GEOLOGY AND ENGINEERING CHARACTERISTICS OF SELECTED LOW-PERMEABILITY GAS SANDS: A SURVEY (ADDENDUM)

Final Report

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"Clinton"-Medina Sandstone, Appalachian Basin

Introduction

The "Clinton"-Medina Sandstone of Lower Silurian age in the Appalachian Basin represents a major tight gas sand resource. The "Clinton"-Medina sands are generally equivalent to the Tuscarora Sandstone covered in the main body of this report, wherein structural elements of the Appalachian Basin have already been reviewed and will not be repeated here. This review of the "Clinton"-Medina Sandstone was prepared by Richard J. Diecchio under the direction of Douglas G. Patchen, Chief, Fossil Fuels Division, West Virginia Geological and Economic Survey. Data have been compiled for three areas of "Clinton"-Medina tight gas occurrence in eastern Ohio (tables 3-6), in northwestern Pennsylvania (tables 7-10), and in western New York (tables 11-14).

Stratigraphy

Lower Silurian strata of the Central Appalachian Basin generally become thicker and coarser toward the east, and thinner, finer, and more calcareous toward the west (fig. 1). In the western portion of the basin, shale is often the dominant lithology, and limestone is common. In the western area, where sandstone usually comprises a minor portion of the section, these sandstones are commonly and informally referred to as the "Clinton"-Medina sandstone. These sandstones are the most important hydrocarbon reservoirs in the western portion of the basin. Areas of "Clinton"-Medina production are shown in figure 2.

Lower Silurian stratigraphic nomenclature varies significantly from state to state (fig. 3). The Lower Silurian is referred to as the Medina Group in New York and Pennsylvania, and as the Cataract Formation (or Group) or the Albion Group in Ohio. In general, this package of strata is characterized by a basal sandstone (Whirlpool) overlain by a shaly unit (Cabot Head or Power Glen). Locally, a carbonate unit (Manitoulin or

Brassfield) occurs between the Whirlpool and the Cabot Head/Power Glen, but this is not typical. The Cabot Head/Power Glen is overlain by a sequence of lenticular sands which includes a middle hematitic facies. These sands are commonly called "Clinton".

The "Clinton" sandstones are given different names in different places. In Pennsylvania they are called the Grimsby. In New York, the lower white sand and middle red sand are called the Grimsby, and the upper white sand is called Thorold. In Ohio the lower white sand is called Cabot Head (Sandstone), the middle red sand is the Grimsby, and the upper white sand is the Thorold. These "Clinton" sands comprise the top of the Lower Silurian, except in Ohio where the Thorold is overlain by an upper tongue of the Cabot Head Shale, which in turn is locally overlain by what is called the Brassfield Dolomite. The upper Cabot Head Shale marks the top of the Lower Silurian wherever it occurs, unless overlain by Brassfield which is considered the top of the Lower Silurian where it occurs. The Medina/Cataract or the Lower Silurian changes facies eastward to a sandstone-dominated unit (Tuscarora) and westward to a carbonate-dominated unit (Brassfield).

The term "Clinton" is taken from the driller's terminology and is incorrectly used. The proper formal stratigraphic designation of the Clinton is that of a Middle Silurian formation or group that occurs in New York, Pennsylvania, Maryland, West Virginia and Virginia, in the eastern portion of the Appalachian Basin. The use of the term "Clinton" for the sequence of Lower Silurian sandstones, therefore, implies an incorrect correlation. The "Clinton" of this report has no relationship to the true Clinton.

Another source of confusion is the term Medina. In New York, the Medina Group is everything above the Ordovician (Queenston) and below the Thorold. In West Virginia and Ohio the term Medina has in the past been used to refer to the Upper Ordovician Queenston or Juniata (red Medina) and the Lower Silurian Tuscarora or Whirlpool (white Medina). Drillers tend to follow the latter designation which is, by and large, obsolete.

(Finley, 1982)

The term "Clinton"-Medina, therefore, has somewhat of a double meaning. The package of middle Lower Silurian sands, which is called "Clinton" in Ohio, and Medina in New York, is over a widespread area called "Clinton"-Medina. In Ohio, where production from the Lower Silurian and Upper Ordovician comes from either the "Clinton" or the underlying "Medina", the gross producing package is referred to as the "Clinton-Medina". The term will be used in both contexts in this report.

As shown on cross sections (figs. 4-5), the Lower Silurian clastics are of a blanket nature throughout the basin. In the areas of interest in this report, these strata are deltaic and are characterized by shaly strata containing discontinuous, lenticular ("Clinton"-Medina) sand bodies. The individual "Clinton"-Medina sandstone reservoirs are in fact multiply-stacked and not laterally extensive and therefore, should not be referred to as a blanket sand.

The "Clinton"-Medina is either classified a tight formation, or pending approval as a tight formation throughout most of its productive area (fig. 6). There are five counties in eastern Ohio in which the "Clinton" is classified tight, but has yet to produce (Meigs, Washington, Monroe, Belmont, and Jefferson). There are four counties in central Ohio (Fairfield, Licking, Knox, and Richland) where the "Clinton" is very productive, and apparently so porous (intergranular) and permeable that it does not qualify as a tight formation.

There is minor "Clinton" production in Greenup, Boyd, and Lawrence Counties, Kentucky. This area will not be dealt with in this review. Tight formation submittals are thought to be in the preparation stage for this area.

Depositional Systems

In New York the Medina Group consists of a westward prograding deltaic system. The Whirlpool Sandstone has variously been described as a longshore bar or beach and an aeolian sand. The Grimsby Sandstone is considered a distributary channel/bar complex

grading upward and to the east into floodplain or tidal flat facies. Similarly, in Pennsylvania, the Medina Group is deltaic in origin, grading laterally into sandy shelf deposits. Diecchio (1982c) suggests, however, that the recent work of Cotter (1982) provides new information on the relative position of the deltaic and shelf facies. Apparently, further evaluation is needed on a regional basis to better define the paleogeography.

In Ohio, the Albian Group, also termed the Cataract Formation (fig. 3), was deposited as a deltaic system, and in general consists of "multi-stacked, coalescing, lenticular sandstones and siltstones deposited as channel sands, river mouth bars, longshore bars and reworked beach ridges" (Ohio Department of Natural Resources, 1980). Although these sands are generally lenticular, cross sections presented by Overbey and Henniger (1971) show that these units are broadly lenticular and, with stacking of multiple units, can approach a blanket configuration. It was therefore considered appropriate to include the "Clinton"-Medina in an addendum to this survey of blanket-geometry tight gas sands. Diecchio (1982c), recounting Knight (1969), reports that in northeastern Ohio the Whirlpool Sandstone represents strandplain deposits, the lower Cabot Head Shale is a prodelta shale, the Cabot Head ("White Clinton") and the Grimsby ("Red Clinton") Sandstones are distributary channel sequences, and the Thorold Sandstone ("Stray Clinton") represents a transition (no specific facies described) into prodelta deposits of the upper Cabot Head Shale. In eastern Ohio, Overbey and Henniger (1971) suggest that the Thorold represents a marine shelf deposit.

Most authors concur that the "Clinton"-Medina represents a deltaic sequence forming the distal portion of the Taconic clastic wedge (Diecchio, 1982c). Recent work by Cotter (1982) on the equivalent Tuscarora Sandstone (fig. 3) strongly implies the occurrence of a fan delta with proximal braided fluvial facies, marginal marine strandplain and deltaic components, and a marine shelf with sand waves and bars. The balance

(Finley, 1982)

between progradational strandplain and delta front facies (blanket-geometry) and channel mouth bar or offshore bar facies (lenticular) will affect the overall reservoir geometry in part of the "Clinton"-Medina trend. The analogy between the "Clinton"-Medina and the Travis Peak fan delta system is very strong, and it appears that both are major fan-delta systems.

Extrapolation Potential

The "Clinton"-Medina tight gas trend is extensively drilled in New York, Pennsylvania, and Ohio and development activity continues at a relatively high rate. The greatest number of wells tapping a single stratigraphic unit for tight gas produce from the "Clinton"-Medina, making up the largest part of 5,160 tight gas sand wells in Ohio (AAPG Explorer, 1982). It is therefore evident that the "Clinton"-Medina trend may not offer the Gas Research Institute the opportunity to foster new gas supplies from an otherwise undeveloped stratigraphic unit or depositional trend. However, studies of the Travis Peak fan-delta system may develop new gas reserves and at the same time research on the Travis Peak may be usable in further, more efficient exploitation of the "Clinton"-Medina and the less developed, equivalent Tuscarora Sandstone.

(Finley, 1982)

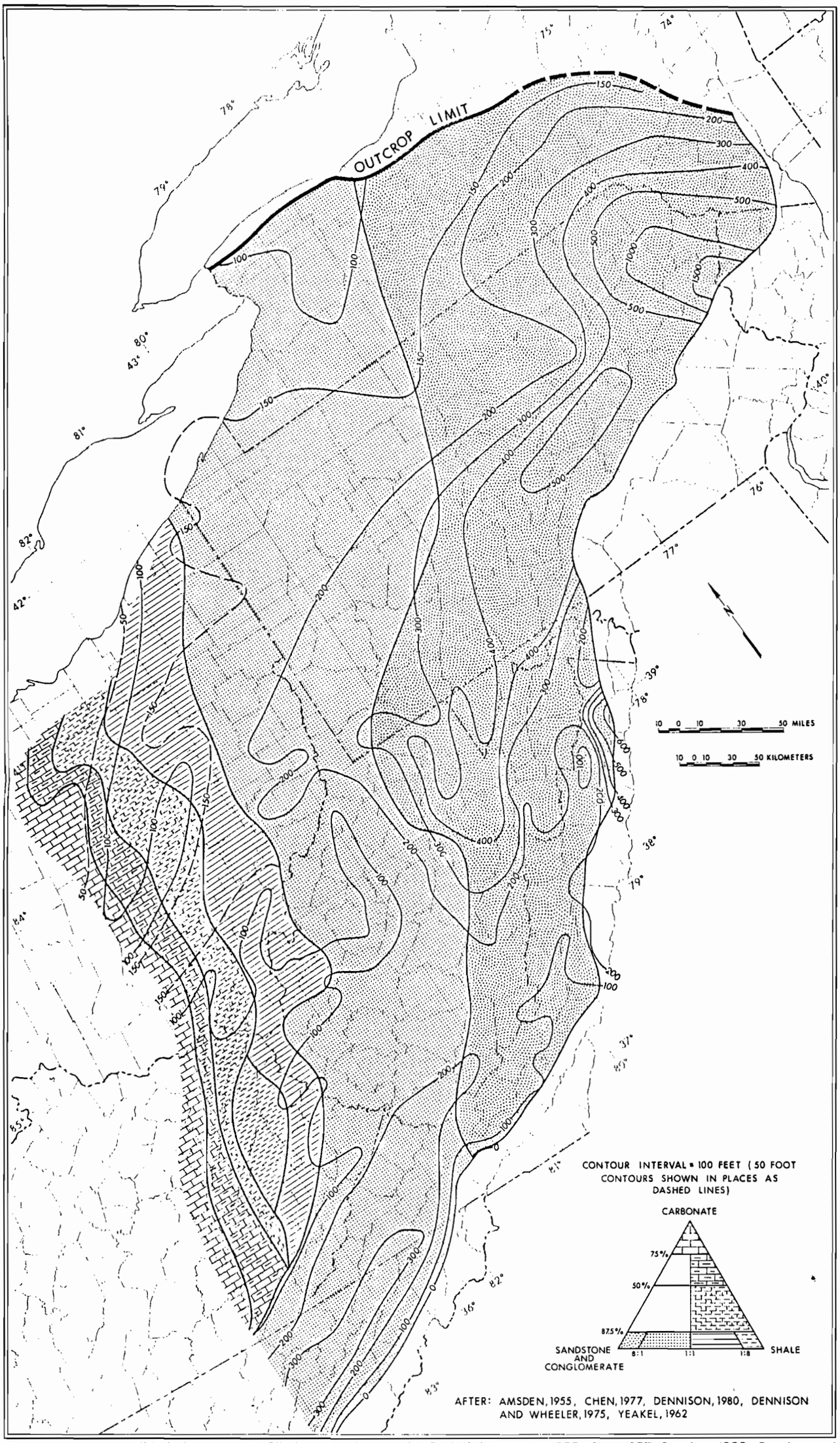

Figure 1. Isopach and lithofacies of Lower Silurian in the Appalachian Basin (after Amsden, 1955; Chen, 1977; Dennison, 1980; Dennison and Wheeler, 1975; Yeakel, 1962).

(Finley, 1982)

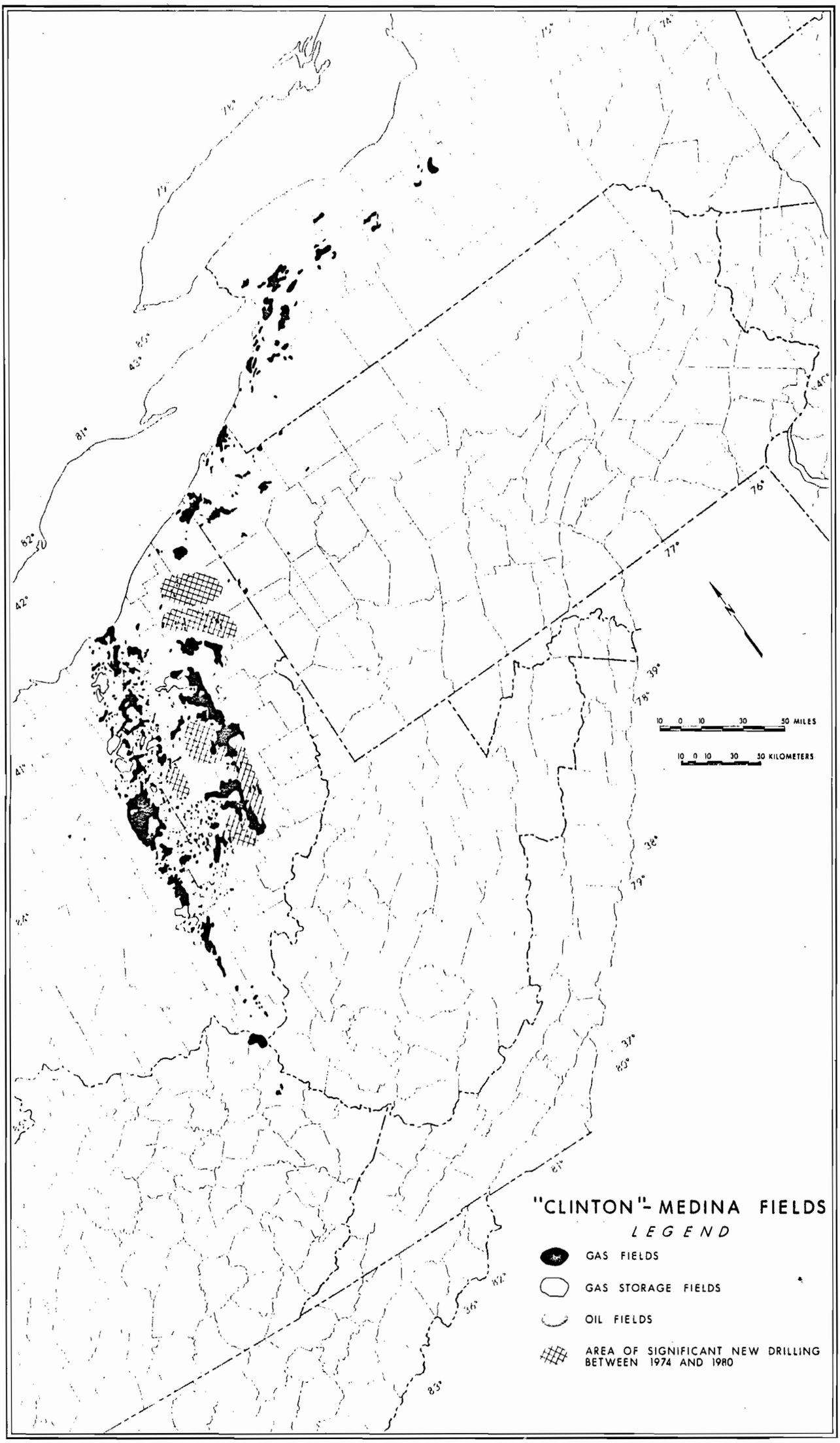

Figure 2. Hydrocarbon production from "Clinton"-Medina fields (after Debrosse and Vohwinkel,1974; Kreidler,1959,1963; Kreidler et al.,1972; Piotrowski, 1981; Wilson and Sutton, 1976).

(Finley, 1982)

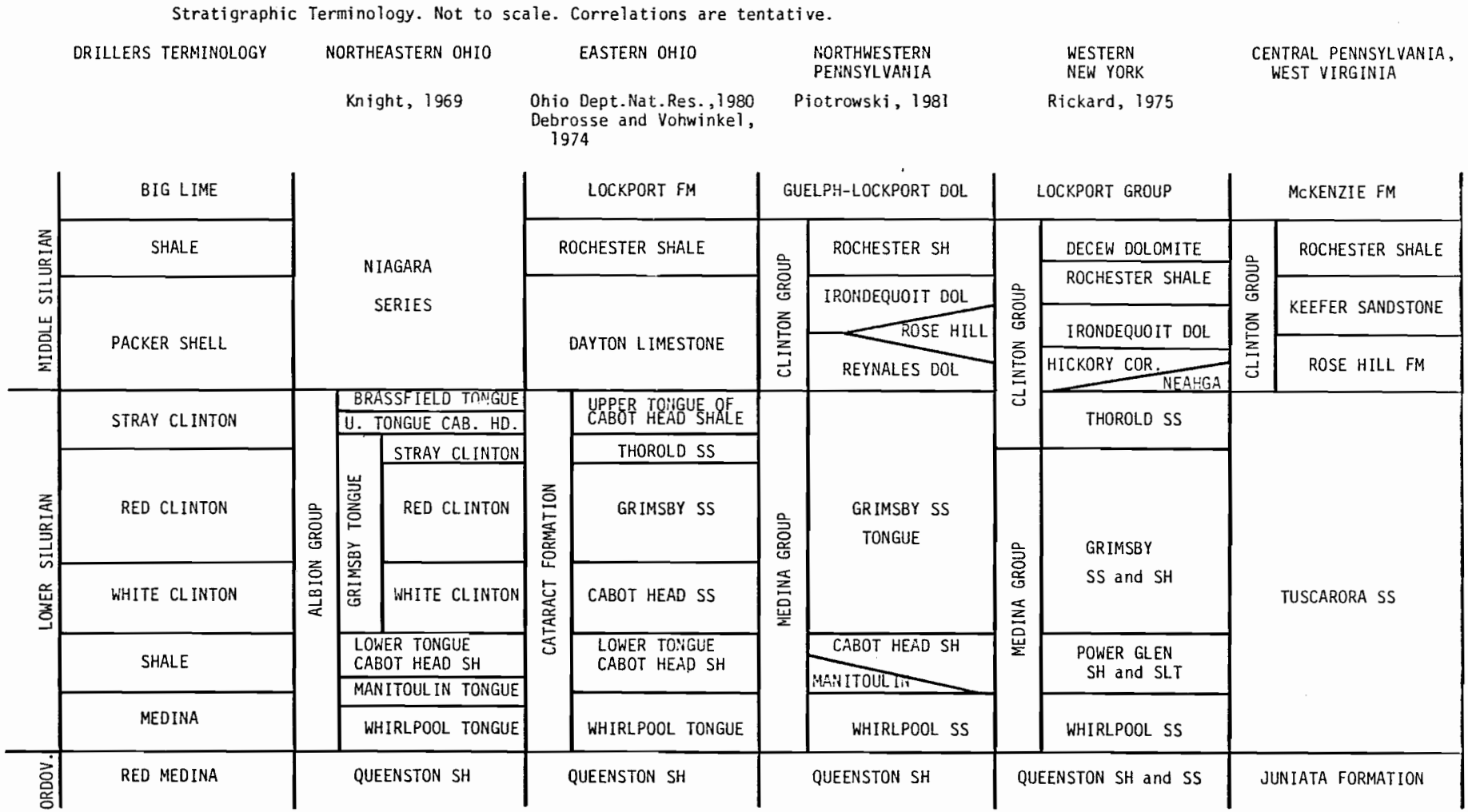

Figure 3. Stratigraphic terminology of the Lower Silurian (after Debrosse and Vohwinkel, 1974, Knight, 1969; Ohio Department of Natural Resources, 1980; Piotrowski, 1981; Richard, 1975).

Table 3. "Clinton"-Medina Sandstone (Albion Group), Eastern Ohio, Appalachian Basin: General attributes and geologic parameters of the trend.

GENERAL ATTRIBUTES

Stratigraphic Unit/Play	Area	Thickness	Depth	Estimated Resource Base	Formation Attitude, other data
"Clinton"-Medina Sandstone (Albion Group), Eastern Ohio, Lower Silurian	Eastern Ohio, generally east of the 83rd meridian, and east of a line from Lorain County (north) to Lawrence County (south).	Albion Group: 220 ft in southeastern Ohio, thinning to the west and north. About 120 ft thick at the western limit of production.	To top of "Packer Shell": over 7,000 ft in eastern Ohio to slightly over 1,000 ft at the western limit of production.	No data. Not included in review of tight gas sands by National Petroleum Council.	Regional dip is toward the southeast at 50 ft/mi.

GEOLOGIC PARAMETERS - Basin/Trend

Structural/Tectonic Setting	Thermal Gradient	Pressure Gradient	Stress Regime
In the relatively undeformed Western Basin Province of the Appalachian Basin. Stratigraphic section thins toward the Findlay Arch in west-central Ohio.	1.0-1.8°F/100 ft.	No data.	No specific data. May be weakly compressional in extreme eastern Ohio toward the deformed portions of the Appalachian Basin.

(Finley, 1982)

Table 4. "Clinton"-Medina Sandstone (Albion Group), Eastern Ohio, Appalachian Basin: Geologic parameters.

GEOLOGIC PARAMETERS - Unit/Play

Depositional Systems/Facies

Generally deltaic to marginal marine strandplain and shallow marine facies associated with the distal portion of the clastic wedge resulting from the Taconic orogeny. Sandstones are lenticular to broadly lenticular and approach blanket-geometry as a consequence of stacking of multi-story sand bodies. Best blanket geometries may be associated with barrier and strandplain facies, while channel mouth and offshore bars will tend to be lenticular.

Texture

Very fine to fine-grained sandstone, angular to subangular, with interbeds of siltstone and shale.

Mineralogy

The White, Red, and Stray "Clinton" of central Ohio consist of 76-90% detrital quartz, 1-4% rock fragments, 1-5% feldspar and other minerals, 2-10% clay, and 2-19% cement.

Diagenesis

Quartz, calcite, hematite and to a lesser extent, clay, siderite, and ankerite have cemented the "Clinton" sandstones. Balance of quartz vs. calcite cement varies locally.

Typical Reservoir Dimensions

Net sandstone reaches a maximum of 90 ft in eastern Ohio, but pinches out to zero to the west. Lateral dimensions of reservoirs may be adequate only for one well or may include up to a 535 mi^2 area (East Canton Field).

Pressure/Temperature of Reservoir

No temperature data. Reservoir pressure varies from 1,100 to 1,390 for two wells in Stark and Wayne Counties.

Natural Fracturing

Present, but most observed natural fractures are healed.

Data Availability (logs, cores, tests, etc.)

Variety of ages and qualities of drillers and wireline logs are available.

Table 5. "Clinton"-Medina Sandstone (Albion Group), Eastern Ohio, Appalachian Basin: Engineering parameters.

ENGINEERING PARAMETERS

		Production Rates				
Reservoir Parameters	**Net Pay Thickness**	**Pre-Stimulation**	**Post-Stimulation**	**Decline Rates**	**Formation Fluids**	**Water Saturation**
Porosity: average = 8%; range = 6-12% rarely as low as 3%. Twenty-five values range from 0.011 to 1.63 md and average 0.19 md; however, only 8 of the 25 values were greater than 0.1 md.	Average = 30 ft; range = 9-63 ft.	Usually too small to measure.	For 10 wells, average = 60 Mcf; range = 20-120 Mcf.	No data.	Oil is produced in some areas.	20-35% in reservoirs with 6% porosity.

Well Stimulation Techniques

Hydraulic fracturing. Nitroglycerine "shooting" formerly was common. No detail on present techniques.

Success Ratio

140% increase in discovery well of Canton gas pool.

Well Spacing

Variable; 80 to 100 acres in Perry County, 46 acres in Canton gas pool.

Comments

Trapping mechanisms are stratigraphic.

(Finley, 1982)

Table 6. "Clinton"-Medina Sandstone (Albion Group), Eastern Ohio, Appalachian Basin: Economic factors, operating conditions and extrapolation potential.

ECONOMIC FACTORS

FERC Status	Attempted Completions	Success Ratio	Drilling/ Completion Costs	Market Outlets	Industry Interest
Approved by FERC in all or part of 35 counties in Ohio, including 5 eastern counties which have not yet produced from the "Clinton"-Medina.	Estimated to be 500 oil and gas pools. Over 5,000 wells produce from tight gas sands in Ohio, most of which are from "Clinton"-Medina.	98%--2,405 producers out of 2,459 wells attempted (as of late 1980).	$60,000 in central Ohio to $420,000 at the unit's deepest point in eastern Ohio (drilling cost only).	Many pipelines exist in the area, including those of Columbia Gas of Ohio, Columbia Gas Transmission Corp., Consolidated Gas Supply Corp., East Ohio Gas Co., and National Gas and Oil Corp.	High. 70% of 1981 well completions in Ohio were in the "Clinton"-Medina.

OPERATING CONDITIONS

Physiography	Climatic Conditions	Accessibility
Part of the Appalachian Plateaus physiographic subdivision. Local relief commonly up to 300 ft, greater in some areas.	Humid, temperate. Most drilling operations cease during winter months.	Terrain does not restrict exploration activities.

EXTRAPOLATION POTENTIAL

	Comments
Good. Major fan delta with marginal marine and shallow marine facies extending into Pennsylvania, New York, and West Virginia. Similar facies expected in deeper Tuscarora equivalent to the east in the Appalachian Basin and in the Travis Peak Formation of the East Texas Basin.	All drilling and completion services readily available as a result of existing oil and gas production.

Table 7. "Clinton"-Medina Sandstone (Medina Group), Northwestern Pennsylvania, Appalachian Basin: General attributes and geologic parameters of the trend.

GENERAL ATTRIBUTES

Stratigraphic Unit/Play	Area	Thickness	Depth	Estimated Resource Base	Formation Attitude, other data
"Clinton"-Medina Sandstone, (Medina Group), Northwestern Pennsylvania, Lower Silurian	Primarily 5 counties: Erie, Crawford, Mercer, Venango, and Warren.	Varies from 150 ft to over 200 ft, north to south. The Grimsby Sandstone within the Medina Group varies from 80 to 180 ft across the area.	Top Medina Group: 2,500 ft along Lake Erie to over 7,000 ft in the southeast corner of Venango County.	No data. Not included in review of tight gas sands by National Petroleum Council. Total Medina production in Pennsylvania equaled 45 Bcf at end of 1980.	Regional dip is toward the southeast.

GEOLOGIC PARAMETERS - Basin/Trend

Structural/Tectonic Setting	Thermal Gradient	Pressure Gradient	Stress Regime
In the relatively undeformed Western Basin Province of the Appalachian Basin.	1.2 - 1.7° F/100 ft.	No data.	No specific data. May be weakly compressional.

(Finley, 1982)

Table 8. "Clinton"-Medina Sandstone (Medina Group), Northwestern Pennsylvania, Appalachian Basin: Engineering parameters.

GEOLOGIC PARAMETERS - Unit/Play

Depositional Systems/Facies

Generally deltaic to marginal marine strandplain and shallow marine facies, as indicated for "Clinton"-Medina in Ohio. Recent work implies that the Medina Group in northwestern Pennsylvania is west (seaward) of equivalent marginal marine shoreline facies but exact stratigraphic relationships have not been worked out.

Texture

Grimsby: fine to medium grained, subrounded to subangular, moderately well sorted, interbedded with shale and silty shale.
Whirlpool: fine to medium grained, subangular, moderately well sorted.

Mineralogy

Quartz sandstone; no detailed data.

Diagenesis

Quartz cement in Whirlpool; quartz cement, with some hematite and clay in the Grimsby. No detailed diagenetic studies.

Typical Reservoir Dimensions

In the Grimsby, 80 to 180 ft sandstone thickness with field areas covered by a single well to areas of approximately 375 mi^2.

Pressure/Temperature of Reservoir

Range mostly 700-1,400 psi, but may vary from 50 to 1,885 psi (for 1,155 measurements in 5 counties). Temperature average = 108° F; range = 95-120° F.

Natural Fracturing

Probably present, but contribution to production is not well known and is estimated to be minor.

Data Availability (logs, cores, tests, etc.)

Variety of ages and quality of drillers and wireline logs are available.

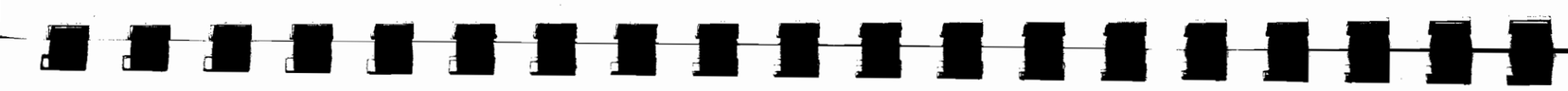

Table 9. "Clinton"-Medina Sandstone (Medina Group), Northwestern Pennsylvania, Appalachian Basin: General attributes and geologic parameters of the trend.

ENGINEERING PARAMETERS

Reservoir Parameters

Porosity: range = 9-12% to the northwest, 6-9% to the southeast. May be as low as 3%.
Permeability: average = 0.050 md; range = 0.0005 to 0.159 md.

Net Pay Thickness

No data.

Production Rates

Pre-Stimulation

Approximately 81% of completions initially had no flow or flow too small to measure.

Post-Stimulation

28% of wells had flow up to 499 Mcfd, 21% of wells had flow up to 999 Mcfd, 30% of wells had flow up to 1,999 Mcfd, and 21% of wells had flow of 2,000 Mcfd or more, based on 1,155 wells.

Decline Rates

No data.

Formation Fluids

Some Medina wells produce water and liquid hydrocarbons; no data on relationship to gas production.

Water Saturation

No data.

Well Stimulation Techniques

Hydraulic fracturing. No detail on techniques.

Success Ratio

Generally successful; see post-stimulation production rates.

Well Spacing

No spacing requirements; variable from 120 to 160 acres in one field.

Comments

Traps are stratigraphic, occurring where sands have greater intergranular porosity.

Table 10. "Clinton"-Medina Sandstone (Medina Group), Northwestern Pennsylvania, Appalachian Basin: Economic factors, operating conditions and extrapolation potential.

ECONOMIC FACTORS

FERC Status	Attempted Completions	Success Ratio	Drilling/ Completion Costs	Market Outlets	Industry Interest
Approved by FERC in Erie, Crawford, Mercer, Venango and Warren Counties, Pennsylvania	Approximately 50 Medina gas pools have been discovered in northwestern Pennsylvania.	88%--1,186 producers out of 1,352 wells attempted (as of late 1980).	$150,000 to $420,000, drilling cost only, depending on depth.	Primarily pipelines of National Fuel Gas Supply Co.; to a lesser extent Consolidated Gas Supply, Peoples Natural Tennessee Gas Pipeline, Diversified Natural Resources and Columbia Gas of Pennsylvania.	High. 100% increase in drilling since tight formation designation in effect. Of 53 new fields or pools discovered in Pennsylvania during 1980, 29 were in the Medina.

OPERATING CONDITIONS

Physiography	Climatic Conditions	Accessibility
Part of the Appalachian Plateaus physiographic subdivision. Local relief commonly up to 300 ft, greater in some areas.	Humid, temperate. Most drilling operations cease during winter months.	Terrain does not restrict exploration activities. Permits required to cut new roads.

EXTRAPOLATION POTENTIAL

	Comments
Good. Major fan delta with marginal marine and shallow marine facies extending into Ohio, New York and West Virginia. Similar facies expected in deeper Tuscarara equivalent to the south and southwest in the Appalachian Basin, and in the Travis Peak Formation of the East Texas Basin.	All drilling and completion services readily available as a result of existing oil and gas production.

Table 11. "Clinton"-Medina Sandstone (Medina Group), Western New York, Appalachian Basin: General attributes and geologic parameters of the trend.

GENERAL ATTRIBUTES

Stratigraphic Unit/Play	Area	Thickness	Depth	Estimated Resource Base	Formation Attitude, other data
"Clinton"-Medina Sandstone (Medina Group), Western New York, Lower Silurian	In western New York in an area of 12 counties: Chautauqua, Cattaraugus, Allegany, Erie, Wyoming, Genesee, Livingston, Ontario, Yates, Seneca, Cayuga and Tompkins.	From 180 ft (southern Chautauqua County) to nearly complete pinch-out in northern Cayuga County for Medina Group. Grimsby Sandstone is thickest (150 ft) in southeastern Allegany County and thins to the west, north, and east.	The top of the Medina Group varies from a depth of 7,000 ft in southeastern Allegany County to outcrop just south of Lake Ontario. Production occurs as shallow as 1,000 ft.	No data. Not included in review of tight gas sands by National Petroleum Council.	Regional dip is southeasterly in the northern counties and southerly in the western part of the area near Lake Erie. Rates of dip average 40-60 ft/mi and may approach 125 ft/mi. Southern Cattaraugus and Allegany Counties are structurally more complex than other areas.

GEOLOGIC PARAMETERS - Basin/Trend

Structural/Tectonic Setting	Thermal Gradient	Pressure Gradient	Stress Regime
Primarily in the relatively undeformed Western Basin Province of the Appalachian Basin. A small part of Cattaraugus County and most of Allegany County is in the Low Plateau Province which is characterized by increased low-relief folding.	1.0-2.1°F/100 ft.	No data.	Mild residual compressive stress associated with Appalachian deformation.

(Finley, 1982)

Table 12. "Clinton"-Medina Sandstone (Medina Group), Western New York, Appalachian Basin: Geologic parameters.

GEOLOGIC PARAMETERS - Unit/Play

Depositional Systems/Facies

Generally westward prograding deltaic to marginal marine strandplain and shallow marine facies, as indicated for "Clinton"-Medina in Ohio. The Whirlpool may be a beach or bar sand and the Grimsby may include distributary channel sands, among other facies, in western New York.

Texture

Grimsby: medium to fine grained, well rounded.

Whirlpool: fine to coarse grained.

Mineralogy

Sandstones are predominantly quartz with some heavy minerals, especially magnetite.

Diagenesis

Both Whirlpool and Grimsby Sandstones are usually quartz cemented and contain only rare calcite cement. The Grimsby contains hematite as grain coatings and interstitial cement.

Typical Reservoir Dimensions

Grimsby Sandstone, the primary producing unit, is 90 to 150 ft thick. Fields contain single producing wells and range up to 120 mi^2 in area.

Pressure/Temperature of Reservoir

Pressure: average = 600 psi; range = 340 to 1,020 psi for 9 wells (not necessarily discovery wells so may be below initial reservoir pressure).

Temperature: up to 100°F in 9 wells (depth not specified).

Natural Fracturing

Probably present, but contribution to production is not well known and is estimated to be minor.

Data Availability (logs, cores, tests, etc.)

Variety of ages and quality of drillers and wireline logs are available.

Table 13. "Clinton"-Medina Sandstone (Medina Group), Western New York, Appalachian Basin: Engineering parameters.

ENGINEERING PARAMETERS

Reservoir Parameters

Porosity: average = 7.1%; range = 2.6-10.1% for unknown number of wells.

Permeability: 0.0455 to 0.087 md for data from 255 wells, probably revised to reflect in situ conditions. Original non-in-situ average value was 0.13 md.

Net Pay Thickness

No data.

Production Rates

Pre-Stimulation

Limited data. 58-6,000 Mcfd range for 4 wells drilled in period 1956-1971.

Post-Stimulation

Limited data. 80-2,700 Mcfd for 14 wells drilled in period 1956-1971. No pre-stimulation flows available for these wells.

Decline Rates

No data.

Formation Fluids

Occasional shows of oil or condensate.

Water Saturation

No data.

Well Stimulation Techniques

Hydraulic fracturing. No detail on techniques.

Success Ratio

No data.

Well Spacing

Variable; as low as 180 acres.

Comments

Traps are stratigraphic, occurring where sands have greater intergranular porosity. Low-relief structures may enhance gas production.

Table 14. "Clinton"-Medina Sandstone (Medina Group), Western New York, Appalachian Basin: Economic factors, operating conditions and extrapolation potential.

ECONOMIC FACTORS

FERC Status	Attempted Completions	Success Ratio	Drilling/ Completion Costs	Market Outlets	Industry Interest
Approved by FERC in Chautauqua and Cattaraugus Counties. Other 10 counties in the area have been applied for.	Approximately 40 Medina pools or fields in western New York.	63% for Medina Group in combination with the underlying Ordovician Queenston Formation (no separate data) (based on 51 wells).	$60,000 to $420,000, drilling cost only, depending on depth.	Medina gas is purchased by Columbia Gas Transmission Corp. and National Fuel Gas Supply Co.	High. Even before the tight formation designation, in 1979, 81% of the gas produced in New York State was from the Medina.

OPERATING CONDITIONS

Physiography	Climatic Conditions	Accessibility
Part of the Appalachian Plateaus and Central Lowland physiographic provinces. Local relief commonly up to 300 ft, greater in some areas.	Humid, temperate. Most drilling operations cease during winter months.	Terrain does not restrict exploration activities. Permits required to cut new roads.

EXTRAPOLATION POTENTIAL

	Comments
Good. Major fan delta with marginal marine and shallow marine facies extending into Pennsylvania, Ohio, and West Virginia. Similar facies expected in deeper Tuscarora equivalent to the south and southwest in the Appalachian Basin, and in the Travis Peak Formation of the East Texas Basin.	All drilling and completion services readily available as a result of existing oil and gas production.

CONCLUSIONS

The Lower Mississippian Berea Sandstone is a wave-dominated delta system including major sand-filled fluvial channel trends, delta front and delta plain facies. It would probably be similar to parts of the Carter Sandstone, Davis Sandstone, and the Olmos Formation and possibly be similar to parts of the Mesaverde Group. The latter statement is speculative, however, since better strandplain development is likely associated with blanket-geometry tight gas sands of the Mesaverde Group. Lack of more detail on depositional systems, on operator interest, and on potential reserves makes assessment of the Berea incomplete relative to potential research interest on the part of GRI.

The "Clinton"-Medina is highly productive from tight gas sands and does not appear to be a stratigraphic unit requiring major research and development efforts to encourage further development. Its eastern equivalent, the Tuscarora Sandstone is not developed and is relatively poorly understood. It seems likely that research and development of a similar fan delta system, such as the Travis Peak Formation, would have beneficial effects on the understanding of the entire "Clinton"-Medina Tuscarora system within the Appalachian Basin.

ACKNOWLEDGMENTS

This work was prepared for CER Corporation, a contractor to the Gas Research Institute, under Contract No. GRI-BEG-SC-111-81, Robert J. Finley, Principal Investigator. The review of the "Clinton"-Medina Sandstone was prepared by Richard J. Diecchio under the direction of Douglas G. Patchen, Chief, Fossil Fuels Division, West Virginia Geological and Economic Survey.

This addendum was compiled as a supplement to the main body of this survey, and was prepared by the same staff of the Bureau of Economic Geology as listed therein. However, all drafting contained in this addendum was originally prepared by the West Virginia Geological and Economic Survey.