Recent Oil and Gas Developments on Public Lands in Western New York State

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INTRODUCTION

Three years ago, in response to a directive to either reduce the energy-related expenses of its recreational programs, or curtail recreational services, the New York State Office of Parks, Recreation and Historic Preservation (the Agency) began a program to find alternative resources to replace the energy used in many of its park facilities. The material included in this report is taken primarily from Buttner (1982).

With a staff of some 2500 permanent, professional staff, the Agency administers 146 state parks, 33 state historic sites and 64 state park campsites covering about one-half million acres of land throughout New York State. These lands, and associated facilities, include such diverse components as: nature and bike trails; woodland cabins and camping areas; cross-country ski trails and ski jumps; modern theaters; nature preserves; managed timberlands; historic sites; canal parks; watersheds and dams; coastal barrier islands; inland and coastal marshes; primitive hiking and camping areas; fresh and salt water bathing areas and a geological museum. About 45 million visitors use these facilities each year. Recently the cost of energy associated with the operations and programs available at these facilities has become a significantly large component of the Agency's budget. Since the Agency's operating funds come primarily from taxes, and reduction in energy costs will lessen the need to generate additional tax revenues.

In order to maintain the various recreational and supporting services that the Agency provides to the public, it had to find some method to reduce the energy cost component of those services. In 1979, the Agency instituted a program to gain access to public hydrocarbon resources known to exist beneath several tracts of parklands in central and western New York State. The main objective of this program is to obtain natural gas resources, in lieu of royalty payments, for use in park facilities in place of the oil and LPG purchased each year for those facilities.

Landscapes and terrains are often selected for addition to the State Park System because of their special features and characteristics. Once in the System, the Agency is committed to the protection of such attributes from any subsequent adverse effects. Such effects can result from any use, recreational or administrative, which might be inconsistent with the environmental setting of those lands. A typical, revenue-driven, oil and gas exploration and development program can cause significant changes in the environmental setting of any tract of land. The Agency is committed to an environmentally-sensitive, integrated resource management program with a limited, focused development driven by operational energy requirements. Developed as an environmentally-sensitive, resource management project, the Agency's program provides a strategy to meet some of its present and much of its future energy needs. The project is expected to have a twenty-year, self-sustaining term. The key element of this long-term program is that the Agency will be able to obtain energy for on-site use as part of its royalty payment credit. To date the project has been placed in operation at three locations in western New York State; the field trip will visit two of those locations, plus several other operations on private tracts. Using competitive bidding procedures, which initially produce a one-time, per-acre bonus payment, and then provide either a yearly rental or a royalty payment, the Agency has entered into lease arrangements with private interests for the development of the energy resources from beneath selected tracts.

Oil and gas production is, of course, a profit-making industry; protection of the environmental and of the public-owned surface resource is not the producer's chief concern. Therefore, procedures insuring this protection must be included in the lease, along with penalties for non-performance. Problems with the operation on oil and gas leaseholds involve either the physical aspects of the land or the style of program management. Examples of the physical aspects of an oil and gas program that require attention include: well-site selection; work-site arrangement and size; location and type of access ways and woods roads; the use of fabric roads; erosion and runoff control: timber handling and clearing of woodlands; wildlife displacement; noise; inclement weather during key operations; gas flaring and fires; alteration of slopes for roads and work sites; oil and salt-water spills; misuse of woodlands by subcontractors; valves without locks; blowouts; drilling of service wells; storage tanks and tank heaters; crossing of streams and wetlands by operator's equipment; well-service activities; spacing requirements; informal ancillary equipment; oil-and gas-collection systems; gas-drying stations; handling of muds, salt waters, hydrofracturing chemicals and various toxic materials; and, the use of woodlands to purge garbage, trash and oil-field refuse.

Some important examples of the management aspects of an oil and gas program include: criteria for site selection; overall road and pipeline developments; degree of sunlighting needed per acre; subleases; easements and special use permits; types of rights being exercised; timed performance incentives; rents; terms; delay rental payments; bonus payments; royalty distributions; hydrocarbon types and amounts that leave the leasehold; logging contracts and limited timber sales; windfall profits and other taxes; resource inventory updates; detailed maps, boundaries and monuments; metering of gas and oil produced by each well; formation pressures; pumping rates; turnkey operations; field operations and emergency managers; road building alignment and site flagging; multiple use of roads and woodlands during operations; gates and locks; signs; hard-hat area restrictions; vandalism; constancy of production and market value; administration of trade secrets and confidential data; audit trails for problems; and, scheduling of work on a leasehold in relation to various public recreational activities.

The lease that was developed to deal with such aspects and situations consists of a framework of items common to all leaseholds on parklands together with appropriate tract-specific stipulations. For example, in addition to the usual components, a lease for one tract of parklands limited the maximum number of wells to be allowed on that tract to three. The framework of the general lease developed by Buttner for use throughout the Park System was assembled from the most appropriate parts of sample leases used by various state and federal agencies and other organizations. Into this framework was inserted a group of special provisions to provide long-term environmental safeguards for public parklands.

This lease requires the Agency to maintain an on-going analysis of the environmental effects of any oil and gas activity on the tract throughout the tenure of a program. This approach to the consideration of environmental aspects throughout the life of a project is distinguished from the usual one-time, environmental-impact review that is done prior to the start of a project. The lease also provides for changes over time in the direction and emphasis of the program.

In order to assure that maximum attention is given to environmental considerations at all phases of each exploration and development program, it is managed through the Office of the Agency's Director of Environmental Management. All bidding procedures, title search work and other related activities are conducted by the Office of General Services, as Administrator. The Division of Land Utilization, Office of General Services under provisions of Subdivision 4a of Section 3 of the Public Lands Law may lease to the highest bidder an interest in real property included, but not limited to; air rights, subterranean rights, etc., when such interests are not needed for present public use. This coordinated effort between an operating agency (Parks) and a service agency (General Services) has produced an especially comprehensive management scheme.

As noted previously, the operation of an oil and gas program on public lands can cause disturbance and modification of both the surface and the subsurface resources. In order to control and limit the effects of such programs on those resources, a set of rules, regulations and policies based on reasonable standards and procedures was developed. These guidelines had to be rigorous enough to control and limit operations yet not so constraining as to discourage private enterprise from investing in an exploration and development program on public lands. A leasehold owner will only invest in drilling and operating an oil or gas well if there is some chance that a reasonable profit will be obtained. Land managers who need to satisfy on-site energy requirements should also appreciate the profit considerations; the greater the profit to the investor, the more royalty energy will be available to the landowner-lessor. As energy resources are depleted and potential reserves become more valuable, managers of public lands will be subjected to increased pressure from both public and private interests.

OIL AND GAS HISTORY IN WESTERN NEW YORK

The oil springs of southwestern New York State were noted by a French missionary in 1627. These springs were located near the present border between Allegany and Cattaraugus Counties. By the late 1800's oil and gas exploration and development programs had developed into a vigorous industry in the region. Although not a major supplier of oil and gas, New York has produced approximately one-quarter to one-third of a billion barrels of oil and perhaps 180 billion cubic feet of natural gas during the last eighty years. In 1980, about 15.65 billion cubic feet of natural gas, valued at $29 million at the wellhead, and about 824,000 barrels of oil, with a wellhead value of $30.8 million, were produced by some 7500 wells in New York State.

The first producing gas well in New York State was drilled by William A. Hart at Fredonia, Chautauqua County in 1821. From this 70-foot deep well, Mr. Hart produced gas for the lamps of Fredonia, the first village to be illuminated by natural gas in the United States. In 1865, six years after the first oil-producing well was developed by Drake at Titusville, Pennsylvania, Job Moses completed the first commercial oil well in New York State in what is now Allegany State Park in Carrollton Township, Cattaraugus County.

Over the last hundred years, the oil-and gas-bearing rocks of western New York have been tapped by more than thirty thousand producing wells. Some of these wells continue to produce oil and gas while others have been abandoned once the easy-to-get hydrocarbons were removed. This primary production of easy-flowing hydrocarbons usually represented as little as 1/5 of the total amount of oil and gas trapped in the rock. This means that 4/5 of the once available original hydrocarbons might still reside in the rocks beneath some of the abandoned well sites.

This drilling, draining and abandoning activity was especially intense in the region that now contains Allegany State Park. Prior to the establishment of the Park, large tracts of its present acreage had been subjected to some rather intense and varied land use forces. Some of these tracts had been homesteaded and farmed, then abandoned; then opened and leased with a pattern of oil and gas wells with connecting pipelines, railroads and other scars of the day; later clearcut to produce raw materials for a variety of forest products that were manufactured by on-site factories; and finally, some of the tracts were set on fire and burned by both natural and other forces.

In the public parklands of central and western New York State, the Agency has discovered more than 250 abandoned drill holes of which 4/5 are located in Allegany State Park. Most of these well holes were abandoned with their lining of steel casing still in place, but, as the need for steel increased during World War II, many of the casings were scavanged. In a few years time, the surface of any abandoned well and well site becomes covered by forest litter, and abandoned wells are very difficult to locate. Beneath the surface cover, the inside walls collapse and soon a small cavern is formed. Developed to this stage, such abandoned, uncased well holes present a continuing hazard to people and animals and to the quality of the ground water and shallow aquifers. Such open conduits also allow valuable subsurface hydrocarbons to escape to the surface thus reducing reservoir pressures. The Agency has developed the equipment and a low-cost methodology that is technically adequate, to plug such abandoned and uncased wells. As new sites are discovered, these methods are used to plug any abandoned wells found at the site. The Agency's leasing program provides substantial protection to control such abandoned wells.

In general, significant oil and gas production in New York State thus far has included discoveries in Chautauqua, Cattaraugus, Allegany and Steuben Counties. These New York Counties directly adjoin the oil- and gas-rich area of northwestern Pennsylvania that includes both the Titusville and Bradford districts. Since political boundaries are transparent to the subsurface oil-and gas-containing rocks of this southwestern New York-northwestern Pennsylvania area, similar exploration and development techniques are used throughout the region. However, the oil and gas industry is regulated somewhat differently by each state.

The oil and gas producing companies operating in the region are small-to-medium-sized firms rather than the large, major oil-and gas-producing companies with world-wide interests. The availability of a well-developed, local oil and gas industry is especially useful to a land manager that is considering an exploration and development program. These development programs are usually based on a leasing arrangement between the administrator of such public lands, as lessor, and the private entity or operator that proposes to explore for and develop the hydrocarbon potential of those lands, as lessee. Each participant, lessor and lessee, has rights, privileges and responsibilities under such leasing agreements.

The concept of an oil and gas lease interest will be new to most students, some geologists and many land managers. A hydrocarbon exploration and development program is a capital-intensive, high-risk activity. In 1982 it costs about $100,000 to drill and complete for production 1500-foot deep gas well in New York State. It costs about half that amount if the well turns out to be a "dry hole". A dry hole is a well that either showed no hydrocarbons or else will not produce hydrocarbons at a rate that is presently economically feasible. (As market conditions become favorable, some dry holes may be re-worked and brought into production using various flow stimulation techniques.)

In order to assemble adequate funding for such exploration and development programs, a partnership is sometimes formed in order to finance both the purchase of leases and the drilling of one or more exploratory wells. Such oil and gas partnerships usually contain one or more general partners and a group of limited partners. For a fee, the general partners supply initial capital, management services, technical expertise, and, in some cases, the leases themselves. The general partners have full and exclusive discretion concerning the management and operations of the program; it is the general partner who will be directly responsible to land managers for maintenance of performance standards. The limited partners supply working capital for the program in exchange for a return of their investment plus a share of the profit after all expenses are paid. The point at which limited partners recover their full investment is called payout.

Although many kinds of financial arrangements are used in the oil and gas business, there are three main types of partial interest in oil and gas programs that should be understood. Usually when a tract of land is leased for an oil and gas exploration and development program, the landowner receives, in addition to other payments, a royalty interest in the program. This royalty interest is typically a one-eighth fractional share of the value of any hydrocarbons produced during the tenure of the program. The lessor's royalty interest is split from the production exclusive of the burden of any operating expenses whatsoever. It is this royalty interest that is designated by the lease to be made available for on-site use to support the Agency's recreational programs.

The remaining seven-eighths of the production forms the working interest and all expenses of the program are paid out of this interest. In order to entice investors to participate in an oil and gas program, the operator often sells off one or more fractional parts of the working interest. These fractional interests, generally called overriding royalty interests, are carved out of the working interest and are free of all operating costs. In some cases, in order to finance other ventures, the original operator might sell off any remaining working interest he holds in the program, sometimes retaining only a small overriding royalty interest in the venture. As with other interests, overriding royalty interests may be assigned and traded at any time during the term of the program's lease. In order to attract more investment capital, the operator of a lease might place news items in various newspapers and trade journals concerning the success of the program. Such publicity will call attention to the oil and gas exploration and development programs.

HABITAT OF OIL AND GAS

Crude oil and natural gas are hydrocarbon by-products of the decomposition of organic matter like that which accumulates today in freshwater and marine wetlands, shallow seas and other bodies of water. Most of these naturally-occurring deposits of oil and gas are at least one-half million years old; many deposits are as much as 400 million years old.

As organic sediment accumulates and is buried beneath successive layers of younger material, various organic and inorganic transformations take place. The processes involved, encouraged by the elevated temperatures and pressures associated with deep burial, convert the organic sediment into various types of hydrocarbon-rich deposits. Depending upon the type and volume of the original sediment, and the rates and scales with which the end result could be oil shale, coal, tar, oil, gas, graphite or a combination of by-products.

When deposited, the sediment source consists of a framework of grains and pore spaces. The grains are the larger pieces of organic matter and other debris while the pore spaces between grains will contain original fluids and finer organic debris. This sediment has two important, fundamental properties: the initial port space or porosity and the amount of connected pore space through which fluids can move called permeability. As the sediment is compressed and converted to rock and hydrocarbons, the pore space may be almost eliminated and the more mobile forms of hydrocarbons, driven by other pore fluids, may migrate from the source rocks to other rock units which have available porosity and permeability. Gradually, over long periods of time, the concentration of hydrocarbons in the host rock becomes significant and such rocks become reservoirs or pools of hydrocarbons.

The term trap may be applied to some types of subsurface features. A trap is a physical deterrent which limits the migration of the hydrocarbons from the host rock. In essence, a trap exists where a bubble of fluid or gas can not escape to the surface forming a pool. A field may consist of one or more reservoir pools. The important characteristics of reservoirs are: structure; texture and composition of the host rock; thickness and form; depth below the surface; porosity and permeability; character of the hydrocarbons; the variability of the properties of the host rock; and the relationship of the trapping mechanism to local and regional geological features. The lessee operator will usually hire a consultant geologist to evaluate the reservoir and the land owner may be able to receive copies of all reports and analysis.

Crude oil is measured in barrels, each of which contains 42 gallons. A barrel of oil produced from wells in the southwestern New York - northwestern Pennsylvania region can be expected, on the average, to yield: 12.5 gallons of gasoline; 9 gallons of distillate fuels; 11.5 gallons of lubricating oils; 1 gallon of wax; 7.5 gallons of residual fuels; and about .5 gallons of refinery waste.

The main types of wells that may be drilled on a leasehold include:

1. <u>New Field Wildcat Wells</u> - These are wells drilled on a geologic feature or in an area which had never before produced oil or gas. In 1980, thirty such wells were drilled in New York State; fifteen found gas and fifteen were judged to be dry holes. Obviously, such ventures can have the lowest probability of success. If a tract of land has never been associated with any oil or gas production, then land owners might find it especially difficult to entice commercial exploration.

2. <u>New Pool Wildcat Well</u> - This is a test well drilled outside the limits of a proven area or pool but in a geological area already productive. Depending upon the habitat of the hydrocarbons of the area, this type of wildcat well can be a less risky venture than the new field wildcats.

3. Deeper and Shallower-Pool Test Wells - These wells are drilled in an attempt to locate either deeper or shallower hydrocarbon resources inside the limits of an area or pool previously proven productive. If successful, such wells can increase the density of production from a particular leased tract.

4. Outpost or Extension Test Wells - These wells are drilled to test for possible distant extensions of a producing pool. Where existing programs have developed outside and close to land boundaries, such types of wells might be the first types considered by a leaseholder. Most of the recent successful oil and gas drilling programs in the northeastern United States has resulted from the extension of known producing fields or pools.

5. Development Wells - These wells are drilled to develop the production of a hydrocarbon field or pool. The growth of a development well field can be a function of many factors such as: state and other regulations; depth of the producing horizon; primary or secondary production; the ease with which the hydrocarbons can be brought to the surface; the complexity of the subsurface geology; the type of hydrocarbons being produced; the market value of the produced oil and/or gas; the availability of capital, equipment, product delivery systems and product purchase contracts; the optimum versus regulated spacing of wells; the availability of well sites on the surface; any stipulations that might be a part of the operator's lease with the landowner; and, other limiting or encouraging factors. As specified in the Agency's standard lease, all drilling plans must be approved prior to their use on park lands. This lease permits adjustment of the plans, well-site locations and well density based on the environmental characteristics of the terrain. In the southwestern New York region most of the active oil fields are between 500 and 2500 feet in depth and the spacing can be as tight as one well per ten acres. The producing gas wells of the region are usually from 2000 to 4000 feet deep and spaced about 1500 feet apart. In addition, wells are excluded from a corridor 660 feet wide inside, and parallel to, property boundaries in some fields.

6. Stratigraphic Test Wells - These wells are drilled to acquire information about the character of the subsurface. They are logged in detail, and carefully studied and evaluated, but they are not drilled for production. Land owners might have to provide a site and the ancillary operational features for such test wells. Since such test wells will provide no direct royalty-derived energy, land owners must consider requests to drill such wells carefully.

7. Service Wells - These wells are drilled to support the production program in an existing producing field. This may be used to stimulate production by injecting into the reservoir various substances such as water, steam, gases, detergents and other fluidizers. Such stimulated production is usually termed secondary production to distinguish it from the more easily obtained primary production.

Land owners must realize that leasing operations are long-term agreements which are extended by various stipulations in the lease. Although there are a variety of leasing arrangements, such agreements usually have a primary term of perhaps ten years that is then followed by a minimum secondary term of an additional ten years. Primary and secondary terms of a lease are not necessarily related to the primary and secondary production history of an oil or gas field. Some oil fields are extremely long-lived and have produced for a hundred or more years. One such field in southwestern New York has produced more than 150 million barrels of oil since first discovered about 100 years ago.

Applied secondary production technology can significantly enhance the overall production of an oil-producing region. The primary oil production of Allegany and Cattaraugus counties was about 80 million barrels over 70 years; secondary production techniques have nearly tripled the total production to some 230 million barrels of oil. It is expected that the oil-producing reservoirs involved still contain almost 14 times as much oil as the yield of primary production. Long-term land use and facility development planning by public land managers and other land owners must recognize the possibility of extended production on leased lands.

A COMPOSITE TEST WELL

Most oil and gas drilling is done to test the oil and gas potential of relatively shallow "pay" horizons. A typical gas well might extend 1,500 feet below the surface and cost between fifty and one-hundred thousand dollars. The drilling and completion of a typical gas well involves many complex operations but might be generalized as follows:

1. An 8" diameter "pilot" hole is drilled by cable-tool (impact) methods to a depth of about 150 feet. This "pilot" hole is then cased with a steel casing pipe of 7" diameter, and cement is placed in the annulus between the outside of the casing and the rock wall. This depth may vary from site to site, but an important benefit of this segment of the well is that near surface ground water is kept from flowing into the hole. This part of the work could take seven days to complete.

2. Next, a 6" diameter hole is drilled by rotary drill from the base of the pilot hole to perhaps 1,400' below the surface. A rotary drill takes about two days to drill 1,250 feet. The hole may then be cleaned and a log made of the rock types encountered. Then the well is encased with pipe of 4½" diameter and this tube is cemented to the rock.

3. The rock types encountered by the drill may then be logged again by using a special logging probe. These logs will give some indication as to where the "pay" horizon(s) might be found. A perforator is then placed in the casing, lowered to the "pay" horizon and activated. This device blows holes in the steel pipe, through the cement, and into the surrounding rock at the "pay" horizon.

4. Typically, the well is then hydrofractured to stimulate the flow of gas from the surrounding host rock to the well site. This process takes a few hours and involves the injection of a mixture of liquid nitrogen, surficant and sand under some 2,800 lbs. of pressure into the well and out into the surrounding rock for some 500 feet in all

directions. After this process, the gas pressure at the wellhead will be between 300 and 1,000 lbs. per square inch, typically.

5. A 1" diameter pipe is installed within the 4½" diameter casing, from surface to bottom, to allow any water that accumulates in the pipe (usually salt water) to be removed at the surface.

6. The various pipes, valves and a buried, marked plastic transmission line are then installed and natural gas is permitted to flow from the well to an on-site meter.

7. The site is restored and the surface piping, which would probably fill the area of the inside of a compact car, is fenced and signed.

OWNERSHIP PATTERNS OF OIL AND GAS RIGHTS ON PUBLIC LANDS IN NEW YORK STATE

In western and central New York State most of the lands now a part of the State Park System were tested by the wildcatter's drill bit for oil and gas resources prior to the acquisition of those lands into the system. This testing, and in some cases extensive development, was financed and conducted by private interests. Those private interests either owned, or else obtained through a lease arrangement the rights to explore for and remove any oil or gas from beneath the lands involved. Most likely, these oil and gas rights were obtained initially from the surface land owner. In New York State, an "ownership" state, a land owner may have obtained the oil and gas rights when the land was acquired. In some other states, subsurface oil resources belong to the landowner only after they are possessed via pumping.

In such ownership states as New York and Pennsylvania, subsurface oil and gas rights may be separated from the ownership and title of the surface. In some cases, as the lands of western and central New York changed ownership over the years, the subsurface oil and gas rights were carried along with the title to the land. As some of those lands were acquired for the Park System (except where the oil and gas rights were reserved by the owner) the public gained ownership of any subsurface hydrocarbons. However, in those cases where the drill bit had proven previously that the subsurface rights had some value, those rights were excepted and separated from the title and, in many instances, sold, traded or leased independent of surface ownership and use.

Managers of public lands and other land owners in ownership states will encounter two main forms of non-public rights: reserved and excepted. Reserved rights are usually easy to determine; they appear in the deed as part of the process which transferred the land to public ownership. Excepted rights were separated from the ownership of the land prior to the existing deed. Excepted oil and gas rights are almost always a problem to unravel and authenticate. One of the major efforts of the Office of General Services, as Administrator for the Agency's leasing program, has been to search the titles of all lands where oil and gas rights were excepted from public parklands prior to their acquisition. Such effort requires dedicated and professional "detective" work, and managers of public land and other land owners generally will need such services.

With the increased interest in New York State's oil and gas resources, there have been many exchanges of the private ownership of both excepted and reserved rights to the oil and gas resources beneath public lands. In more than a few cases such rights have been split into various arrangements of vertical, horizontal, time-related, resource-related and rock-type-related patterns. This often results in many entities having various levels of royalty interest in a single tract. The exercise by private entities of such excepted and reserved oil and gas rights on public parklands can take place at any time, and must be a concern of both the public and the managers of such lands. In western New York State, some 36,000 acres of the Park System have oil and gas exceptions and reservations. The exercise of such rights within the 700,000 acres, Allegheny National Forest of western Pennsylvania has caused significant disruption of that composite of public lands and private inholdings. Part of the National Forest adjoins New York's 64,000 acre Allegany State Park. Many of the oil-and gas-rich rocks that made the Bradford, Pennsylvania area a famous "oil patch", extend northwestward beneath both the National Forest and Allegany State Park. As a result, the subsurface oil and gas rights to some 92% of the Forest were long ago acquired by private interests and many tracts are now in various stages of development. (The situation at Allegany State Park will be discussed later.) The Forest Service has documented its experience with oil-and gas-rights management in a comprehensive handbook. Public land managers and other land owners should review the Service's handbook and associated materials. Note that the Forest Service is concerned primarily with the management of private oil and gas programs on public lands while the State Park System, although concerned primarily with the management of a public-sponsored leasing program conducted by private operators, is also involved in the management of private-sponsored programs on public lands.

Where subsurface rights are held by other than the surface land owner, that owner must recognize those rights. When oil and gas rights are held, the owner of those rights has a just claim or privilege to move on to the surface land and operate a hydrocarbon exploration and development program. These rights apply to activities on specific tracts, but they are not exclusive rights to surface use nor do they provide any general privileges on adjacent or proximal tracts where no rights are held. Because of this, any geological or geophysical studies, surveys, mapping, tests or other programs that are proposed by private entities to be conducted on public lands should have prior approval of the agency that manages the lands for the public. The reason for this is that there often exists a mixture of public and private interests to oil and gas rights on some public lands. Such programs could violate certain rights of those interests. Such approval is now needed for any programs which would use State Park roads, woodlands, lakes, islands and coastal zones.

Both the operator and the landowner have equal responsibility to consider and reasonably accommodate each other's interest and stewardship. Capricious, irresponsible or otherwise improper actions by either party are inconsistent with the rights, privileges and responsibilities of each party. It is the policy of the State Park System to apply the same general standards and procedures to all operators of oil and gas programs on public parklands, be they operators on state-leased tracts or operators on tracts via reserved or excepted rights. This policy is based on Agency's experience with both types of operators over the last several years.

For example, the future of present surface features of some 40% of the public lands within Allegany State Park (there are some private lands within the legal Park boundaries), are of special concern. The subsurface oil and gas rights of some of these public lands are held by private interests, and, with the increased value of oil and gas, those rights can be expected to be exercised at any time. The tracts involved, although concentrated in the southeast quarter of Allegany, are spread almost like a "crazyquilt" throughout the entire park. These rights are now far too expensive to be purchased by the public. Using a comprehensive lease as a management framework, the Agency has better control over how the public's surface lands will be treated by these private oil and gas interests. The Agency's oil and gas operation has provided experience with a public-sponsored program on certain tracts that have been valuable in managing similar, private-sponsored programs on its other lands.

As excepted and reserved rights are uncovered and authenticated, land managers and other land owners may wish to evaluate and classify each prospect. Once classified, it is then possible to estimate the thresholds for various factors that will cause such prospect tracts to be candidates for private oil and gas programs. Since excepted and reserved rights may be exercised at any time, independent of the plans and control of any entity or public agency that holds the surface rights, such evaluations are important. The indicator factors that one of the authors (Buttner, 1982) has used to develop such a classification system include:

1. Chain of Title - Is it distinct or diffuse? Are the rights excepted or reserved?

2. Operations - Were there previously, or are there now, oil and gas operations on the tract, on neighboring tracts or in hydrocarbon-bearing rock units or rock types which occur beneath the tract?

3. Resource Potential - Given the overall setting and regional production history, is it likely that the resource potential will be low, moderate or high?

4. Interest in the Tract - Have there been inquiries concerning the tract? Have programs that involve the tract been described in trade papers and journals? Are academic and/or industrial workers engaged in research that involves the tract?

5. Applications - Have applications for drilling regulatory agencies? (By agreement with the New York State department that

regulates well drilling, all applications for permits to drill on lands in the State Park System must first be approved by the Agency's Manager of the Oil and Gas Program.)

6. Proximal Transmission and REfining Facilities - Is the tract traversed by, or reasonably near, a natural gas transmission line? How far are the nearest refining facilities and, if pipelines are not used, can oil collection trucks reach any oil producing wells that might be operated on the tract?

7. Existing Road Systems - Are there any existing road systems, either external to, or within the tract, which might reduce road building and maintenance costs?

8. Terrain Characteristics - Are there unusual features of the tract such as special wood lots, perched bogs, eagle nesting areas, endangered species, steep slopes, earthquake hazards, extensive wetlands, nature study areas, unusual wildlife, ski jumps, beaver colonies, bike trails or other features that would conflict with oil and gas operations?

9. Extension or New Pool Possibilities - Is there some possibility that the tract might be a candidate site for either an extension well or a new pool wildcat?

10. Seismic Survey Activity - Have there been recent seismic surveys on private lands in proximity to the tract? Has there been a request by the subsurface-rights owner to conduct seismic or other studies on the tract?

11. Change in Ownership Patterns - Have changes in oil and gas rights or the purchase of the leasing privileges to exercise those rights taken place? Are these rights being assembled by a single entity?

12. Market Sensitivity - Given that there is a potential for oil and gas development to take place on the tract, how sensitive to market fluctuations are such operations and plans?

13. Overall Candidacy Rating - What is the overall rating for this tract given its characterization based on the above indicator factors?

Usually an operator, either leaseholder or rights holder, will contract for the various services needed to drill, test and complete wells, conduct various seismic and other studies, perform any well stimulation and hydrofracturing work that might be required, and provide a variety of other special well field services. It is important that land managers and other land owners require that all operators on public lands inform any contractors or subcontractors of the need to precisely conform with various provisions of any oil and gas management programs.

Access to a tract that is scheduled for development can be a particular problem for land managers. The Agency's program requires that the primary access to any tract of parklands be via existing park entrance roads and then continued, as necessary, via approved woodland roads and corridors. Otherwise the public parklands will end up with a maze or privately-controlled, informal entrances.

SUMMARY

This report provides guidance for those who are either considering, or expect to be required to consider, initiatives for the siting of oil and gas programs on the lands they manage or own. Such initiatives can be grouped into three types of situations. One type of situation involves the development of a landowner-sponsored proposal for the establishment of an oil and gas exploration and development program on public land. Following competitive bidding procedures, a lease is awarded to an operator-lessee to conduct a long-term, landowner-supervised, environmentally-sensitive oil and gas program on a tract of public land. In return for the grant of this privilege, the landowner-lessor receives various payments together with a royalty interest in any oil and gas produced from the tract. This fractional interest is exclusive of the burden of any production expenses and is taken by the landowner in the form of energy from the wellhead. Such free energy, usually natural gas, is used to replace some or all of the higher-priced energy purchased by the landowner to support various on-site programs, activities, services and facilities. In some jurisdictions, it may also be possible to use excess royalty payments to support other types of expenses.

A second type of situation arises when a non-public entity proposes to exercise the rights it holds for the exploration and extraction of any oil and/or gas beneath a tract of land presently in public ownership. Because of the capital-intensive, high-risk nature of the oil and gas business, such ventures will usually result in revenue-driven programs that include maximum technical development. Unless specifically negotiated in exchanged for some privilege, the public land owner has no right to any form of production-related compensation. Such privilege might include the right-of-way for a transmission pipeline which crosses public lands outside the tract under development, for example. Likewise, the landowner can not exercise the same level of control and supervision of activities on this tract as would be possible on a land owner-leased tract. Any powers the land owner exercises are derived from the land owner's responsibility to the public as the caretaker-steward of the land, of its natural resources, and of its recreational attributes. The land owner can only guide the activities of private enterprise on public land. Working with the private interests, the landowner can usually coordinate plans for such things as: roadway alignments; woodland rights-of-way; informal trails and work zones; timber cutting and management; erosion control and slope improvement; wildlife habitat enhancement; and the protection of special habitats. The exercise of private rights on public lands is an intrusion into the public's use of such lands. If such intrusions are possible, then managers of public lands and other interested parties must carefully prepare for them; to be caught without a plan of action will surely place a hardship upon the land.

The third type of situation combines a public land owner-sponsored, requirement-driven program with one or more private rights-sponsored, revenue-driven programs. Experience with a leasing program provides a keen basis for the active coordination and firmest control of any private program.

The field trip will attempt to show as many different types of oil and gas operations as possible by visiting a mixture of operations taking place on public and private tracts. Since it is impossible to forecast where these operations will be at the time of preparation of this report, the field trip itinerary will be provided to all participants on the day of the trip. Well logs, core and other materials will be available for discussion and examination.

In general, the trip will visit the Medina gas fields, the Allegany gas storage fields and various western oil and gas developments. We have provided a review of the stratigraphic units of western New York, some of which may be examined in the field and in various logs.

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As mentioned previously, in order to allow for flexibility in the selection of work sites and on-going field operations in October, a detailed road log and site descriptions can not be published with this article; an itinerary will be provided each participant. It is expected that the field trip will visit tracts under various stages of development. We would like to thank the following owners/operators for their support and cooperation: Abaterra Energy; Alden-Aurora Gas Company; Bowman Development Company; Clover Oil and Gas Company; Elcoex; Felmont Oil Corporation; H.L. Murry; National Fuel Gas Supply Corporation; N.Y.S. Natural Gas Corporation; Saxtet Energy; Summit Petroleum Corporation; U.S. Gold Corporation; WITCO Chemical; and, any others that might provide assistance.

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COMPOSITE PALEOZOIC STRATIGRAPHIC SECTION

FOR SOUTHWESTERN NEW YORK

PERIOD		GROUP	UNIT	THICKNESS	PRODUCTION
Penn.		POTTSVILLE	OLEAN Ss, Cgl	75-100'	
Miss.		POCONO	KNAPP Ss, Cgl	50-100'	
DEVONIAN	UPPER	CONEWANGO	Sh, Ss, Cgl	700'	
		CONNEAUT	CHADAKOIN Sh, Ss	700'	
		CANADAWAY	UNDIFF. † Sh, Ss	1100-1400'	Oil, Gas
			PERRYSBURG# Sh, Ss		Oil, Gas
		WEST FALLS	JAVA NUNDA Sh, Ss RHINESTREET	375-1250'	Oil, Gas
		SONYEA	MIDDLESEX Sh	0-400'	Gas
		GENESEE	Sh	0-450'	
	?		TULLY Ls	0-50'	Gas
	? MIDDLE	HAMILTON	MOSCOW Sh LUDLOWVILLE Sh SKANEATELES Sh MARCELLUS Sh	200-600'	Gas
			ONONDAGA Ls	30-235'	Gas, Oil
	LOWER	TRISTATES	ORISKANY Ss	0-40'	Gas
		HELDERBERG	MANLIUS Ls RONDOUT Dol	0-10'	
SILURIAN	UPPER		AKRON Dol	0-15'	Gas
		SALINA	CAMILLUS Sh, Gyp. SYRACUSE Dol, Sh, Salt VERNON Sh, Salt	450-1850'	
		LOCKPORT	LOCKPORT Dol	150-250'	Gas
		CLINTON	ROCHESTER Sh IRONDEQUOIT Ls	125'	
	LOWER		SODUS Sh REYNALES Ls THOROLD Ss	75' 2-8'	
		MEDINA	GRIMSBY Sh, Ss WHIRLPOOL Ss	75-160' 0-25'	Gas Gas
ORDOVICIAN	UPPER		QUEENSTON Sh OSWEGO Ss	1100-1500'	Gas
			LORRAINE Sh UTICA Sh	900-1000'	
	MIDDLE	TRENTON-BLACK RIVER	TRENTON Ls BLACK RIVER Ls	425-625' 225-550'	Gas
	LOWER	BEEKMAN-TOWN	TRIBES HILL-CHUCTANUNDA Ls	0-550'	
CAM-BRIAN	UPPER		LITTLE FALLS Dol	0-350'	
			GALWAY (THERESA) Dol, Ss	575-1350'	Gas
			POTSDAM Ss, Dol	75-500'	Gas
PRECAMBRIAN			GNEISS, MARBLE, QUARTZITE, etc		

STRATIGRAPHY

The lower Paleozoic strata in this region vary in thickness from 6000 feet near Lake Erie to over 12,000 feet in Allegany County, near the Pennsylvania border. They cover a time span from upper Cambrian to Pennsylvanian - about 200 million years. While most of the region is a southward dipping homocline, in the subsurface there are gentle NW-SE trending folds that plunge to the southwest. These are sometimes offset by reverse faults associated with doming anticlines that are related to deep seated thrusting - sometimes producing gas traps along the anticlines (Van Tyne and Foster, 1979).

The stratigraphic units described on the following pages represent a generalized section for Chautauqua, Cattaraugus and Allegany Counties, and are based on the correlations of Rickard (1975) with general descriptions compiled from various other sources.

STRATIGRAPHIC UNITS

There may be some gas potential in nearly all of the Paleozoic section. It begins with the Upper Cambrian dolomitic Theresa Sandstone which, near the Pennsylvania border, occurs about 11, 750 feet beneath the surface (Fisher, 1966). These sandstones are unconformably overlain by Middle Ordovician gray dolomitic limestones, over 700 feet thick, that form the Trenton and Black River Groups, and the Utica black shale - another 130-250 feet of strata. There are also some gas occurrences in the Upper Ordovician quartz siltstones and fine-grained sandstones of the Lorraine Group (550-700 feet), the Oswego Sandstone (100-650 feet) and the Queenston Formation (700-1000 feet). Though the Queenston appears as a fine-grained maroon shale near the surface, it becomes much sandier southward in the subsurface. Yet most of the oil-gas potential occurs in the younger strata above this sequence (Van Tyne, 1974), and these units will be briefly discussed on the following pages:

Lower Silurian-Medina Group (Vanuxem, 1837).

Though the Medina Group is a relatively thin sequence, the abundance of well-sorted sandstones with subordinate shales and the near absence of limestones and carbonate cement make it the principal reservoir for natural gas in this region (Fisher, 1966). The gas occurs only in certain units or facies of certain units, indicating that lateral changes in porosity and permeability are the chief factors controlling gas migration. Oil production potential is considered insignificant (Van Tyne, 1974). The important units are:

WHIRLPOOL FORMATION ("White Medina" of drillers).

Lithology: A white-light gray pure (95%) Quartz sandstone, medium-coarse grained, with well rounded and frosted surfaces embedded in quartz cement. The unit is medium-to thick bedded and planar cross-bedded and is unfossiliferous.

Thickness: 8 to 15 feet, increasing to 25 feet eastward toward Rochester, but it is absent east of Springville (Fisher, 1954).

Contact Relations: Forms a sharp disconformable contact with the maroon-red sandstones of the Upper Ordovician Queenston Formation, frequently with the presence of mudcracks (Fisher, 1966); forms a sharp but conformable upper contact with the gray, thin-bedded siltstones of the Grimsby eastward or dark gray shales and calcareous siltstones of the Power Glen Formation westward.

Age: Niagaran Series

Environment: Aeolian dunes and beach environment of Queenston-Juniata delta complex that was reworked into supratidal shoals and sandflats by transgressing seas.

POWER GLEN FORMATION

Lithology: A series of interbedded gray shale and siltstones becoming green-gray in the upper third of the unit. As with the Whirlpool Sandstone, the coarsest deposits are in the center of the unit. It grades westward into the Manitoulin Dolostone, and contains abundant pelecypods and brachiopods.

Thickness: It is 50 feet in Niagara Gorge and thins eastward and disappears near Gasport where the Grimsby overlies the Whirlpool.

Contact Relations: Forms a sharp lower contact with the white sandstones of the Whirlpool Formation, and grades laterally into the maroon sandstones of the Grimsby Formation (i.e. forms a sandwich between the "White Medina" and the "Red Medina" sandstones).

Age: Niagaran Series

Environment: Nearshore marine or lagoonal (low energy).

GRIMSBY SANDSTONE

Lithology: Consists of 3 facies - lowest (A) is a pink-white-pale green mottled fine-grained, rippled and cross laminated quartz sandstone and siltstone with interbedded maroon shale and sandstones. Middle (B) facies is a dark maroon hematitic sandstone with large scale planar crossbeds. The upper (C) facies is a deep red knobby shale with mottles of gray-green calcareous lenses (Fisher, 1966).

Thickness: The three facies are thickest in this area (100-125 feet) and then thin eastward and westward. They contain brachiopods and ostracodes.

Contact Relations: Forms a sharp but conformable lower contact with the green-gray shales of the Power Glen Formation or the white quartz-rich Whirlpool Sandstone; the upper contact produces a sharp disconformity with the gray, fine-grained sandstones of the Thorold Formation (Rickard, 1975).

Age: Niagaran Series

Environment - Facies A is nearshore marine (subtidal-intertidal) while Facies B represents the beach and sandflats and overwash of a barrier island (intertidal-supratidal). The C facies represents the low energy lagoonal environment behind the barrier chain.

Lower Silurian - Clinton Group (Vanuxem, 1837)

As the Medina Group, the lower two thirds of the Clinton is also a relatively thin sequence with several disconformities, and it can be clearly noted in the driller's logs. The white quartz sandstones (Thorold-Kodak Formation) are the only nearly continuous units that separate, with a sharp break, the red hematitic sandstones and shales of the Medina from the gray-fine-grained limestones of the upper Clinton (Rickard, 1975).

THOROLD SANDSTONE

Lithology: A light gray, fine-grained, thin bedded argillaceous (20% clay matrix) angular quartz sandstone. It appears to be a reworked sequence of the "B" facies of the Grimsby Formation, with the absence of red hematite cement from coastal winnowing (Fisher, 1966). Though discontinuous, it is correlative eastward with the Kodak Sandstone. Both are similar in appearance and contain lingulid brachiopods and ostracodes. It forms the base of the Clinton Group.

Thickness: The member varies in thickness from 0-12 feet, with 2-4 feet being the average.

Contact Relations: The gray fine-grained sandstone forms sharp disconformable contacts between the adjacent units (Rickard, 1975) and when present, forms a key bed between the Medina and upper Clinton Group.

Age: Niagaran Series

Environment: The numerous regional disconformities and the appearance of the thin-bedded quartz sandstones suggest reworking along the transgressing Niagaran Sea.

NEAHGA FORMATION

Lithology: An irregular bedded, knobby, calcareous gray-green shale and siltstone. Though discontinuous, it is correlative with the Maplewood Shale eastward, based on the presence of conodonts and ostracodes.

Thickness: It occurs as an elongate lens and varies in thickness from 0-6 feet with 2-3 feet being the average.

Contact Relations: It also forms a sharp disconformity, with slight relief, between adjacent members.

Age: Niagaran Series

Environment: The position and lithology suggest the presence of shallow transgressive lagoonal deposits in association with the coastal sands of the Thorold Formation.

HICKORY CORNERS LIMESTONE

Lithology: It occurs as a dark gray, thin-bedded shaley or crystalline limestone. The 2-4 inch layer of shale clasts and phosphate nodules (Kilgour, W.J., 1963) suggests a disconformity. Worn brachiopods (Pentamerus) and bryozoan are common, though ostracodes are the important index fossils.

Thickness: It varies in thickness from 0-8 feet, with 4-5 feet being common, and it may be an important marker bed.

Contact Relations: Though conformable with adjacent members in the Rochester area, it occurs along disconformable contacts in western N.Y. The lower contact may occur on the Neahga, Thorold, or Grimsby Formation; the upper contact is against the Rockway Formation. Near Buffalo it is overlain by the gray-tan, medium-crystalline Merritton Limestone Member. The contact contains a 6-inch zone of rounded chert pebbles, black phosphate sands, and green glauconite with pyrite - suggesting another disconformity. The unit varies in thickness from 2-3 feet and contains some Pentameroides brachiopods indicating its younger age.

Age: Niagaran Series

Environment: The Hickory Corners Member was deposited in a low energy restricted (lagoonal?) environment by the transgressing Niagaran Sea; the Merritton Member was deposited later, in a similar environment and was later reworked and extensively eroded. The chief reason for the lowered sea level and extensive disconformities during the Lower Silurian is now believed to be related to the period of continental glaciation across the Gondwana continents near the south polar region (McKerrow, etal. 1979)

Upper Silurian - Clinton Group (Vanuxem, 1837)

The upper third of the Clinton Group also transgresses the boundary into the Upper Silurian, and provides a more continuous section of strata in western N.Y.

IRONDEQUOIT LIMESTONE - Rockway Dolomite Member

Lithology: Unit consists of a tan-gray sparsely fossiliferous, massive, fine-grained dolomitic limestone with a few interbedded gray-brown shale layers, large brachiopods and conodonts.

Thickness: Comprises 12 feet of buff weathered dolomitic limestone and interbedded shales.

Contact Relations: The lower contact contains worn limestone and chert pebbles with pyrite over the Merritton Limestone; the upper is gradational into the subtidal facies of the Irondequoit Limestone.

Age: Niagaran Series

Environment: The association of thin-bedded dolomitic limestone and gray shales suggests an intertidal (lagoonal) carbonate environment.

IRONDEQUOIT LIMESTONE

Lithology: Forms a light gray, coarsely crystalline crinoidal limestone with thin seams of calcareous shale. Occurs in biohermal "reef-like" masses with abundant crinoids, corals, bryozoans and brachiopods.

Thickness: Consists of 6-8 feet of fossiliferous, crystalline limestone.

Contact Relations: Gradational with the fine-grained dolomitic Rockway Member; upper contact is sharp with the brownish-gray shale of the Rochester Formation.

Age: Niagaran Series

Environment: High energy subtidal "reef-like" shoal with common wave agitation and selective winnowing.

ROCHESTER FORMATION

Lithology: While the lower 10 feet are a brown-gray shale, it grades upward into dark blue-gray fossiliferous, calcareous shale with frequent thin-bedded dolomitic limestones that become more prevalent higher in the section.

Thickness: The unit is about 55 feet thick across this region and contains brachiopods, bryozoan, cephalopods and an important ostracode zone.

Contact Relations: Forms a sharp but conformable lower contact with the coarsely crystalline Irondequoit Limestone; the upper contact is a gradational contact into the Decew Dolomite.

Age: Niagaran Series

Environment: The Rochester Shale is the marginal offshore marine shales that grade eastward into the coastal plain deposits represented by the Herkimer Sandstone.

DECEW DOLOMITE

Lithology: An irregular bedded dolomitic shale and fine-grained dolomite with convolute slump structures and some brachiopods.

Thickness: The unit varies in thickness from 8-15 feet in this area and forms the top of the Clinton Group.

Contact Relations: The lower contact is gradational with the Rochester Shale; the upper is sharp but conformable with the Lockport Formation.

Age: Niagaran

Environment: Intertidal and subtidal carbonate mudflats.

Upper Silurian - Lockport Group (Hall, 1839)

The groups consists of four formations, most of which are buff colored, medium-thick bedded replacement dolomites with Stylolites, carbonaceous partings and mineralized cavities. Time correlations are now based upon important conadont zonations (Rickard, 1975).

Lithology: A. basal Gasport Fm. - a coarse-grained, rickly fossiliferous, biohermal limestone and dolomite with brachiopods, corals, bryozoans and stromatopoids (Zenger, 1965). It is 15-30 feet thick.
B. Goat Island Fm. - a sugary, massive, dolomitic limestone with abundant crinoids, brachiopods, and white chert nodules (20-25 feet).
C. Eramosa Fm. - a dark gray, silty, thin-medium bedded bituminous dolomitic limestone with brachiopods and cephalopods (15-20 feet).

D. Guelph - Oak Orchard Fm. - a buff-dark gray, medium to thick bedded, massive bituminous dolomitic limestone with strunatolitic algae corals and oolite horizons (120-140 feet).

Thickness: The Lockport averages 160-170 feet across the region.

Contact Relations: The lower contact with the Decew is sharp, but conformable; the upper contact (drill data) with the Salina Group is conformable.

Age: Niagaran Series

Environment: The association of bioherms, oolites, crinoids suggests a subtidal patch reef environment with well agitated crinoid and oolite banks.

Upper Silurian - Salina Group (Dana, 1863)

The presence of a restricted shallow seaway in the Trade Wind Belt south of the equator caused intense evaporation and the precipitation of dolomite, anhydrite and halite along with red and green shales and siltstones. Although the group is 400-700 feet thick, less than 100 feet are exposed in surface outcrops and most of the information comes from the subsurface analysis of Rickard (1966).

VERNON SHALE

Lithology: The unit consists of red shale and buff dolomite with anhydrite; and some red-green shale and siltstone near the top. The proportion of dolomite, anhydrite and halite increases west of Rochester.

Thickness: Approximately 200 feet of red-green shale occur in the subsurface. The middle contains brachiopods, molluscs, eurypterids and cyathaspid fishes.

Contact Relations: The basal contact is conformable with the dolomitic shales of the upper Guelph Formation of the Lockport; the upper contact is conformable with the Syracuse Formation.

Age: Cayugan Series

Environment: Deposits accumulated in and along the edges of the evaporite marine "Salina Basin" in Illinois, Pennsylvania, New York and Ontario.

SYRACUSE FORMATION

Lithology: Consists of gray shale, buff dolomite and anhydrite, with some salt layers.

Thickness: The Syracuse Formation, though not exposed, is recognized as being about 100 feet thick in this region (Kriedler, 1957).

Contact Relations: The lower contact is sharp but conformable with the Vernon Shale, the upper is conformable with the Camillus Shale.

Age: Cayugan

Environment: Chemical precipitates of anhydrite and halite in the basin, with thin bedded dolomite and anhydrite along the supratidal sabkha along the basin margin.

CAMILLUS FORMATION

Lithology: The Camillus consists of knobby green-maroon mudstone and shale with some zones of dolomite and anhydrite. Red shales with eurypterids occur eastward.

Thickness: The unit is about 80-100 feet thick in this area.

Contact Relations: While the basal member is gradational with the underlying Syracuse Formation, lack of exposure makes recognition of the upper contact difficult, but it may be disconformable with the Bertie Formation.

Age: Cayugan

Environment: Clastic shale and mudstone deposited from the east as nearshore tidal flats into the Salina Basin with the precipitation of evaporites.

BERTIE FORMATION

Lithology: The Bertie consists of three members:

A. basal Falkirk - a massive, dark gray dolomitic limestone with some eurypterids.

B. Scajaquada - a dark shale and marly limestone (waterlime).

C. Williamsville - a laminated, fine-grained dolomite with a conchoidal fracture.

Thickness: The Falkirk, a resistant unit, varies in thickness from 18-25 feet; the Scajaquada is only 4-10 feet thick, and the Williamsville averages 5-8 feet in thickness. The entire Bertie Formation in west-central N.Y. is then between 40-50 feet.

Contact Relations: The lower contact with the Camillus Shale may be disconformable; the upper contact with the Akron Formation is gradational.

Age: Cayugan

Environment: The units represent intertidal and supratidal mud flats along the edge of the Salina Basin.

AKRON FORMATION

Lithology: The Akron is a fine-grained, gray-buff mottled dolomite with cavities from the solution of calcareous corals.

Thickness: In this region the Akron Dolomite is about 6-8 feet thick.

Contact Relations: The lower contact into the Falkirk Dolomite is gradational; the upper contact is disconformable with the lower Devonian Bois Blanc Limestone.

Age: Cayugan Series

Environment: The sequence represents a low energy intertidal and subtidal or lagoonal environment with an erosional surface.

Lower Devonian Stratigraphy

BOIS BLANC FORMATION (Ehlers, 1945)

Lithology: The unit is thin and is usually a sandy calcareous quartz arenite at its base, grading into a dark gray, fine-grained limestone. It is dominated by brachiopods, rugose corals and conodonts.

Thickness: It is discontinuous, lens-like, and varies from 2-3 inches up to 4 feet. Its presence, or the contact relations (see below) provide an important horizon marker in well cores.

Contact Relations: Though six possible contact relations with the overlying coarsely-crystalline crinoidal Onondaga Limestone are possible (Oliver, 1966, p.35) the lower contact forms a disconformity of a few inches and exhibits sandy quartz grains mixing with a fine-grained limestone. The upper contact may again be sandy (another disconformity) and forms a sharp contact with the crystalline Onondaga.

Age: Ulsterian Series - correlates eastward with the Schoharie Formation.

Environment: The irregular appearance of the limestone across a sandy regional disconformity associated with the older Oriskany Sandstone represents the periodic reworking of these sand deposits along the migrating uppermost Lower Devonian strandline with local lagoonal carbonate deposition.

Middle Devonian Stratigraphy

This interval exhibits the last major limestone unit in this part of the Appalachian Basin and demonstrates the effect of basin subsidence in controlling the clastic distal marine sediments of the evolving Catskill Delta Complex.

ONONDAGA FORMATION (Vanuxem, 1843)

<u>Lithology</u>: The Onondaga has been subdivided into 4 members by Oliver (1954). Beginning as a crystalline crinoidal-coralline limestone with numerous reef and reef shoals, it becomes finer-grained and more chert-rich upward. The units are laterally persistent and quite extensively developed.

A. basal Edgecliff Member - a light gray, coarse, coralline limestone with reef-like characteristics that grades vertically into a fine-grained gray limestone with irregular <u>light</u> gray chert nodules (50 feet). Gas is associated with the porous bioherms and reefs in this unit.

B. Clarence Member - a fine-grained gray limestone with abundant <u>dark</u> gray chert nodules - the unit grades eastward (Central N.Y.) into the thin-bedded argillaceous Nedrow Member. The abundance of chert (up to 75%) in this unit has been noted as the "flint bed" in many drillers logs. In this area it grades eastward into the coarse gray reef flank deposits of the Edgecliff bioherms (40 feet).

C. Moorehouse Member - a medium-grained, gray, massive limestone with both light and dark chert nodules, and an abundance of corals and brachiopods (55 feet).

D. Seneca Member - contains the basal "Tioga bentonite" soft, white clay bed of volcanic origin (4-10 inches) that is an important datum marker and key bed in this region. The limestone is a dark gray, massive unit that becomes darker and more argillaceous upward (40 feet).

<u>Thickness</u>: The formation attains a thickness of about 180 feet across the region.

<u>Contact Relations</u>: The lower contact forms a sharp disconformity with the Bois Blanc Formation; the individual members have gradational contacts; the upper contact is gradational into the black calcareous shales of the Marcellus Formation.

<u>Age</u>: Erian Series

<u>Environment</u>: The various carbonate facies with rugose and tabulate corals, crinoid banks, brachiopods, horizontal laminations, and planar cross-beds, all indicate features associated with reef, reef flank, carbonate shoals, and subtidal carbonate environments.

Middle Devonian - Hamilton Group

MARCELLUS FORMATION (Oatka Creek)

Lithology: The Oatka Creek Member consists of thin bedded black and blue-black fissle, bitumenous shale with some brachiopods.

Thickness: The entire Marcellus Formation consists of about 50 feet of the Oatka Creek Shale.

Contact Relations: The lower contact is gradational with the Onondage Limestone, and contains abundant pyrite nodules; the upper contact is sharp and conformable with the Stafford Limestone.

Age: Erian Series

Environment: Restricted marine environment because of effect of basin subsidence; sediments indicate offshore clays coming from the Catskill delta complex.

SKANEATELES FORMATION

Lithology: The Skaneateles exhibits an upward coarsening sequence beginning with a fine-grained black limestone (Stafford Member) that grades upward into blue-black and gray shales of the Levanna Member. The Levanna becomes coarser and medium-bedded higher in the section.

Thickness: The Stafford is 3-4 feet thick and is overlain by about 50 feet of gray Levanna Shale.

Contact relations: There is a sharp contact with the massive, dark gray Stafford Limestone and a similar contact with the overlying thick bedded, medium-grained Centerfield Limestone.

Age: Erian Series

Environment: Transgressive-regressive succession across the distal prograding slope of the Catskill Delta.

LUDLOWVILLE FORMATION

Lithology: The Ludlowville consists of four members that represent clearwater carbonate sections bounding a thick interval of gray shales.

A. The basal Centerfield limestone is a gray, thick-bedded medium-coarse-grained fossiliferous limestone. (6-8 feet)
B. The Ledyard Member is a thin bedded or knobby gray-black shale with fossiliferous pyrite concretions (26-30 feet).
C. The Wanakah Member is a calcareous, concretionary, blue-gray shale with abundant tabulate corals along its base (35 feet).
D. The Tichenor Member is a light gray, crinoidal limestone (8-10 feet).

Thickness: The entire Ludlowville Formation is about 75-80 feet through this region.

Contact relations: The Centerfield Limestone produces a sharp but conformable contact with the black shales of Levanna Member, and the Tichenor Limestone forms a sharp, slightly disconformable contact with black shales of the Kashong Member.

Age: Erian Series

Environment: The Ludlowville represents a periodic clearing of the seas during the otherwise continuing progradation of the marine slope of the Catskill Delta.

MOSCOW FORMATION

Lithology: The Moscow consists of thin-bedded black shales of the Kashong Member (6 feet) grading up into the knobby gray shales of the Windom Member (30 feet).

Thickness: The Moscow here forms a thickness of about 35 feet.

Contact relations: The lower contact is sharp and disconformable with the coarse-grained crinoidal Tichenor Limestone, while the upper contact is also disconformable with lenses of the Leicester Pyrite and dark gray Penn Yan Shale.

Age: Erian Series

Environment: Moderate basin subsidence gradually produces a more restrictive marine environment.

TULLY FORMATION

Lithology: The Tully Formation is represented by the thin-bedded black irregular lenses of the Leicester Pyrite and, while present eastward, is represented by a disconformity across this region.

Thickness: Interval is represented by a few inches of pyrite nodules in black shale.

Contact relations: Irregular lenses of pyrite occur between the knobby dark gray calcareous shales of the Windom and the black fissle shales of the Penn Yan Formations.

Age: Erian Series

Environment: Restricted reducing environment associated with limestone deposition along the delta front shoals and non-deposition in the deeper part of the basin.

Upper Devonian Stratigraphy

The Upper Devonian section in this region, a frequent reservoir for local oil and gas, consists of nearly 2500 feet of interbedded marine sandstones and shales that form an upward coarsening sequences through the Senecan and Chautauquan Series to form the Genesee, Sonyea, West Falls, Canadaway, Conneaut, and Conewango Groups.

The subdivisions are based on the recognition of rhythmic units of black and gray shales and thin interbedded turbidite siltstones that thicken eastward to form the lower slope of the Catskill deltaic complex. The base of the Genesee, Sonyea and Westfalls Formations are each marked by basal black shales associated with regional basin subsidence (Geneseo, Middlesex and Rhinestreet) that are then overlain by prograding gray shales and siltstones (Penn Yan - West River, Cashaqua, and Angola) of the Catskill Delta. The best key horizons as marker beds include the base of some of these shales or the associated siltstones.

GENESEE GROUP: This sequence consists of three formations:

Lithology:
A. basal Geneseo and Penn Yan black and dark gray shales that are sparsely fossiliferous and grade laterally into each other (2 inches to 3 feet).
B. Genundawa Formation - a gray, thin bedded, fine-grained limestone (2 inches to 2 feet - a marker horizon).
C. West River - a gray to dark gray fissle shale (15 feet).

Thickness: The Genesee Group varies in thickness from 10 to 20 feet.

Lower contact: Defined by the presence of the irregular Leicester Pyrite lenses that form a non-depositional disconformity during the development of the Tully Formation elsewhere (a key bed).

Upper contact: The dark gray shales of the West River grade vertically into the black shales of the Middlesex Formation.

Age: Senecan Series

Environment: The sequence repeats the offshore and distal delta slope environments of the Marcellus Formation, and represents the second major stage of progradation for the Catskill delta.

SONYEA GROUP: (Colten and deWitt, 1958) This sequence consists of two shale formations.

Lithology: A. the basal Middlesex Formation is a black fissle shale (6 to 8 feet) that grades upward into B. the gray Cashaqua Shale which varies in thickness from 45 to 75 feet.

Thickness: The Sonyea Group varies in thickness from about 50 to 80 feet across this region.

Contact relations: The lower contact is gradational with the dark gray shales of the West River Formation, while the upper is gradational with the black fissle shales of the Rhinestreet Formation.

Age: Senecan Series

Environment: The sequence repeats the offshore and distal delta slope environments of the Genesee Group and reflects the third major period of progradation for the Catskill Delta.

WEST FALLS GROUP: (Pepper deWitt and Colten, 1956) This sequence now consists of three shale formations.

Lithology:

A. the basal Rhinestreet Formation is a black fissle shale that is 150-200 feet thick.
B. Angola-Nunda Formations are a series of gray shales and siltstones with interbedded thin limestones and calcareous siltstones. The Angola is the more western equivalent of the Nunda. The units vary in thickness from 220 to 365 feet.
C. Hanover Formation (Java Formation of Pepper and deWitt, 1950) consists of the Pipe Creek Member - a unit only 1-2 feet in thickness with conodonts and carbonized plants; and the Hanover Shale - a unit of gray shales with interbedded thin limestones that is 85-95 feet thick and a continuation of the Angola Shale lithology.

Thickness: The West Falls Group varies in thickness from 450 to nearly 650 feet across the area.

Contact relations: Along the lower contact the black shales of the Rhinestreet are gradational into the gray shales of the Cashequa Formation; at the upper contact the gray medstones and siltstones of the Hanover Formation are gradational with the black fissle Dunkirk Shale.

Age: Senecan Series

Environment: The sequence illustrates the distal and proximal delta slope environments of the Catskill Delta, and represents the fourth major interval of clastic progradation into the subsiding basin.

CANADAWAY GROUP (Caster, 1934) This sequence consists of six formations and represents the final pulse of deltaic progradation during the Devonian Period.

Lithology:

A. basal Dunkirk Formation - a black fissle shale with carbonized plant remains and conodonts, about 120 feet in thickness. Its eastern equivalent is the gray shales and massive siltstones of the Caneadea Formation.
B. Gowanda Formation - a succession of gray and black shales with interbedded massive but thin gray siltstones and concretions, varying in thickness from 120 to 230 feet.

C. Laona Formation - a gray massive siltstone with a unique assemblege of brachiopods and pelecypods. It varies from 3-25 feet in thickness and forms a series of elongate lenses over the area.
D. Westfield Formation - a series of gray shales with a few thin-bedded siltstones and a sparse marine fauna that varies in thickness from 100 to 220 feet.
E. Shumla Formation - a gray massive siltstone similar in texture and form to the Laona Formation but without the distinctive fauna. It attains a thickness up to 35 feet.
F. Northeast Formation - a thick series of gray shales and interbedded siltstones in which the siltstones become thicker and more numerous higher in the section. The unit varies in thickness from 400 to 600 feet.

In Cattaraugus County units B-F cannot be separated, and this thick 1000-foot sequence of undifferentiated gray shale and interbedded siltstones is referred to as Forty Bridge Formation (Rickard, 1975) in the Salamanca region.

Thickness: The Canadaway Group nearly reaches a thickness of 1000 feet across this region.

Contact relations: The black shales of the Dunkirk form a gradational lower contact with the gray shales of the Hanover Formation; along the upper contact the gray shales and siltstones of the Northeast Formation now grade into the massive fine grained sandstones and brown-gray knobby shales of the Dexterville Formation.

Age: Chautauquan Series

Environment: The sequence reflects the proximal delta slope environments of the Catskill Delta and represents the fifth and final pulse of progradation into western New York.

CONNEAUT GROUP (Rickard, 1975) This sequence represents the first appearance of the proximal delta slope of the Catskill Delta in this region, and consists of two formations.

Lithology:
A. basal Dexterville Member consists of a series of gray knobby shales and interbedded gray siltstones with the brachiopod *Pugnoides duplicatus* as an index fossil (100 feet).
B. Ellicot Member is very similar in lithology but without the characteristic brachiopod (150 feet).

In Cattaraugus County where *Pugnoides* is absent the members are not differentiated and the lateral equivalent is the Chadakoin Formation (250 feet).

Contact relations: Since the lithologies are similar, the lower contacts are gradational; the upper contact occurs at the base of the Panama and Wolf Creek Conglomerate.

Age: Chautauquan Series

Environment: As noted, the presence of shales and interbedded fine-grained sandstones indicates the initial presence of a coarser sequence representing the proximal delta slope environments.

CONNEWANGO GROUP (Butts, 1908) This sequence represents the marine and non-marine environments of the Catskill Delta.

Lithology: Gray shales and siltstones with beds and lenses of tan sandstone and conglomerate, red mudstones, gray crossbedded sandstones. (Cattaraugus Facies of Fisher & Rickard, 1975)

A. basal conglomerates (Wolf Creek and Panama) occur as layers and lenses in crossbedded tan sandstones (6 feet)

B. Venango Member - consists of knobby gray shales interbedded with gray-dark gray siltstones with marine fossils (pelecypod Ptychopteria)

C. Cattaraugus Member - contains a varying lithology of shales, siltstones and sandstones (gray, green and red) as layers and lenses with Calcareous nodules, dessication cracks, and plant fossils.

Thickness: The group thins westward, but averages 650 feet in thickness.

Contact relations: Because of the varying lithology, the contact relations also become more variable and the units are separated by several attributes (i.e. facies) as defined by Rickard (1975).

Age: Chatauquan Series

Environment: Marine-non marine fluctuations from changes in position of deltaic lobes and differential basin subsidence to produce delta platform sands, river mouth base, tidal and fluvial channels, mud and overbank deposits.

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