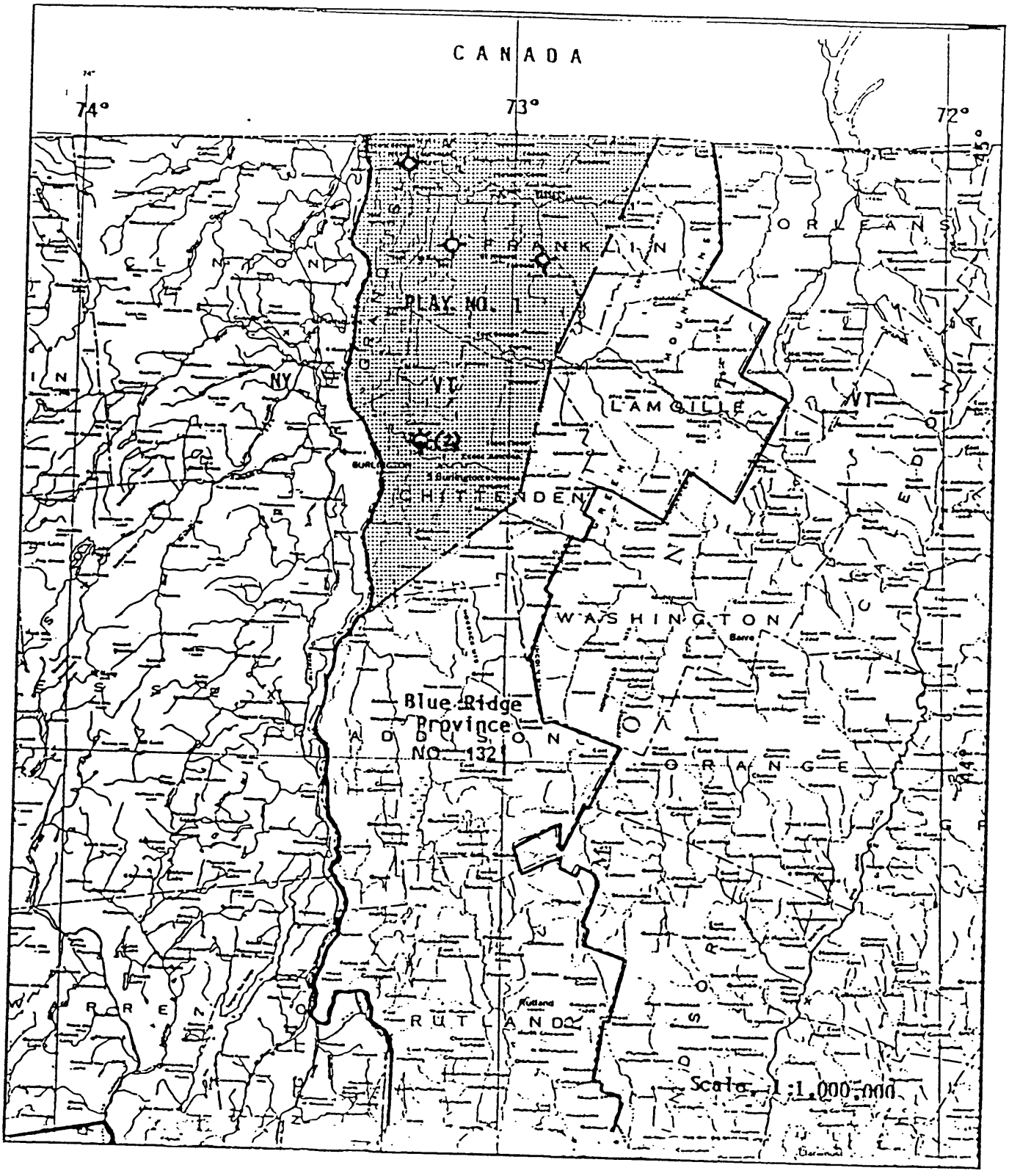

Figure 5. Location of Play No. 1. Northwest Vermont.

Table 1. Source and reservoir rocks described in Play No. 1.
Modified from Beiers, 1976

SYSTEM		SERIES	GROUP	FORMATION	LITHOLOGY
ORDOVICIAN	UPPER	CINCINNATIAN	RICHMOND		SHALES AND SILTSTONE
			LORRAINE		INTERBEDDED SHALE AND SILTSTONE
				UTICA	BLACK SHALE
			TRENTON		THIN BEDDED LIMESTONE
	MIDDLE	CHAMPLANIAN	BLACK RIVER		LIMESTONE
			CHAZY		LIMESTONE AND DOLOMITE
	LOWER	CANADIAN	BEEKMANTOWN	BEAUHARNOIS FM.	DOLOMITE
CAMBRIAN	UPPER	CROIXAN		THERESE FM.	DOLOMITE
			POTSDAM	CHATEAUGUAY FM.	QUARTZ SANDSTONE
				COVEY HILL FM.	FELDSPATHIC SANDSTONE

Marine influence becomes dominant in the deposition of the overlying Beekmantown Group. This group, composed mainly of light to dark gray coarsely crystalline dolomite, commonly becomes vuggy in part.

The dolomite of the Beekmantown Group is overlain, unconformably, by the Chazy Group. The base of this group is, in type section, a calcareous light gray sandstone and is overlain by limestones and shaly limestones.

The Chazy Group was followed in some regions by a hiatus and, in other regions, by the direct deposition of the Black River Group. In outcrop this group is composed of gray dolomites overlain by gray limestones.

Generally, the Trenton Group is characterized by thin-bedded limestones of many different petrographic types. In the upper part of the Trenton, limestone becomes progressively more and more shaly indicating a gradual deepening of the sedimentary basin and an increasing volume of fine grained clastics from the adjacent hinterland.

The change from the Trenton carbonate sequence to the black, massive, calcareous shales of the Utica seems abrupt in outcrop. This shale is noted for its petroliferous odor when freshly broken. To the west in the Appalachian basin, the Utica shale is one of the principal source beds for oil and gas. The distinctive black shales grade vertically to slightly calcareous, gray, thinly interbedded shales and siltstones of the Lorraine Group.

The Lorraine Group is a flyschoid sequence. Facies changes are present. The group varies from gray shales and fine siltstones to siltstones and fine-grained sandstones.

The tectonic history in play 1 is complicated. Two fault systems exist--a system of normal faults related to movement of the Precambrian basement rocks and a system of thrusts that originated during the first Appalachian orogenesis, the Taconic orogeny. Thrust faulting is important because it created fractured shales and permitted migration of hydrocarbons from source bed to reservoir

strata. The Taconic orogeny of Late Ordovician age produced the series of thrust faults with tectonic transport from the southeast to the northwest (Beiers, 1976).

Five known deep wells have been drilled in play area 1 (table 2).

Taylor (1964) described previous wells as follows:

> Gregoire 1 bottomed at 5075 feet. It was spudded in Lower Cambrian (Dunham?) dolomite. At about 329 feet, it entered Middle Ordovician Trenton Shale below an overthrust. Shale was drilled to 4,914 feet where dolomite was encountered.
>
> From 4,914 feet to total depth, the section consisted of interbedded dolomite and shale (presumably Trenton). Dolomite found at and below 4,914 feet is different from Lower Cambrian dolomite drilled at the surface.
>
> Vermont Gas and Mineral Corp. officials reported oil and gas shows in Gregoire 1. Gas was gaged at 50 Mcfd [thousand cubic feet per day]. A study of well cuttings revealed small amounts of hydrocarbons (gilsonite?) at various depths, and an oily film on samples (from 2,616 to 2,662 feet) produced a yellow color characteristic of oil when tested with carbon tetrachloride.
>
> Gas has also been found in several shallow water wells in northern Vermont. An oil show also was reported at 287 feet in a water well on the Kellas farm on Isle la Motte.
>
> Many hydrocarbon indications have long been known in the northern part of this basin in Quebec. A gas test was drilled in 1885 in Nicolet County. Since then, more than 100 wells of varying depths have recorded gas and oil shows in Cambrian-Ordovician rocks.
>
> Commercial gas has been produced near Three Rivers in Quebec for several years. Late in 1963, a gas discovery was reported at La Baie 5 well, southwest of Three Rivers in Yamaska County near the mouth of the Nicolet River. This well was reportedly drilled to 4,437 feet, with 637 feet of Potsdam Sandstone at total depth. Casing was set at the top of the Potsdam and a 105-foot section was fractured. Reportedly, the well then produced gas at 3.3 MMcfd.

Table 2. Blue Ridge Province. Play No. 1, Wildcat wells.

Name	Counties in Vermont	Drilling Date Completion	Final Status	Drilled to:	Remarks
Hutchins No. 1.	Grand Isle	1965	D & A	5,120 ft.	
No. 1 Yandow	Franklin	?	D & A	3,500 ft.	
Gregoire No. 1	Chittenden	?	D & A	5,075 ft.	oil and gas shows
Gregoire No. 3	Chittenden	?	D & A	?	No data available.
# 1 Burnor Columbia Gas	Franklin	10/25/84	D & A	6,970 ft.	Temporarily abandoned. Contract depth was 10,500 ft.

D & A = dry and abandoned
Well data, courtesy, Wallace de Witt, Jr., (1986).

Resource potential, Play No. 1.--Although oil shows have been reported in shallow wells drilled in the U.S. and Canadian parts of the basin, gas shows have provided the major hydrocarbon potential. Shales and siltstones of the Lorraine and Utica formations form the principal source rocks; however, due to their high level of maturation in the area, their main potential is for dry gas. In the wells drilled, gas shows occur in the shale sequence in the overthrust zone where geologic structures are clearly evident. The key to the problem may be locating fracture porosity because primary porosity has been largely obliterated in the thrusted sequence. Where they exist, fractures tap the gas in the shale and siltstone sequence and act as permeability channels (Beiers, 1976).

Play No. 2A.--The play area covers approximately 3560 square miles in Virginia and North Carolina (figs. 6 & 7). Table 3 lists the counties in the area.

Table 3.--Blue Ridge province. Play 2A included in the following counties.

Virginia:	North Carolina
Bedford:	Ashe
Franklin	Alleghany
Floyd	Wilkes
Carroll	Wautauga
Grayson	Avery
	Mitchell
	Caldwell
	Yancey
	Madison
	Haywood
	Swain

Play No. 2B.--The play area covers approximately 820 square miles in North Carolina, Tennessee, and Georgia (fig. 8). Table 4 lists the counties in the play area.

Table 4. Blue Ridge province, Play 2B included in the following counties.

North Carolina	Tennessee	Georgia
Swain	Polk	Fanin
Graham		Gilmer
Cherokee		Pickens
		Cherokee
		Murray
		Gordon
		Bartow

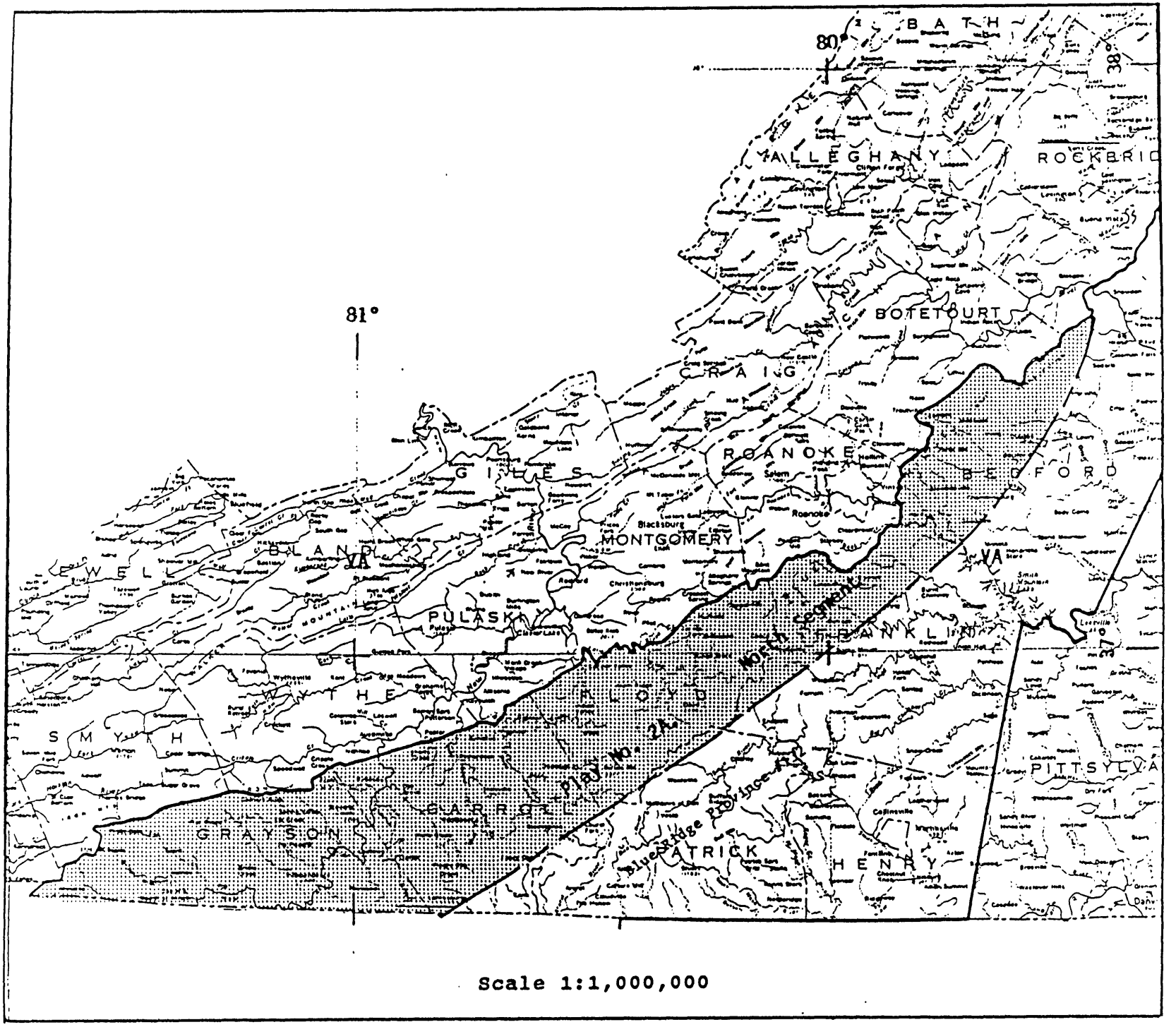

Figure 6. Location of Play No. 2A (northeast part), Virginia.

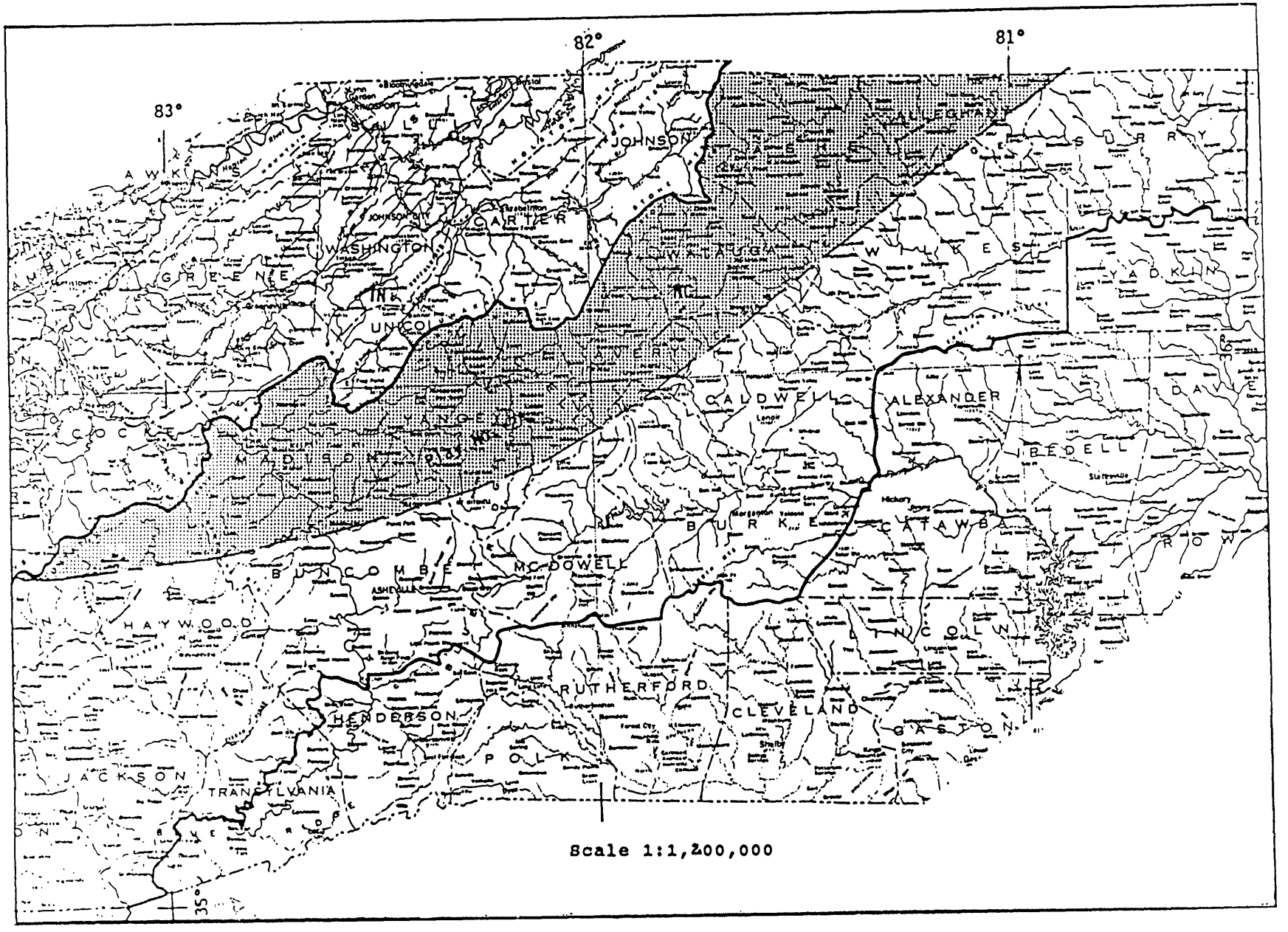

Figure 7. Location of Play 2A (southwest part), North Carolina.

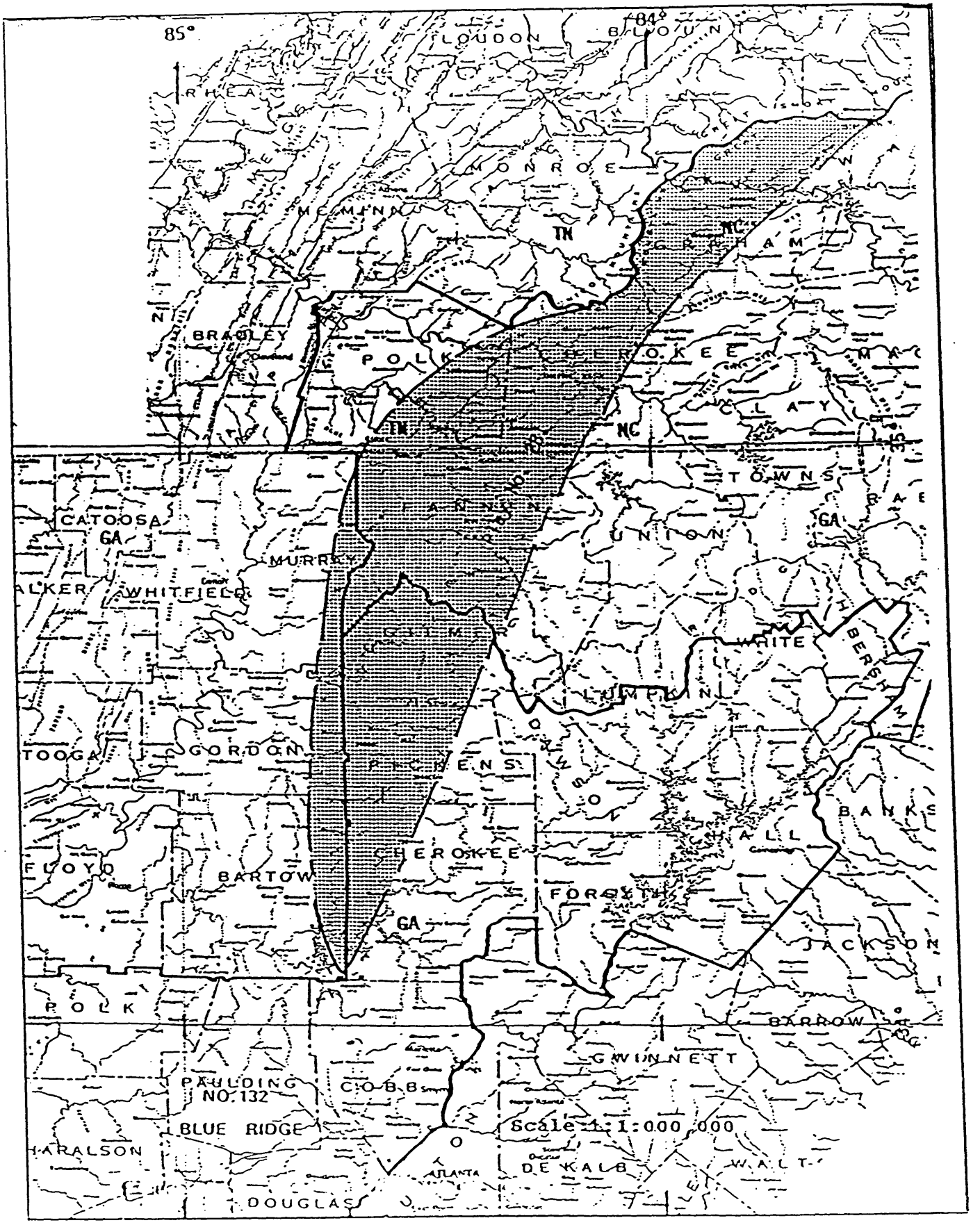

Figure 8. Location of PLAY NO. 28 North Carolina, Tennessee, and Georgia.

Some observations on Plays 2A and 2B.--Within the central and southern Blue Ridge province, the Knox Group, predominantly dolomite and limestone, is the most likely hydrocarbon reservoir of the Paleozoic sedimentary sequence beneath the Blue Ridge Mountains. TheKnox Group is Late Cambrian to Early Ordovician (Table 5). However, as of this date, no commercial oil or gas has been obtained from the Knox in the Valley and Ridge province, contiguous to and immediately west of the Blue Ridge. Some oil and gas has been found in the upper part of the Knox along the western side of the Valley and Ridge in Lee County, Va. and adjacent Tennessee. Organic source material for oil and gas could be in the shales of the older Conasauga Group of Middle to Late Cambrian age or in the Middle Ordovician Blockhouse, Athens, and Sevier Shales. Because of the excessively high levels of thermal maturation older shales of Late Proterozoic Ocoee Group to Early Cambrian Chilhowee are not considered a potential source rock in Plays 2A and 2B.

In eastern Tennessee, along Chilhowee Mountain at the toe of the Blue Ridge, the Blue Ridge thrust sheet rides over Paleozoic rocks as young as Devonian and Mississippian. These strata, the Chattanooga Shale, Grainger Formation, and Greasy Cove Formation, are composed almost entirely of siliciclastic beds (Table 6). The Chattanooga is about 25 feet thick and consists of dark gray carbonaceous shales. It overlies quartzites of the Bays Formation (Ordovician) unconformably. The overlying Grainger is about 1,000 feet thick and consists of shale, sandy and silty shale, siltstone, and massive sandstone. The youngest Mississippian beds exposed beneath the Blue Ridge thrust sheet, the Greasy Cove Formation, are about 1,000 feet thick and consist of limestone, sandstone, siltstone, and shale. The general lithology of these Devonian and Mississippian strata in eastern Tennessee, an area of relatively low thermal maturity, suggests that they may contain suitable source beds and reservoir rocks for the generation and entrapment of hydrocarbons.

The extent of Devonian- and Mississippian-age rocks beneath the Blue Ridge thrust sheet is unknown. Small occurrences of Fort Payne Formation and the overlying Floyd Shale, both of Mississippian age, crop out along the toe of the Blue Ridge (Cartersville) thrust sheet in Polk County, northwestern Georgia. Their location and age suggest that some less mature Paleozoic rocks may be preserved regionally beneath the Blue Ridge thrust sheet in the southern Appalachians. It is not likely, however, that these younger strata extended far to the east before they were cut out in the subsurface by the Blue Ridge thrust. The Fort Payne overlies the Rockmart Slate (Ordovician) unconformably along the toe of the Blue Ridge in northwestern Georgia (Robert C. Milici, personal [written] commun., 1988).

As yet, wells have not been drilled through the crystalline rocks of the Blue Ridge in play areas 2A and 2B to verify the wedge of underlying Paleozoic sedimentary rocks. Because oil or gas seeps have not been reported there, I assumed that the thick sequence of

Table 5. Potential source and reservoir rocks in Plays 2A and 2B (Cambrian to Middle Ordovician).

SYSTEM		GROUP	FORMATION	LITHOLOGY
Ordovician	Middle		Sevier	Shale, limestone, calcareous sandstone
			Athens	Shale, limestone, siltstone
			Blockhouse	Shale and limestone
	Lower	Knox		Dolomite
Cambrian	Upper			
	Middle	Conasauga		Shale, dolomite, siltstone
	Lower		Rome	sandstone
			Shady	Dolomite
		Chilhowee		Conglomerate, quartzite, sandstone, siltstone, and shale
Proterozoic	Upper	Ocoee		Conglomerate, quartzite, siltstone, shale, and slate

Table 6. Potential source and reservoir rocks in Plays 2A and 2B (Middle Ordovician to Upper Mississippian).

Systems and Series	Formations		Lithology
	North	South	
Upper Mississippian		Floyd	Shale
Lower Mississippian		Fort Payne	Chert, dolomite, shale
	Greasy Cove		Limestone, sandstone,
	Grainger		siltstone, shale
Upper Devonian	Chattanooga		Shale
Middle Ordovician	Bays		Quartzites
		Rockmart	Slate, siltstone, conglomerate

overthrust crystalline rocks may provide (1) a seal, (2) fracture porosity of the reservoir rocks, and (3) consequently, may serve as a migration path for hydrocarbons from the fractured reservoir strata.

Resource Potential of Plays 2A and 2B.--The apparent high conodont alteration index (CAI) and thermal maturation values of source and reservoir rocks preclude the presence of oil. Some small, noncommercial amounts may be present as condensate. Dry, nonassociated gas, although completely speculative, is most likely present. Structure, depth of burial, source, reservoir, and traps are favorable conditions for hydrocarbon accumulation. Unfavorable factors, for exploration, include the high level of thermal maturation (high CAI) for the eastern Valley and Ridge and contiguous Blue Ridge, absence of oil or gas seeps, high cost of drilling through crystalline overthrust, and the current depressed economics of the petroleum industry.

Acknowledgments

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