COMPILATION OF REGIONAL STRATIGRAPHY AND PRODUCTION TRENDS, "CLINTON" - MEDINA SANDSTONE, APPALACHIAN BASIN

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(Diecchio, 1982)

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(Diecchio, 1982)

1. STRATIGRAPHIC SUMMARY

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 (see Figure 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, which are the most important hydrocarbon reservoirs in the western protion of the basin, are the main topic of interest in this report. Areas of "Clinton" - Medina production are shown in Figure 2. Separate outlines for each of the three states in which these strata are very productive (Ohio, Pennsylvania, and New York) are provided herein.

Lower Silurian stratigraphic nomenclature varies significantly from state to state (see Figure 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" Sanstones 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 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 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 drillers 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 Ordorician 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.

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 the cross sections (Figures 4 and 5), the Lower Silurian clastics are of a blanket nature throughout the basin. In the area of interest in this report, these strata are deltaic and are characterized by shaly strata containing discontinuous, lenticular ("Clinton"-Medina) sand bodies. The "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 it's productive area (see Figure 6). There are 5 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 report. Tight formation submittals are thought to be in the preparation stage for this area.

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b. Appalachian Basin
Northwestern Pennsylvania

1. General Attributes

a. Stratigraphic Unit

Medina Group (Lower Silurian), which is comprised of, in ascending order, the Whirlpool Sandstone, the Cabot Head Shale, and the Grimsby Sandstone. By and large, the Grimsby is usually the productive unit (see Figure 3).

b. Area

Production from the Medina in Pennsylvania is restricted to the northwest corner of the state. The information presented in this section is a summary of the stratigraphy and production characteristics of the Medina Group in the five counties in which this production occurs, namely, Erie, Crawford, Mercer, Venango, and Warren Counties (see Figures 2 and 6).

c. Thickness

The Medina Group in northwestern Pennsylvania ranges in thickness from about 150 feet along Lake Erie to over 200 feet in southern Mercer and Venango Counties (Piotrowski, 1981, plate 4). The Whirlpool Sandstone is zero to 20 feet thick (Piotrowski, 1981, plate 6). The Cabot Head Shale reaches a maximum thickness of over 80 feet in the western portion of the area, and thins to zero in eastern Warren County, (Piotrowski, 1981, plate 7). The Grimsby Sandstone reaches thicknessess of about 180 feet in southwestern Venango County, and thins to less than 80 feet in Erie and Crawford Counties (Piotrowski, 1981, plate 8).

d. Depth

The top of the Medina Group is shallowest (about 2500 feet deep) in the northwest, along Lake Erie, and drops to depths in excess of 7000 feet toward the southeast (southeast corner of Venango County).

e. Estimated Resource Base

The recent classification of the Medina Group in northwestern Pennsylvania as a tight formation should double the total area of Medina fields in Pennsylvania. By the end of 1980 a total of 45 BCF of gas had been produced from the Medina in Pennsylvania. If the above approximation is accurate, one might estimate a

resourse base of about 45 BCF of gas. Since the Medina was classified as tight, drilling activity has increased almost 100% (Harper, 1982).

2. Economic Factors

a. Stratigraphic Unit
Medina Group

b. FERC Status
The Medina Group was classified as a tight formation in Erie, Crawford, Mercer, Venango, and Warren Counties, Pennsylvania, on 30 September, 1981.

c. Number of Fields, Sizes of Fields
There are about 50 Medina gas pools in northwestern Pennsylvania. They range in size from single well pools to multi-pool fields, such as the Conneaut field which covers an area of about 25 miles by 15 miles.

d. Success Ratio
Of the 1352 total wells ever drilled to the Medina (Pennsylvania Oil and Gas Association, 1981), 1186 were completed as producers, a success rate of 88%. In the Pierce field, of the first 60 reported penetrations into the Medina, 56 were successful completions (Kelly and McGlade, 1969). The success rate in this field for the Medina (the Oriskany is also a producer) is therefore 93%.

e. Drilling/Completion Costs
At the current rate of $60/foot, drilling costs would be as high as $420,000 per well in the deeper areas, or as low as $150,000 per well in the shallower areas. These estimates do <u>not</u> include completion costs.

Kelly and McGlade (1969) estimated that when the Pierce field was being drilled (during the 1960's), the average well cost was about $0.275 per MCF of gas produced, including completion costs.

f. Market Outlets
The major utility company operating pipelines in the northwestern five counties of Pennsylvania is National Fuel Gas Supply. Other companies that operate pipelines, but to a much lesser extent, are Consolidated Gas Supply, Peoples Natural, Tennessee Gas Pipeline, Diversified Natural Resources, Columbia Gas of Pennsylvania, and UGI. (Lytle and Balogh, 1977)

g. Industrial Interest
As reported by Patchen et al (1981, Table 12), of the 53 new fields or pools discovered in Pennsylvania during 1980, 29

were in the Medina. This exploratory drilling had taken place before the Medina was classified as tight. Based on this information, industrial interest in the Medina in northwestern Pennsylvania is high.

3. Geologic Parameters-Northwestern Pennsylvania
   a. Structural/Tectonic Setting
      The area under consideration in northwestern Pennsylvania is located west of any prominent structural features associated with the Appalachian orogenies. This area is part of the undeformed, western portion of the Appalachian basin. Regional dip is toward the southeast, toward basin center.

   b. Thermal Gradient
      Thermal Gradient values range from 1.2 to 1.7 ^{0}F/100 ft. in the northwestern portion of Pennsylvania (West Virginia Geological Survey, 1982).

   c. Pressure Gradient
      Information not readily available.

   d. Stress Regime
      Information not readily available.

4. Geologic Parameters-Medina Group
   a. Stratigraphic Unit
      Medina Group.

   b. Depositional Systems/Facies
      The Medina Group in northwestern Pennsylvania was deposited in a deltaic environment that is channel dominated toward the southeast and bar dominated toward the northwest (Piotrowski, 1981). Recent studies of equivalent strata in central Pennsylvania (Tuscarora Sandstone) by Cotter (1982) have shown that marine shelf conditions existed east of the Medina area. This may require a re-evaluation of the environmental interpretation of the Medina Group in Pennsylvania.

   c. Texture
      The lowest formation of the Medina Group, the Whirlpool Sandstone is a medium to fine-grained, subangular, moderately well-sorted, gray to white, moderately well-indurated quartzite (Pennsylvania Oil and Gas Association, 1981).

      The middle unit of the Medina group, the Cabot Head Shale, is a marine, dark green to black shale with siltstone interlaminae (Piotrowski, 1981).

      The upper formation of the Medina group, the Grimsby Sandstone is

a medium to fine-grained, subrounded to subangular, moderately well-sorted, pink and white, moderately well-indurated quartzite that is occasionally hematitic and interbedded with shale and silty shale (Pennsylvania Oil and Gas Association, 1981).

d. Mineralogy
Based on very limited information, the Whirlpool Sandstone is seemingly monomineralic, a silica-cemented quartz sandstone. The Cabot Head Shale is probably comprised of a variety of clay minerals, with interbeds of quartz-rich siltstones. The Grimsby Sandstone is a quartz sandstone that is cemented primarily by silica and hematite, with minor amounts of intergranular calcite and clay.

e. Diagenesis
A detailed diagenetic study of the Medina Group in Pennsylvania has not been done. Both the Whirlpool and the Grimsby are reported as moderately well indurated (Pennsylvania Oil and Gas Association, 1981). One would expect more silica cementation to occur in clean sandstones (such as the Whirlpool) than in sandstones containing hematite and clays (such as the Grimsby).

f. Typical Reservoir Dimensions
The Medina fields of northwestern Pennsylvania range in lateral extent from single producing wells up to about 375 square miles. The Medina Group ranges in thickness from 150 to 200 feet. The Grimsby Sandstone, which is usually the reservoir, ranges from about 80 feet thick in the northwest to about 180 feet thick in the southeast. Although the Grimsby is wedge shaped, thinning toward the northwest, within the area of a given field thickness variations are only on the order of a few tens of feet.

g. Pressure/Temperature of Reservoir
Based on over 1155 measurements taken within the 5 counties, rock pressure ranges from 50 to 1885 PSI, and most values are between 700 and 1400 PSI. Based on data for 15 wells spaced throughout the area, reservoir temperature ranges from 95 to 120^{o}F, with an average value of 107.9^{o}F. (Pennsylvania Oil and Gas Association, 1981)

h. Natural Fracturing
Natural fracturing is probably present, but probably only contributes to production in a minor sense.

i. Data Availability
Data in this report is taken from the references as cited. Data in the form of well cuttings, drillers logs, and wire-line logs

are on file at the Pennsylvania State Geological Survey office in Pittsburgh.

j. Trapping Mechanism
Medina traps in northwestern Pennsylvania are usually stratigraphic. Pools are located where the sands have greater intergranular porosity, presumably due to depositional conditions. Structure does not play an important role in entrapment, but some fracture porosity does occur. (Piotrowski, 1981)

5. Engineering Parameters
a. Stratigraphic Unit
Medina Group

b. Reservoir Parameters
Porosity is primarily intergranular in the Grimsby Sandstone, with minor fracture porosity. Sandstone porosity is greater in the northwest portion of the area (9-12%) and generally lower (6-9%) toward the southeast (Piotrowski, 1981). Porosity is greater than 10% in the Grimsby of the Pierce field (Kelly and McGlade, 1969). Of 15 wells reported by the Pennsylvania Oil and Gas Association (1981), porosity ranged from 3.01% to 9.5%, and average porosity is 5.94%.

Permeability values reported by the Pennsylvania Oil and Gas Association (1981) are contained both in the text and in addenda. If both sources are considered, permeability values reported for 27 wells range from 0.0005 millidarcies to 0.159 md, with an average value of 0.050 md, after fracturing.

It should be mentioned that of the 27 wells reported by the Pennsylvania Oil and Gas Association (1981), only 1 well was in Erie County, where, according to Piotrowski (1981), one might expect to find higher porosity. This single Erie County well (Envirogas, D. Yosten No. 1) does have the second highest of all 27 porosity values (7.58%). The highest value reported (9.5%) is in the Monroe Resources, Max Warner No. 3 well in Warren County. The permeability value reported for the Erie County well (0.0759 md) is not one of the highest values reported, as there are 4 wells in Crawford County with higher values, the highest of which is 0.159 md.

c. Net Pay Thickness
The Grimsby Sandstone, which is usually the pay zone of the Medina Group, ranges in thickness from less than 80 feet in the northwest (along Lake Erie) to over 180 feet in the southeast (southern Venango County). The Grimsby is wedge shaped and becomes thicker towards the southeast. Southeast of the 5 county area included herein, the Grimsby reaches a thickness in excess of 220 feet.

(Diecchio, 1982)

d. Production Rates
The following table summarizes the effect of stimulation on producing wells in the 5 county area of Pennsylvania, as listed by the Pennsylvania Oil and Gas Association (1981). Production date are not available soley for wells that were completed naturally.

production rate (MCF/day)	Natural Open Flow (number of wells)	Flow after Hydrofracturing (number of wells)
none	960	0
1-99	128	60
100-199	16	58
200-299	17	60
300-399	8	86
400-499	5	60
500-999	15	246
1000-1999	15	346
2000-2999	9	114
3000-3999	3	48
4000-4999	5	29
5000 or more	5	48*
	1186 wells	1155 wells

*6 of these produced at a rate in excess of 10,000 MCF/day. Maximum reported value: 15,000 MCF/day.

e. Formation Fluids
Oil and salt water are reported in Medina wells in northwestern Pennsylvania. Salt water is present in minor quantities. Oil is produced at rates as high as 50 barrels/day, after fracturing, in some wells in Crawford County.

f. Water Saturation
Information not available.

g. Bore Hole Shut In Pressure
BHSIP values not available.

h. Well Stimulation Techniques
The enhancement technique used for Medina reservoirs in northwestern Pennsylvania is hydraulic fracturing.

i. Success Ratio
Refer to table in section 5d for hydrofracturing effectiveness.

j. Well Spacing
Pennsylvania has no Medina spacing requirements. A minimum distance of 1320 feet is required to qualify for NGPA Section 103 well classification. There has been no in-fill

(Diecchio, 1982)

drilling, as defined in FERC order 99. (Pennsylvania Oil and Gas Association, 1981)

In the Perce field, although there are no spacing requirements, average well spacing is 1 well every 120 to 160 acres (Kelly and McGlade, 1969).

6. Operating Conditions

a. Stratigraphic Unit
Medina Group

b. Physiography
The 5 counties in northwestern Pennsylvania are contained within the Appalachian Plateaus physiographic province of Fenneman (1946). This province is characterized as a mature dissected plateau of moderate to strong relief. Maximum relief in this area is somewhere on the order of 2000 feet. The terrain poses virtually no restriction to drilling.

c. Climatic Conditions
Climate is humid and temperate. Most drilling operations cease during the winter months.

d. Accessability
Roads can be created, if not existing. Permits to cut roads are necessary and are provided by lease and oil and gas rules and regulations.

e. Extrapolation Potential
All Medina production to date in Pennsylvania is restricted to the 5 counties included herein. There have been about 30 penetrations into the Medina southeast of this area, and of these there has only been about 5 gas shows in the Medina. It could, therefore, be reasonable not to expect much production any great distance beyond (southeast of) these 5 counties in Pennsylvania. The trends included herein may be extrapolated into adjacent portions of Ohio and New York, and possibly beneath Lake Erie and into Ontario.

References for Figures

Figure 1. Thickness and lithofacies of Lower Silurian
Amsden, 1955; Chen, 1977; Dennison, 1980; Dennison and Wheeler, 1975; Yeakel, 1962.

Figure 2. "Clinton" - Medina Fields
Debrosse and Vohwinkel, 1974; Kreidler, 1959, 1963; Kreidler et al, 1972; Piotrowski, 1981; Wilson and Sutton, 1976.

Figure 3. Stratigraphic Terminology
Debrosse and Vohwinkel, 1974; Knight, 1969; Ohio Department of Natural Resources, 1980; Piotrowski, 1981; Richard, 1975.

Figure 4. Generalized Cross Section A-A'
Modified from Heyman, 1977; Well logs as cited.

Figure 5. Generalized Cross Section B-B'
Modified from Horvath et al, 1970.

Figure 6. FERC Status of "Clinton" - Medina
Appalachian Company, 1982; Envirogas/Templeton Energy, 1981; Ohio Department of Natural Resources, 1980; Pennsylvania Oil and Gas Association, 1981.