HYDROCARBON POTENTIAL IN THE ST. LAWRENCE LOWLANDS OF NORTHERN NEW YORK

by

Dan A. Billman, P.G., Geologic Consultant

for

New York State Energy Research and Development Authority

1999

ABSTRACT

This study investigates the regional geology, hydrocarbon potential, past oil and gas industry activity, and technical and economic implications of future drilling and production activity in the northern New York state portion of the St. Lawrence Lowlands. This study includes collection and analysis of relevant well data including, drilling reports, well logs and completion information, remote sensing data to identify hydrocarbon accumulations, anecdotal information and non-traditional oil and gas exploration data.

After consideration of all data, and incorporation of analog Canadian St. Lawrence Lowlands data, it has been postulated that hydrocarbon generation and migration likely took place in the New York St. Lawrence Lowlands and sufficient reservoir rock likely exists in the Cambrian – Ordovician sedimentary section. However, the sedimentary section is likely shallow and thin (1000' and less) and orogenic events may have caused fracturing which could breech existing traps. Two areas have been delineated for further potential review, given their structural style and position.

INTRODUCTION

Production established in Quebec, Canada (Canadaian St. Lawrence Lowlands) has caused an interest to evaluate the oil and gas potential of the New York St. Lawrence Lowlands. The New York portion of St. Lawrence Lowlands lies across the three northern most counties of New York, Clinton, Franklin and St. Lawrence. The St. Lawrence River and Canada form the western and northern boundaries, while Lake Champlain and Vermont form the eastern border, and to the south rise the Adirondack Mountains (*Fig. 1*).

This study focuses on determining the presence of reservoir rock by analyzing limited analog well and drilling data (including sample logs, mud logs, electric logs and production/natural show data) acquired from state agencies and supplemented with published outcrop, regional geologic and basin studies. Comparative analog data from Canada and southwestern New York are employed to provide indirect indications of permeable and porous reservoir in the study area.

Hydrocarbons trapping and sealing mechanisms were studied. Assuming stratigraphic trapping would be subtle, especially given the lack of subsurface data, structural trapping was emphasized. A review of regional structural studies and the analysis of available remote sensing data delineate these structural traps. Public domain geophysical data has been used in characterizing the geology and hydrocarbon potential of the study area. Lastly, anecdotal examples of current producing fields are compared to the area of study. This allows for a general understanding of possible field sizes and associated economics of those fields.

GENERAL GEOLOGY

Stratigraphy

The St. Lawrence Lowlands are predominantly comprised of Cambrian - Ordovician sediments (*Fig. 2*). The Cambrian Potsdam Sandstone (Canadian Napean) *(Fig. 3)* lies unconformably on the faulted, Pre-Cambrian basement metamorphics (*Fig. 2*). The Potsdam is a transgressive sequence. The sandstone is generally a quartzose sandstone (orthoquartzite). Locally there are described conglomerates, basal breccia and fanglomerates (Kirchgasser, 1971).

The lowermost member of the Potsdam tends to reflect the composition of the Grenville basement rocks (Fisher, 1977). The Potsdam Sandstone is typically medium- to thick-bedded, to laminated. It is occasionally cross-stratified with ripple marks in the upper portion and horizontally bedded, except at the base were it onlaps on the Pre-Cambrian (VanDiver, 1983). Vertical burrows are common. The sandstone is typically composed of red- to pink- to white grains, medium grained, occasional rock fragments, with minor interstitial clay. Locally, it is described as friable (Kirchgasser, 1971), otherwise, the sandstone is quartz cemented. The textural and mineralogical maturity suggests an environment of deposition of a reworked shoreline with increased energy up section.

The Theresa Formation (Canadian March) of the Beekmantown Group (*Fig. 3*) overlies the Potsdam conformably and transitionally. The Theresa is a calcite and/or dolomite cemented sandstone and often feldspathic. The formation has mixed carbonate - clastic influences. Original fabrics are typically altered by burrowing and bioturbation (Kirchgasser, 1971). The Theresa - Potsdam transition zone often contains mudcracks (Erickson and Bjerstedt, 1993). Carbonate rock increases up-section from the Lower Theresa to the Upper Theresa (Selleck, 1984; Selleck, 1993). Sand grains are typically well rounded and medium to coarse grained. Lenses of disarticulate brachipod debris with limited molluscan fauna and algal stromatolite horizons are common. The immaturity of the sandstones combined with the fossil assemblage suggests a low energy, possible sub-tidal, depositional environment (Kirchgasser, 1971). The Theresa has been interpreted as a shoaling upward sequence (Erickson and Bjerstedt, 1993).

The Ogdensburg Formation of the Beekmantown Group lies conformable above the Theresa Formation (*Fig.3*). The Ogdensburg Formation is predominately a dolomite with varying amounts of calcite, quartz grains and cement, feldspar, pyrite and clay minerals (Harris and Friedman, 1982). The subfacies of the Ogdensburg Formation are interpreted as intertidal to supra tidal with deposition occurring on an eperic carbonate shelf (Harris and Friedman, 1982). The subfacies within the Ogdensburg include 1) quartzose feldspathic dolostone, 2) dolomitized and silicified osparite, 3) laminated dolostone, 4) fossiliferous dolostone, and 5) algal-laminated dolostone (Harris and Friedman, 1982). This group of sediments have been interpreted as a series of peritidal upward shoaling parasequences (Friedman, 1994).

Deposition of the Beekmantown dolomites was terminated by an uplift at the end of the Lower Ordovician, which is marked by the Knox Unconformity. Lying unconformable on the Beekmantown dolomites are the limestones of the Middle Ordovician, Black River Group and Trenton Limestone (*Fig. 3*).

Hydrocarbon Source, Migration and Resource Potential

The Middle Ordovician, Utica Shale lies conformable above the Trenton Limestone. The Utica Shale is typically considered the source rock for the area. Where the Utica has been faulted into position against lower formations, hydrocarbon migration is postulated (Dykstra and Longman, 1995). Models indicate that gas generation in the lowlands likely occurred 75-100 million years after deposition, during the Devonian (Dykstra and Longman, 1995). Total Organic Content has been measured and reaches up to 3% in the Utica Shale and slightly less in the Lorraine Group (Beiers, 1976). Similar tests also indicate a late stage of maturation, which is evident in the gas analysis from samples from the Canadian Lowlands. These analyses indicate methane concentrations ranging from 88% to 96% (Beiers, 1976).

Thermal maturation models indicate that hydrocarbon generation likely occurred during early Taconic Orogeny periods and culminated with the emplacement of the thrust sheets (Dykstra, 1993). However, the traps in front of the thrust sheets were likely charged in the Devonian, after much of the porosity likely was diagenetically destroyed or altered (Milici, 1996). The Ordovician carbonate interval may have the greatest potential for producing gas as it has a lower thermal maturity than the underlying strata (Guo, et al. 1990).

Log analysis by Aguilera (1978) indicates that the Utica Shale of the Quebec Lowlands may contain 5 BCFG per square mile (640 acres) and the average well could produce initially, approximately 500 MCF/D. This estimate is based on daily production rates of approximately 296 MCF/D after 20 years. Milici (1996) suggests that this average is too optimistic and indicates that the 20 year average daily rate would likely be much closer to 50 MCF/D. Therefore, Aguilera (1978) has likely overestimated the total resource potential.

Structural Geology and Hydrocarbon Trapping

Two main events compose the tectonic history of the Lowlands: A system of normal faults (with possible strike-slip left lateral movement and reactivation (Shaw, 1993)) related to the Pre - Cambrian shield and a system of thrust faults originated during the Taconic Orogeny, possibly reactivated during subsequent orogenies (Beiers, 1975, 1976). Kumarapeli and Saull (1966) described the system of Precambrian normal faults in the St. Lawrence Lowlands and compared them to the East African Rift Valley.

The Potsdam Sandstone was deposited on a fault block Pre-Cambrian surface (*Fig. 4*) (Fisher, 1977; Robinson, 1982, Dykstra and Longman, 1995). Therefore, sedimentation was likely affected by the irregular surface, which in turn implies that facies would be indirectly related to previous structure. These faults have possibly been reactivated since the Cambrian and have created potential hydrocarbon traps (*Fig. 5*) (Beiers, 1975, 1976). Flower structures, indicative of strike slip movement and possible reactivation of the normal faults, have been documented in the section (*Fig. 6*).

The Cambrian - Ordovician sedimentary section was deformed during the Taconic Orogeny. During this event, the carbonate section was faulted and over thrusts were formed (*Fig. 7*). The over thrusts have also created potential hydrocarbon traps (*Figs. 8&9*). Beier (1975, 1976) divides the Quebec Lowlands into four zones from west to east: the platform, the external zone, the internal zone and the nappe zone.

The platform is bound by the Taconic thrust sheets to the east and the up-thrown crystalline basement to the west. The platform zone is also characterized by active, normal faults during the earliest Paleozoic (Milici, 1996). The external zone is characterized by subhorizontal thrusting within the Utica and Lorraine Formations (Beiers, 1975, 1976) and this faulting has increased the fracturing of the shale sections, which is likely the cause of numerous gas shows in the interval during drilling (Milici, 1996). The internal and nappe zones are characterized by relatively large scale imbricate thrust sheets which could cause potential hydrocarbon traps in the footwall structures beneath thrust sheets (subthrust plays) (Beiers, 1975, 1976, Milici, 1996).

Porosity and Permeability Development

Within the Potsdam and clean sandstones of the Theresa, the sandstone is locally described as friable (Kirchgasser, 1971); otherwise, the sandstone is quartz cemented. This friable (possibly primary, intergranular porosity) sandstone would likely be a quality reservoir rock. Also, several large gas flows have been associated with Potsdam secondary fracture porosity in the Canadian Lowlands (Beiers, 1976). However, in the Canadian Lowlands, the Potsdam often has poor primary porosity, due to cementation by carbonates, silica and clay minerals (Beiers, 1975).

Within the Ogdensburg Dolostone and the less clastic, upper Theresa, voids are common in northern New York and Ontario (Selleck, 1987). Often the voids are partially mineralized with chert, pyrite, dolomite, calcite or quartz. The voids were likely formed by dissolution of anhydrite (Selleck, 1987). Within the Beekmantown Group, porosities include 1) vuggy and minor moldic, 2) intercrystalline, 3) fracture, 4) interparticle in carbonate grainstones and 5) interparticle between quartz grains in sandstones of the Theresa Formation (Selleck, 1987). Milici (1996) believes that porosity within the Beekmantown Group, would be dependent predominantly on fracturing.

In early Ordovician and Late Silurian, the Taconic Orogeny had resulted in the burial of the Cambrian and Lower Ordovician section to depths sufficient for the onset of hydrocarbon generation (Dykstra and Longman, 1995) and could continue through the Devonian (Dykstra and Longman, 1995). Once any generated hydrocarbon was trapped, further heat and pressure likely caused any oil to be further broken down leaving bitumen staining in fractures and pores and generating natural gas. Bitumen is found in pores and fractures of the Beekmantown Formation (Dykstra and Longman, 1995).

ANALOG DATA

Canadian Lowlands

Milici (1996) states that the Quebec Lowlands stratigraphy and geology are sufficiently similar to the New York Lowlands so that an analog of hydrocarbon potential can be estimated. The structure of the Champlain Valley and St. Lawrence Lowlands is similar to that of the Quebec Lowlands as shown by the COCORP New England transect (Ando, et al., 1984, Milici, 1996). Some of the activity and success of drilling in the Quebec Lowlands have spurred interest in the hydrocarbon potential of the St. Lawrence Lowlands, New York.

Pointe du Lac Field (*Fig. 10*) was discovered in 1955 when a local farmer was attempting to drill a residential water well. The well blew-out at 100 meters, (320 feet) in unconsolidated glacial sand, and was not controlled for approximately six months. Between 1962 and 1972, the field was extensively drilled, producing 2.5 BCF before being converted to storage. Based on thermal maturity, the gas from Pointe du Lac was generated in the Ordovician Lorraine and Utica Formations (Betrand and Dykstra, 1993, Dykstra and Longman, 1995, Milici, 1996). Though the field is within unconsolidated Pleistocene sediments, it is important that gas geochemistry points to an Ordovician source.

The search continued for over thrust fields and in 1972 the St. Flavien Field (*Fig. 10*), a Beekmantown Dolomite anticlinal play, was discovered. The field contains two producing wells and six dry holes. Before being turned to storage, it produced 5.7 BCF with an estimated 7.75 BCF gas in place. Although dozens of Quebec Lowlands wells have been drilled, no commercial production has since been established.

Bow Valley Industries drilled the St. Simon No. 1/1A in 1991, with the intent to penetrate a porous and permeable Beekmantown section in the over thrust play (*Fig.11*) (Petzet, 1992) (Dykstra, 1992). The St. Simon structure is a large, fault-bound autochthonous block (*Fig.10*). As an analog, Dykstra used the Wilburton deep field of the Arkoma Basin, eastern Oklahoma (Petzet, 1992) (Dykstra and Longman, 1995). A section of Beekmantown from 4110.2 meters to 4127.2 meters was cored and two porous zones were encountered. The porous zones were saturated with pyrobitumen (Dykstra, 1992, Dykstra and Longman, 1995). Drill stem tests were completed and gas samples were collected. Attempts were made, unsuccessfully, to flare the gas and after analysis of the gas it was determined that the samples contained approximately 93% carbon dioxide, 5% methane and 2% other gases (Dykstra, 1992, Dykstra and Longman, 1995).

New York Lowlands and New York State

The Morrisonville well, in Plattsburgh Township, Clinton County, Dannemora Quadrangle, was drilled in 1898 and 1899. A fire on the rig destroyed most of the well records. Approximately 800' to 900' of Potsdam sandstone was encountered. Of that, only "one stratum was markedly water bearing" and "a trifling amount of oil was also found in one of the beds" (Cushing, 1899, Newland and Hartnagel, 1932, Fisher, 1968). Minor shows of gas and oil have also been noted in the Cambrian-Ordovician section in the fold and thrust belt of Vermont (Milici, 1996).

In Jefferson County, just south of the Frontenac Arch, and southwest of the St. Lawrence Lowlands, three wells were drilled in the Adams area in 1891 (Newland and Hartnagel, 1932). Each well reached basement in less than 1000 feet. Well No. 1 spudded on the Trenton Limestone and at 400' encountered enough gas to run the boiler on the rig. Gas was encountered further down the hole as well. Gas flow in the No. 1 well ceased after one year due to water encroachment. The No. 2 well encountered gas at 350', likely in Trenton, but the flow did not sustain through the drilling of the well. The No. 3 encountered a small flow of gas, which was followed by large amounts of brine. Wells were also drilled north and east of Adams, near Watertown and Rodman (1890 and 1886, respectively) with minor shows of gas, but yielded no sustainable flows (Newland and Hartnagel, 1932).

Still farther southwest along the Lake Ontario shoreline, the Urban-Snow Company drilled the K.& E. Keysor #1 in northern Cayuga County as a Theresa-Potsdam test, drilled to the basement. The well was drilled with the intent of encountering the "normal" clean, white sandstone of the Theresa-Potsdam Sandstones, as seen in the offset, A.& B. Hunter #1 (*Fig. 12*). Instead of the "normal" section, an anomalous, organic rich siltsone was encountered (*Fig. 13*). Samples from the anomalous section were analyzed and a paraffin rich crude oil was found (Robinson, 1989, 1991). Total organic carbon ranged from 3.6% to 4.8% (Robinson, 1989, 1991).

East of the Cayuga County site, Eastern States Exploration Company drilled the L.A. Halloran #1 (31-067-21335) and the R.G. Stell #1A (31-067-21336), in Onondaga County. Both wells were Theresa - Potsdam tests. The R.G. Stell #1A (Fig. 14) shows that the Theresa - Potsdam interval had a significant temperature kick, indicating gas entry and expansion into the borehole. The Theresa and Potsdam are difficult to distinguish with standard geophysical logs (Robinson, 1991) and this set of logs is not an exception.

MISCELLANEOUS GEOLOGIC DATA

Three government sites in the St. Lawrence Lowlands region have been studied over recent years. The former Plattsburgh Air Force Base, just inland from Lake Champlain, Clinton County, and two potential high tech research sites, west along the St. Lawrence River, were subject to geologic engineering studies. These studies were reviewed from an "oil and gas" perspective and have been incorporated into hydrocarbon potential review of the region.

Plattsburgh Air Force Base at Plattsburgh, NY

The borings required for this project occurred at numerous sites northwest and southwest of the City of Plattsburgh, Clinton County. Formations investigated include the Utica Shale through Potsdam Sandstone (Cambrian - Ordovician section). The Utica Shale, Beekmantown (Ogdensburg Member) and Potsdam Sandstone are fractured in the study area. Fractures vary from partially to fully calcite filled. The fractures are high angle (45 degrees to 90 degrees) (Anonymous, 1960). Milici (1996) believes that porosity within the Beekmantown Group is dependent predominately on fracturing, and these fractures support that belief.

Nuclear Breeder Reactor Site at Waddington, NY

On this northern St. Lawrence County site, the Ogdensburg Formation was the predominant formation investigated. The Upper Ogdensburg on site is a dark gray, sandy dolostone, stylolites are common, and slightly vuggy. The Middle Ogdensburg Formation grades conformably upward and downward. The Middle Ogdensburg is shaley, light gray in color, and slightly vuggy. The Lower Ogdensburg is gray to dark gray, more sandy that the rest of the formation, and more vuggy than the rest of the formation. The vugs are often partially filled with calcite or dolomite.

Two joints were observed in the cored Ogdensburg Formation: hairline joints, with high angle dips (>70 degrees) varying from single planes to "stair step" patterns with very minor offset and the second, calcite and/or dolomite filled lower angle (<70 degrees) with a "stair step" pattern. Significant offset was observed in only one boring. Breccia, possible fault gouge, was observed in one boring also (Dineen, etal, unknown date).

Superconducting Super Collider, St. Regis Valley Site at Massena, NY area

On this northern St. Lawrence County site, the Ogdensburg Member of the Beekmantown Group, Theresa Formation and Potsdam Sandstone were investigated in anticipation of tunneling the area for the proposed Superconducting Super Collider.

The Ogdensburg Formation (350 foot cored) had virtually 100% recovery and Rock Quality Designation (RQD) greater than 90%. RQD is the percentage of measured sample that is greater than 4 inches in length; porous and/or fractured rock tends to break easily and therefore has lower RQD values. These two factors, high recovery rates and high RQD values, combined, indicate minimal fracturing. Borehole permeability tests zero permeability for most intervals, and those few intervals with measurable permeability had calculated values in the 0.0001 millidarcy range (Anonymous, 1987b).

Approximately 160 feet of Theresa Formation was cored for this investigation. The cores were all 100% recovery and RQD values ranged from 100% to 64%. The decreased RQD's occurred toward the base of the Potsdam Sandstone. Borehole permeability tests showed negligible permeability throughout the zone (Anonymous, 1987b).

Approximately 400 feet of Potsdam Sandstone was cored for the purposes of this study. One borehole (BHM87-8) encountered friable, red to pink, banded sandstone beds with interstitial clay. The RQD for the Upper Potsdam averaged 94%; however, the RQD for the Lower portion was more variable with a range of 100% to 45%. Borehole permeability for the Upper Potsdam was effectively zero. The Lower Potsdam was only very slightly more permeable, in the 0.0001 millidarcy range (Anonymous, 1987b).

REMOTE SENSING DATA

Remote Sensing/Fracture Analysis Data

As part of a 1997 NYSERDA study, Earth Satellite Corporation completed a fracture analysis using Landsat satellite imagery of the State of New York. The study included a Geologic Analysis (*Fig. 15*) which includes interpreted: 1) thrust and normal faults, 2) anticlines, synclines and monoclines, and 3) lineaments/fractures. Also, included is a Fracture Density Analysis (*Fig. 16*). The fracture density analysis of the St. Lawrence Lowlands indicated two areas of higher fracture density an area located between Ogdensburg and Potsdam and an area due west of Plattsburgh.

Geologic interpretation of the Ogdensburg to Potsdam area shows fractures parallel to the St. Lawrence River. Assuming the river is an expression of a past extension event (Kumarapeli and Saull, 1966, Beiers, 1975, 1976), one would expect to find a southwest to northeast fracture pattern roughly parallel to the river. The sediments above the rifted Pre-Cambrian surface would drape across horst and graben structures, causing fracturing along the inflection of the strata. The fractures identified are as predicted by Kumarapeli and Saull (1966) who described the system of normal faults in the St. Lawrence Lowlands and compared them to the East African Rift Valley.

The geologic interpretation of the Plattsburgh area, however, is characterized by south to north trending structures (anticline and syncline), faulting and fractures, roughly paralleling Lake Champlain. These orientations are likely related to the Taconic thrusting from the east (Beiers, 1975, 1976).

Aeromagnetic Data

Magnetic methods have been used in oil and gas exploration to determine: 1) the depth to basement in under explored basins, 2) basement features that effect the depositional patterns of overlying strata, and 3) structures in the overlying strata that may have been caused or affected by basement features. Magnetic data is often very useful for determining basement structure because the Precambrian, igneous and metamorphic rocks have a higher concentration of magnetic minerals (magnetic susceptibility) than sedimentary rocks of the Cambrian and Ordovician. Typically, Precambrian has a measurable response, while the overlying sedimentary strata is largely unmagnetic; thus a magnetic survey "sees" through the stratigraphic column and images the basement. Variations within basement are not the only factors in quantifying magnetic anomalies. Magnetic anomalies are also dependent upon the strike, dip, depth and body geometry. Therefore, it is important to combine the magnetic interpretation with other geologic controls.

For the purposes of this study, Aeromagnetic data was acquired from the National Oceanic and Atmospheric Administration, National Geophysical Data Center. The data was collected at 0.5 - 1.0 mile line spacing and was originally contained in three separate sets (Nos.163,164,165). Pearson, deRidder and Johnson, Inc. (PRJ) reprocessed the data, using methods outlined below (also, refer to attached areomagnetics data).

The Total Magnetic Intensity is basically the "raw data" depicting the magnetic susceptibility of the underlying Precambrian combined with any magnetic susceptibility of the overlying sedimentary section. The patterns on these images are largely due to the variations in subsurface topography on the Precambrian surface, as well as possible changes in Precambrian rock types/contacts (magnetic susceptibility).

The Reduced to Pole (RTP) filtering removes the directional dependency of the earth's field and transforms an anomaly into one that would be observed with vertical magnetism. The maps remove the affects of an inclined magnetic field, thereby positioning the anomaly more accurately over the causative body.

Horizontal gradient maps (shadowgraph) filtering enhances high frequencies, subtle line-oriented anomalies and small, high frequency magnetic responses. It depicts basement lineations, faults and boundaries between different strata or provinces. The horizontal gradient operator produces maximum ridges over edges of magnetic basement blocks and faults, or linear features, related to near linear stratigraphic contacts.

The Depth Sliced RTP maps discriminate among shallow, intermediate and deep features. However, given the shallow depth to basement (0 to 1000 feet) in much of the study area, the intermediate and deep depth slices are more accurately described as shallow and deep basement respectively. The shallow depth slice is, in part, representative of the area's glacial features. Glacial sediments are likely rich in magnetic minerals as much of the sediment was derived from the Precambrian/Canadian Shield. While portions of the shallow depth slices appear to be "drumlin-like" features, they are likely due to glaciation events.

The deeper depth slices are consistent with the expected regional structural geology. Within the western portion of the data set, the dominant features are roughly parallel to the St. Lawrence River as predicted by Kumarapeli and Saull (1966) who described the system of normal faults in the St. Lawrence Lowlands and compared them to the East African Rift Valley. These possible horst and graben features are important in that the horsts would likely contain thicker sections of Potsdam Sandstone. Overprinted on the St. Lawrence parallel trend is a series of north - south features, which are possibly Taconic Orogeny features.

Further work was performed on the western portion of the data by Billman and Fagan (1998), especially in the area between Potsdam and Ogdensburg. Three scenarios were incorporated into the analysis: 1) a magnetic susceptibility (differing rock type) model (*Fig. 17*), 2) a single horst model (*Fig. 18*), and 3) numerous blocks model (*Fig. 19*). The susceptibility model does not appear to be valid as the response of the differing rock types would be too pronounced (note the scale change on the total magnetic between model 1 versus models 2 and 3) through a thin sedimentary cover. As this type of response is not seen in the actual Total Magnetic Intensity data, this model is discarded. The single horst model produced a response similar to those seen in the actual Total Magnetic Intensity data, however, not as complicated as seen in the actual Total Magnetic Intensity data. The last model was then designed as a more complicated system of numerous horsts/blocks. The numerous block model's response more closely approximates the actual Total Magnetic Intensity data.

CONCLUSIONS AND COMMENTS

Established production in the Canadian Lowlands lead to the investigation of the New York Lowlands. Hydrocarbon generation and migration has been documented in the Canadian St. Lawrence Lowlands an in New York southwest of the Adirondak Mountains. The Utica Shale has been documented as the source of numerous fields and shows in the Canadian Lowlands. Review of the literature, well data and remote sensing data leads to the following remarks.

1. It is suggested that one should expect a similar hydrocarbon generation and migration history in the area of the New York St. Lawrence Lowlands, as observed in Canada.

2. It has been shown that there is sufficient reservoir rock in the Potsdam Sandstone, Theresa Formation and the Ogdensburg Formation of the Beekmantown Group of the St. Lawrence Lowlands. The Potsdam Sandstone and clastic portions of the Theresa Formation contain both primary and secondary porosity within the interval. The carbonate portion of the Theresa Formation and the Ogdensburg Formation contain vuggy, intercrystalline, fracture and dissolution porosities.

3. Sedimentary hydrocarbon traps tend to be subtle and are difficult to delineate, given the lack of subsurface data. However, structural traps are predicted at: 1) Thrust and fold traps generated during with the Taconic Orogeny, 2) Traps associated with Precambrian horsts causing flexure and pinch-out traps, and 3) traps related to strike-slip motion along faults (strike-slip faults are documented in Canada Lowlands and postulated in the New York Lowlands).

4. Hydrocarbon shows have been documented in the St. Lawrence Lowlands (Morrisonville well). Hydrocarbon shows have been documented in New York, in the Ordovician - Cambrian section, southwest of the Adirondack Mountains. Hydrocarbon production has been established in the Canadian Lowlands, the production was sourced from the Utica Shale and was structurally trapped in the Beekmantown (St. Flavien Field).

5. Non-traditional oil and gas data can supplement limited traditional data. In this study, the non-traditional data documented: 1) Partially to fully mineral filled, high-angle fractures occur in the Beekmantown Group, at the Plattsburgh site, 2) The Beekmantown Group contains abundant vuggy porosity at the Waddington site, 3) Breccia, possible fault gouge, was observed at the Waddington site, 4) Borehole permeability, though minimal, increases with depth towards the

base of the Potsdam Sandstone at the Massena site and 5) RQD values decrease with depth indicating increased fracturing with depth at the Massena site.

6. Given the shallow nature of the sedimentary section in the St. Lawrence Lowlands as well as the overwhelming evidence of fracturing, (outcrop studies, core studies, Landsat imagery analysis and as predicted by structural analysis), there is concern that the trapping mechanisms for potential reservoirs been breached. This concern can be satisfied only through increased analysis, quite possibly including drilling.

7. The Aeromagnetic data and Landsat analysis point to two areas of interest for further study and/or drilling: the area between Ogdensburg and Potsdam and the area west of Plattsburgh. The Ogdensburg/Potsdam area has a strong fracture density interpretation as well as strong Aeromagnetic indications of a "blocky" basement structure. Further study of this area would include the possible horst block flexures and pinch-outs reservoir traps. A Plattsburgh area study of the possible structural and fault traps associated with the Taconic Orogeny would further illuminate hydrocarbon potential.

DISCLAIMER:

This report is limited in scope, as per the "Frontier Basins Geologic Investigation, Geological Services Requested" (RFP) No. 374-96. Further technical and economic review would be necessary if the RFP scope were to be expanded.

All information within this report is subject to change with time and/or the incorporation of additional data. Dan A. Billman, Geologic Consultant, upon receiving additional or updated information, reserves the right for future adjustments of any estimations or assumptions applied within this report. This report was prepared under accepted geologic and economic practices. Dan A. Billman, Geologic Consultant, makes no guarantee, either expressed or implied, on the accuracy of information and data provided through outside sources.

Prepared by:
Dan A. Billman, P.G.
Geologic Consultant

REFERENCES AND BIBLIOGRAPHY:

Aguilera, R., 1978, Log Analysis of Gas-bearing Fractures in the Saint Lawrence Lowlands of Quebec, SPE 7445, SPE.AIME 53rd Annual Fall Technical Conference and Exhibition, p.16.

Ando, C.J., B.L. Czuchra, S.L. Klemperer, L.D. Brown, M.J. Cheadle, F.A. Cook, J.E. Oliver, S. Kaufman, T. Walsh, J.B. Thompson, Jr., J.B. Lyons and J.L. Rosenfeld, 1984, Crustal Profile of a Mountain Belt: COCORP Deep Seismic Profiling in New England Appalachians and Implications for Architecture of Convergent Mountain Chains AAPG Bulletin, v. 68, no. 4, p.819-837.

Anonymous, 1960, Operational Base Unitary Silo, Plattsburgh A.F.B., New York, New York State Geological Survey, Open File No. 6xF 332.

Anonymous, 1987a, A New York State Proposal for the Superconducting Super Collider, The St. Regis Valley Site, Geology and Tunneling, New York State Geological Survey, Open File No. 6qS 070, v. 3, p. 1-38.

Anonymous, 1987b, A New York State Proposal for the Superconducting Super Collider, The St. Regis Valley Site, Geotechnical Data, New York State Geological Survey, Open File No. 6qS 070, Attachment D.

Beiers, R.J., 1975, Quebec Lowlands Overview and Hydrocarbon Potential, Ontario Petroleum Institute Annual Meeting, v. 14, no. 6, p. 1-20.

Beiers, R.J., 1976, Vast Sedimentary Basin of Quebec Lowlands Major Interest to SOQUIP, Oil & Gas Journal, v. 74, p. 194-208.

Billman, D.A. and J.P. Fagan, 1998, Hydrocarbon Potential of the St. Lawrence Lowlands of Northern New York: A Frontier Basin Investigation, AAPG Bulletin (Eastern AAPG Meeting abstract), v. 82, no.9, p. 1765.

Clark, T.H., 1965, Oil and Gas Potential of Quebec and the Maritime Provinces, Ontario Petroleum Institute Annual Meeting, v. 4, no. 11.

Cushing, H.P., 1899, The Morrison Well, 53rd Annual Report of the Regents, p. r68-r69.

Dineen, R.J., J.F. Davis and R.H. Fakundiny, unknown date, Report of the Geological Survey - New York State Museum and Science Service, to the Atomic and Space Development Authority on the Nuclear Breeder Reactor Site at Waddington, New York, New York State Geological Survey, Open File No. 6xF 332.

Dolfi, R.U. and G.M. Friedman, 1983, Regional Lithofacies of Lower Ordovician (Canadian-Age) Strata of New York and New England, Northeastern Geology, v. 5, no. 1, p. 40-53.

Dykstra, J.C., 1992, Drilling for Deep Gas in Quebec, in Projected Deep Borehole Opportunity in the Albany Basin, New York, editor: G.M. Friedman, Northeastern Geology, v. 14, no. 1, p. 65-66.

Dykstra, J.C., 1993, Recent Gas Exploration in the St. Lawrence Lowlands, Quebec, Ontario Petroleum Institute Annual Meeting, v. 31, no. 10.

Dykstra, J.C. and M.W. Longman, 1995, Gas Reservoir Potential of the Lower Ordovician Beekmantown Group, Quebec Lowlands, Canada, AAPG Bulletin, v. 79, no. 4, p.513-530.

Earth Satellite Corporation, 1997, Remote Sensing and Fracture Analysis for Petroleum Exploration of Ordovician to Devonian Fractured Reservoirs in New York State, Final Report, April 1997, 4538-ERTER-ER-97.

Erickson, M.J. and T.W. Bjerstedt, 1993, Trace Fossils and Stratigraphy in the Potsdam and Theresa Formations of the St. Lawrence Lowlands, New York, Field Trip A3 (2), New York State Geological Association 65th Annual Meeting, editor: J.T. Bursnall, September 24-26, 1993, p. 97-130.

Friedman, G.M., 1994, Upper Cambrian - Lower Ordovician (Sauk) Platform Carbonates of the Northern Appalachian (Gondwana) Passive Margin, Carbonates and Evaporites, v. 9, no. 2, p. 143-150.

Harris, R.L. and G.M. Friedman, 1982, Depositional Environments of the Subsurface Ogdensburg Formation (Lower Ordovician) in Northern New York State, Northeastern Geology, v. 4, no. 3&4, p. 151-166.

Fisher, D.W., 1968, Geology of the Plattsburgh and Rouses Point, New York - Vermont, Quadrangles, New York State Museum and Science Service Map and Chart Series no. 10, p. 1-51.

Guo, B., J.E. Sanders and G.M. Friedman, 1990, Columbia Gas Company No. 1 Finnegan Boring, Washington County, New York: Microlithofacies and Petroleum Prospects in Lower Paleozoic Platform Strata Beneath Taconic Allochthon, Northeastern Geology, v. 12, p. 238-265.

Kirchgasser, W., 1971, Precambrian and Lower Paleozoic Stratigraphy, Northwest St. Lawrence and North Jefferson Counties, New York, Field Trip B, New York State Geological Association 43rd Annual Meeting, editor: B.B. Van Diver, May 7-9,1971, p. 1-24.

Milici, R.C., 1996, Blue Ridge Thrust Belt (068), Piedmont Province (069), Atlantic Coastal Plain Province (070), Adirondack Province (071) and New England Province (072), in 1995 National Assessment of United States Oil and Gas Resources - Results, Methodology, and Supporting Data, USGS DDS-30, release 2, editors: D.L. Gautier, G.L. Dolton, K.I. Takahashi and K.L. Varnes, CD-ROM.

Newland, D.H. and C.A. Hartnagel, 1932, Review of the Natural Gas and Petroleum Developments in New York State, February 1932, p. 165-167.

Petzet, G.A., 1992, Quebec Cambro-Ordovician Exploration Focuses on Wilburton Arbuckle Analog, Oil & Gas Journal, v. 90 (February 17), no. 7, p. 82-83.

Robinson, J.E., 1982, Natural Gas Potential of the Potsdam Formation in New York State, Proceedings from: Appalachian Basin Industrial Associates Fall Meeting, p.11.

Robinson, J.E., 1989, Ordovician Petroleum Potential in New York State, Proceedings from: Appalachian Basin Industrial Associates Spring Meeting, p.91 - 106.

Robinson, J.E., 1991, Ordovician oil potential in New York detailed, Oil & Gas Journal, April 1, 1991, p. 74-78.

Selleck, B.W., 1984, Stratigraphy and Sedimentology of the Theresa Formation (Cambro-Ordovician) in Northwestern New York State, Northeastern Geology, v. 6, no. 2, pp. 118-129.

Selleck, B.W., 1987, Origin of Voids in Peritidal Facies of the Theresa Formation and Ogdensburg Dolostone (Lower Ordovician), New York and Ontario, Northeastern Geology, v. 9, no. 2, pp. 76-88.

Selleck, B.W., 1988, Middle Ordovician Stratigraphy and Sedimentology - Southern Lake Champlain Valley, Field Trip B3, New York State Geological Association 60th Annual Meeting, editor: J.F. Olmsted, October 8-9, 1988, p. 245-261.

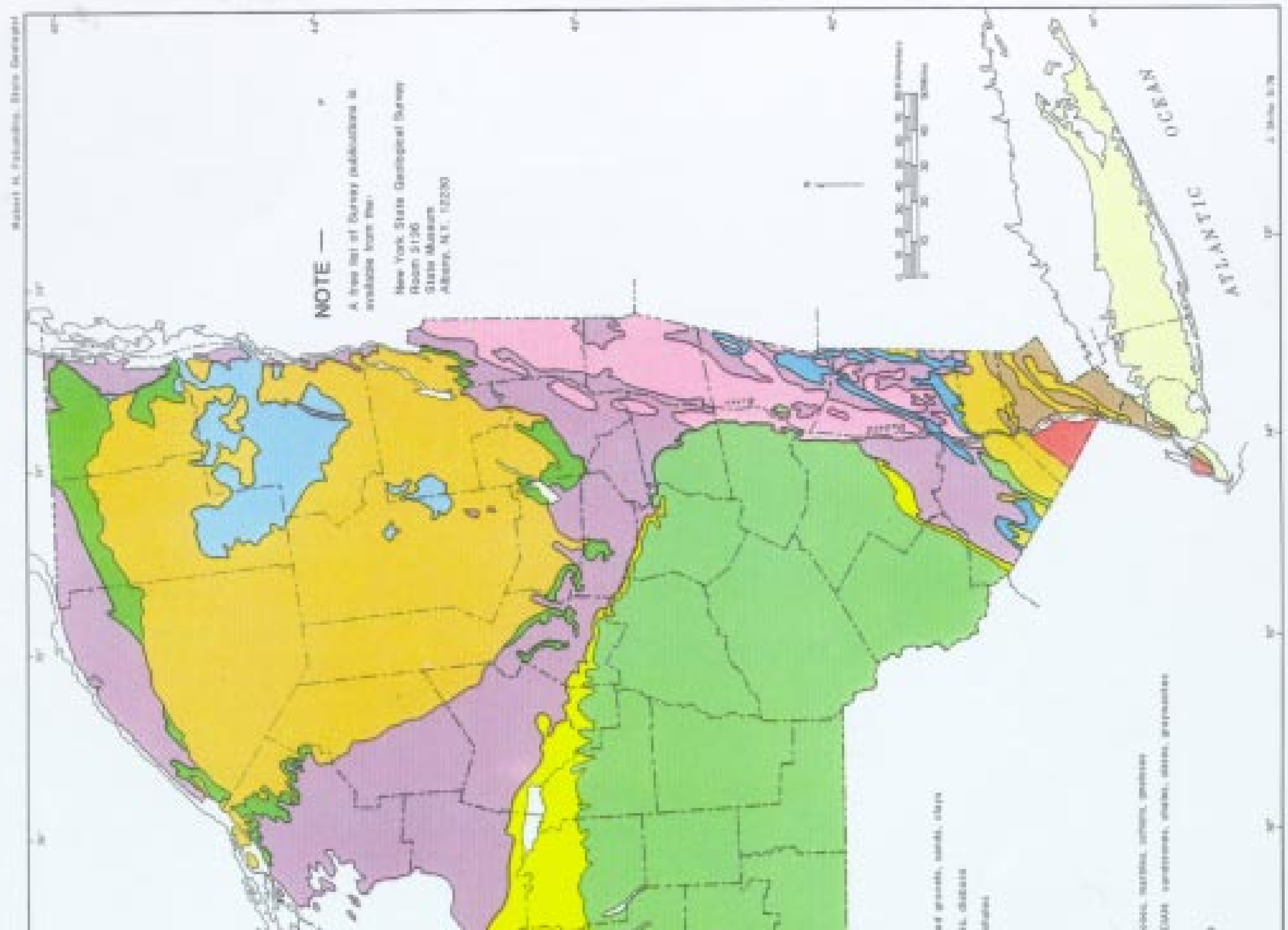
Selleck, B.W., 1993, Sedimentology and Diagenesis of the Potsdam Sandstone and Theresa Formation, Southwestern St. Lawrence Valley, Field Trip B3, New York State Geological Association 65th Annual Meeting, editor: J.T. Bursnall, September 24-26, 1993, p. 219-228.

Shaw, B.R., 1993, Strike-slip Interpretation of Basin-bounding Faults of the St. Lawrence Lowlands Basin in the Quebec City Area, Canada, AAPG Bulletin, v.77, no. 5, p.743-760.

Van Diver, B.B., 1983, Geologic Transverse from Potsdam to the Thousand Islands, Field Trip 2, New York State Geological Association 55th Annual Meeting, September 23-25, 1983, p. 1-19.

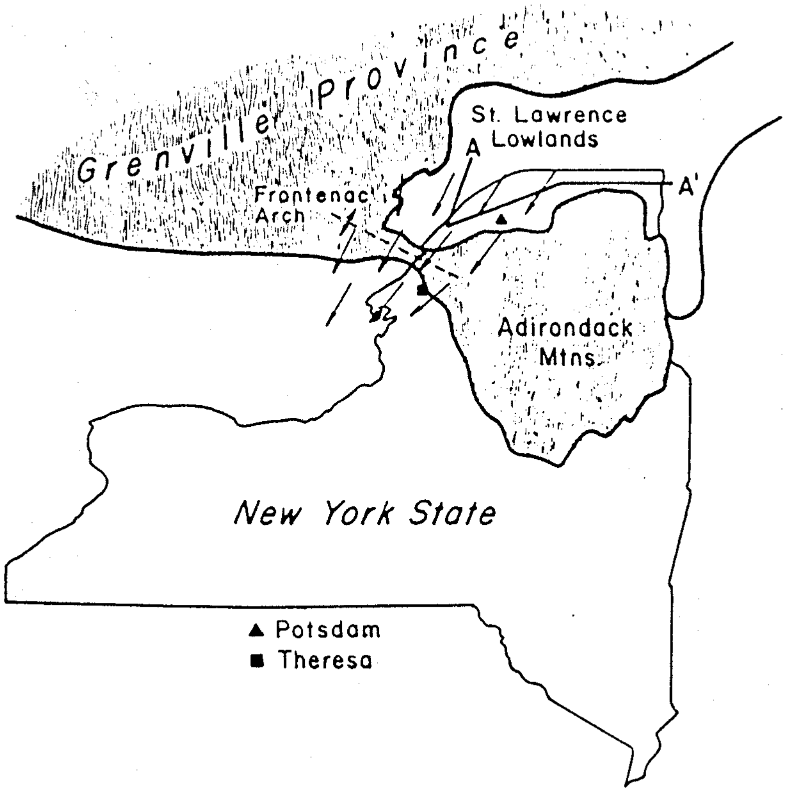
FIGURES

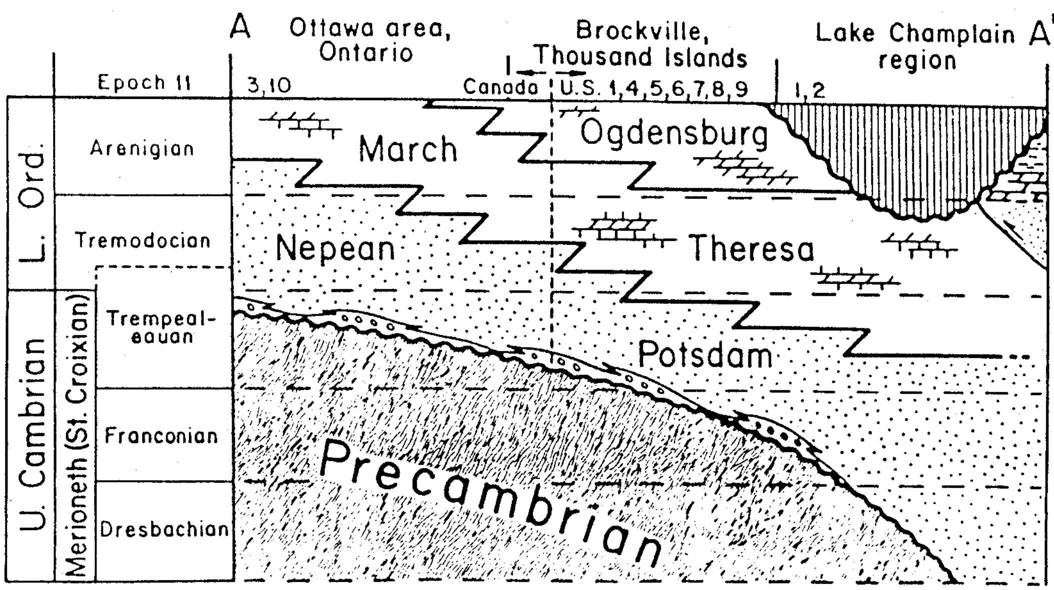
Figure 1:	State Geologic Map
Figure 2:	Canadian/United States Schematic Section and Map
Figure 3:	Strat Column
Figure 4:	Dykstra Schematic
Figure 5:	Beiers' Seismic
Figure 6:	Shaw's Flower Structure
Figure 7:	Beiers' Schematic cross-section
Figure 8:	Beiers' faulted seismic
Figure 9:	Beiers' Faulted seismic
Figure 10:	St. Flaven and Point du Lac fields (Dykstra)
Figure 11:	Dykstra's St. Simon cross-section
Figure 12:	Robinson's Potsdam Cayuga Co. log
Figure 13:	Robinson's Potsdam Cayuga Co. log
Figure 14a&b:	ESEC's Stell #1A
Figure 15:	Earth Satellite Corp's Geologic Interpretation of the Adirondack sheet
Figure 16:	Earth Satellite Corp's Fracture Density Analysis of the Adirondack sheet
Figure 17:	Susceptibility/Rock Type Model
Figure 18:	Single Horst Model
Figure 19:	Numerous Blocks Model



GENERALIZED BEDROCK GEOLOGY
of
NEW YORK
Compiled by the
Geological Survey, New York State Museum
1986
Lake Ontario
Lake Erie
ATLANTIC OCEAN
NOTE —
EXPLANATION

FIGURE 1





(From Erickson & Bjerstedt, NYSGA Fieldguide, 1993)

FIGURE 2

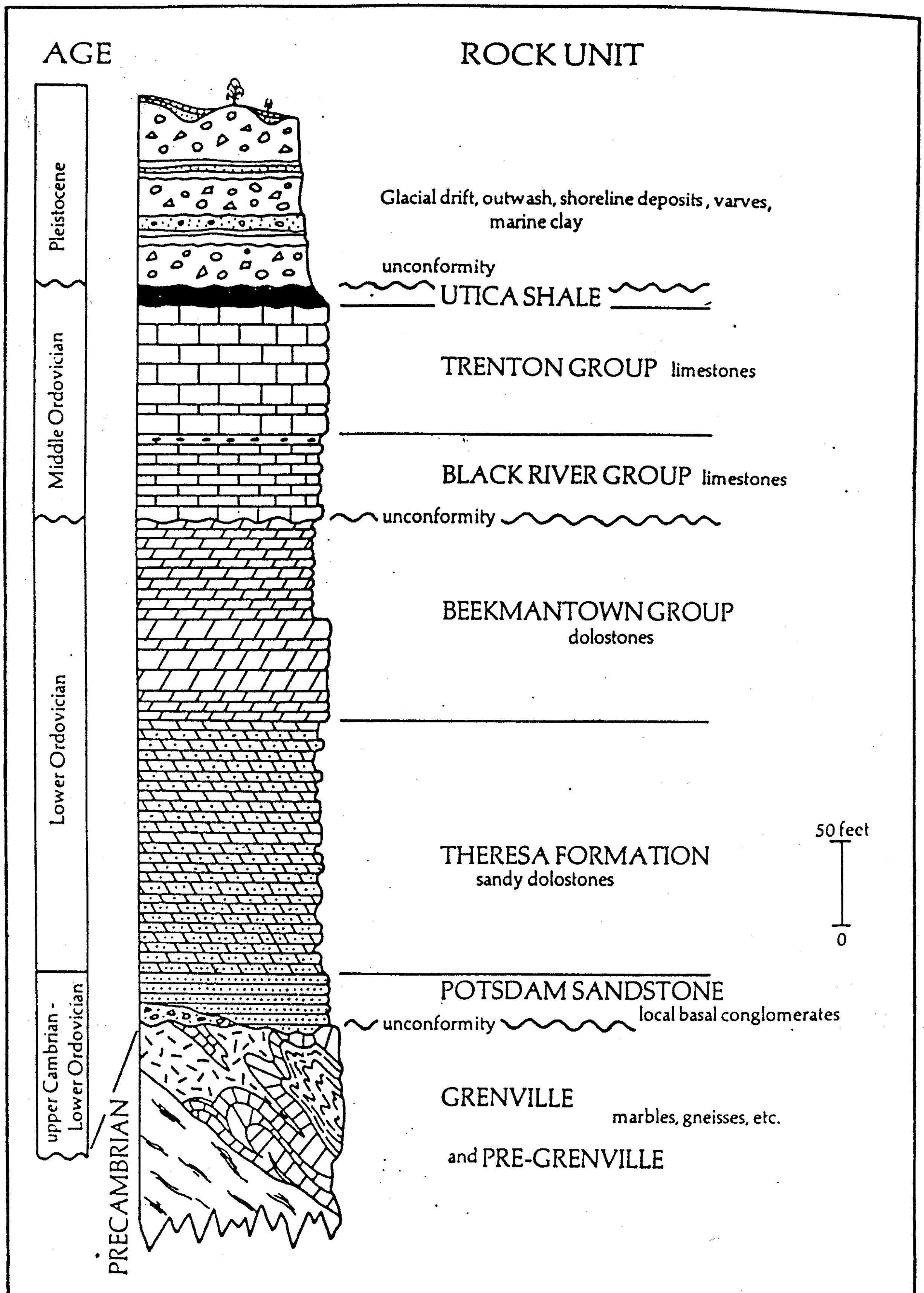


Figure 2. Composite Stratigraphic column for the Adirondacks and bordering lowlands of northwestern New York. From Van Diver (1980).

(From VanDiver, NYSGA Fieldguide, 1983)

FIGURE 3

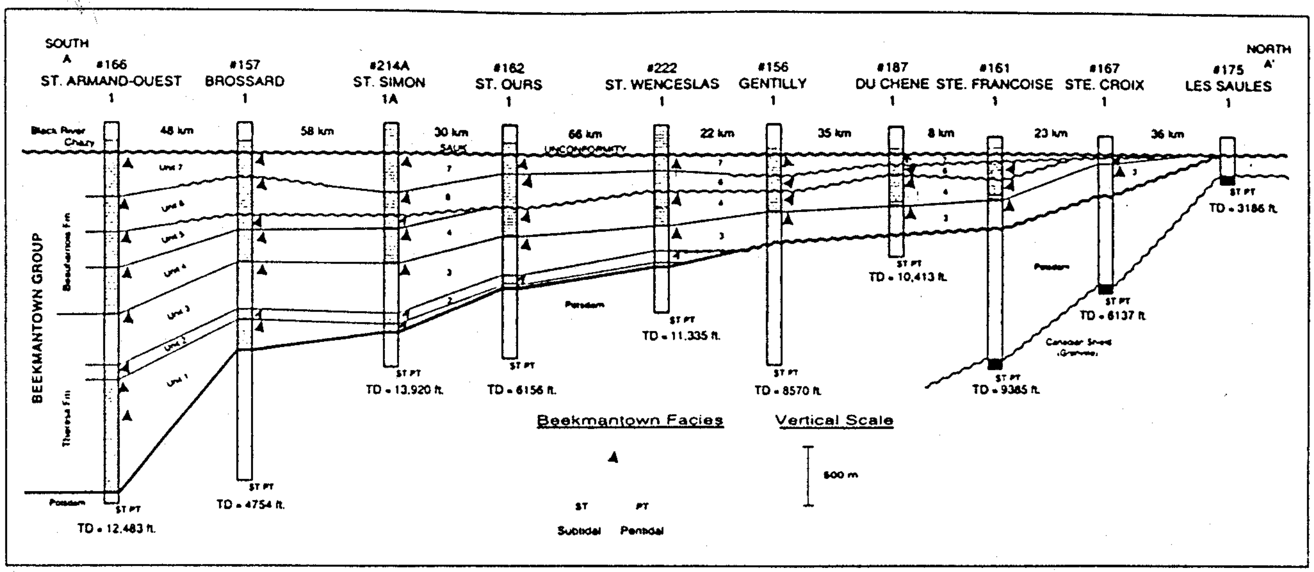


Figure 6—Regional cross section across the Quebec Lowlands area showing the geometry of the various units in the Beekmantown Group. Location of this section is shown in Figure 1.

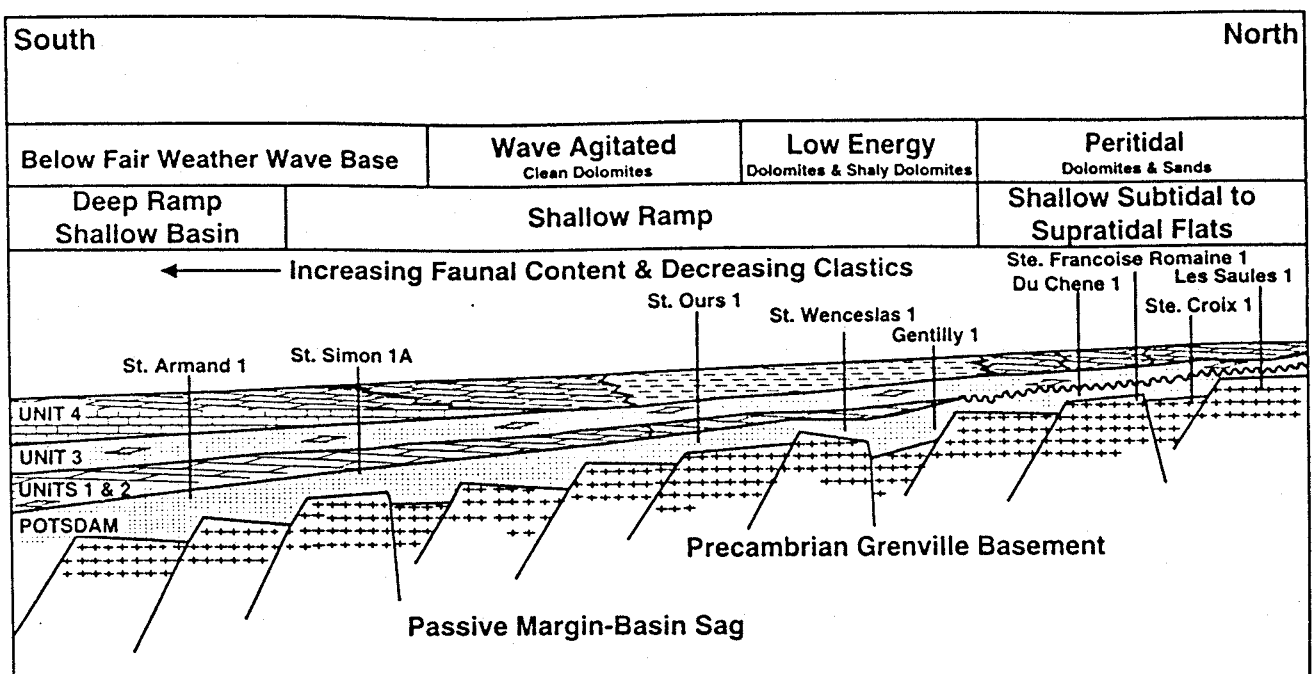
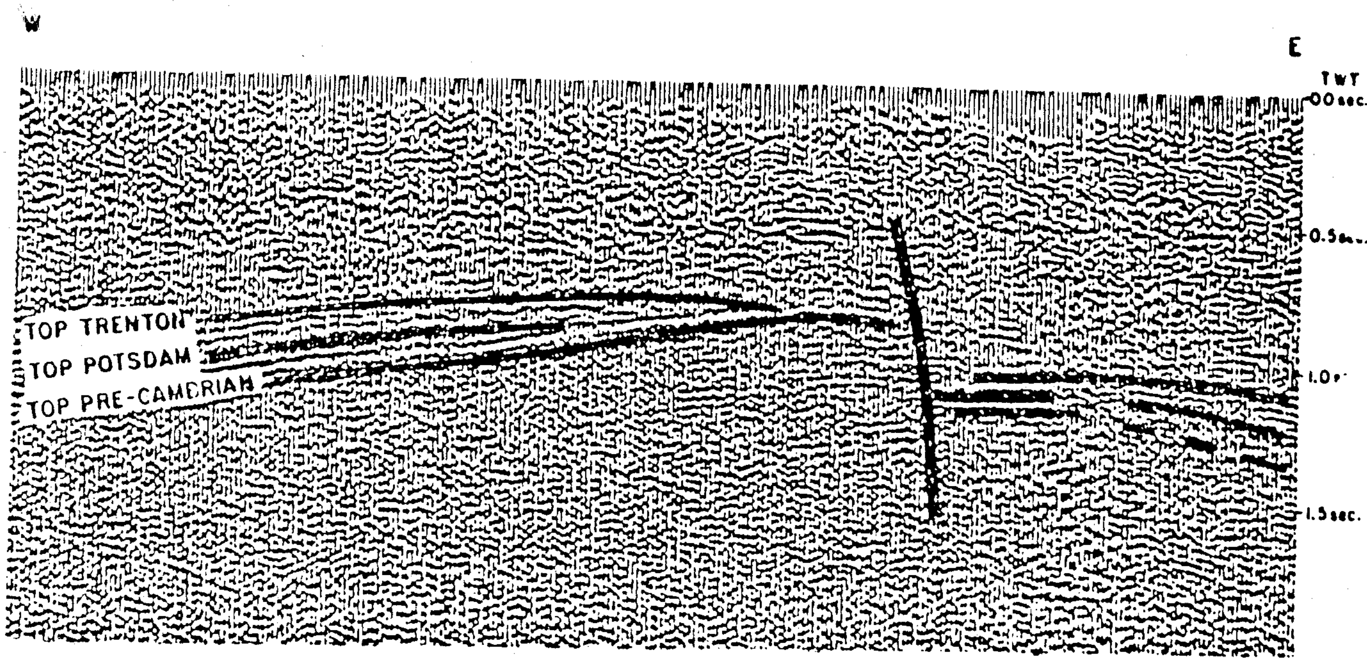


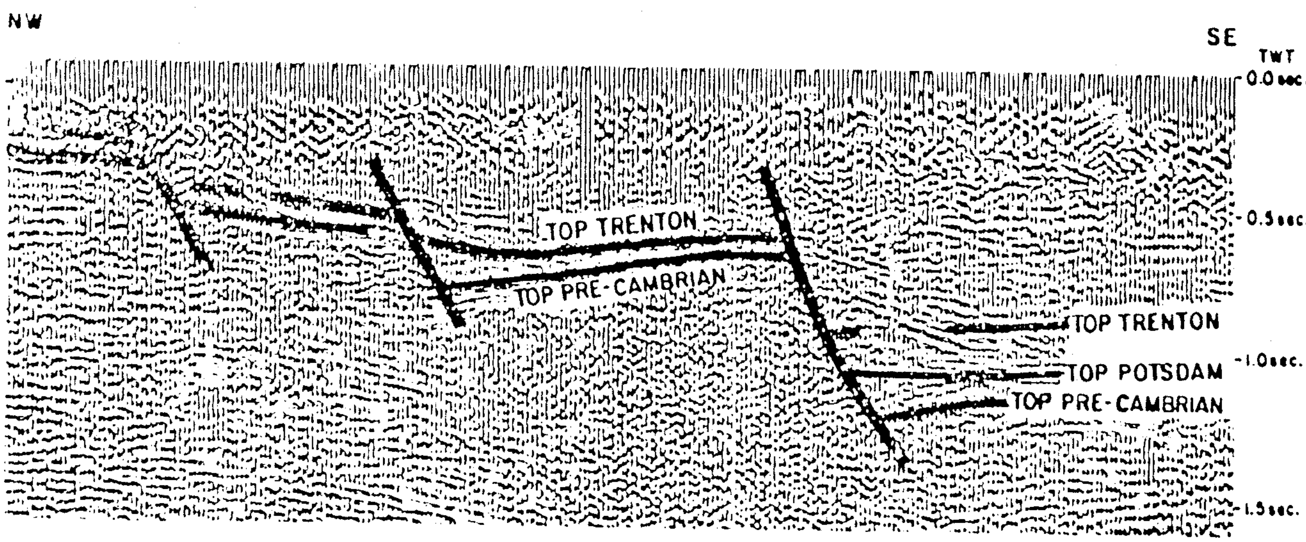
Figure 7—Schematic depositional profile of the carbonate ramp during unit 4 deposition.

(from Dykstra & Longman, AAPG Bulletin, 1995)

FIGURE 4



a) BASEMENT HIGH PINCHOUT



b) STEP FAULTING AND ASSOCIATED FAULT TRAPS

TECTONIC FEATURES IN
THE PLATFORM ZONE
QUEBEC LOWLANDS

≃ 1 mile

FIGURE 5

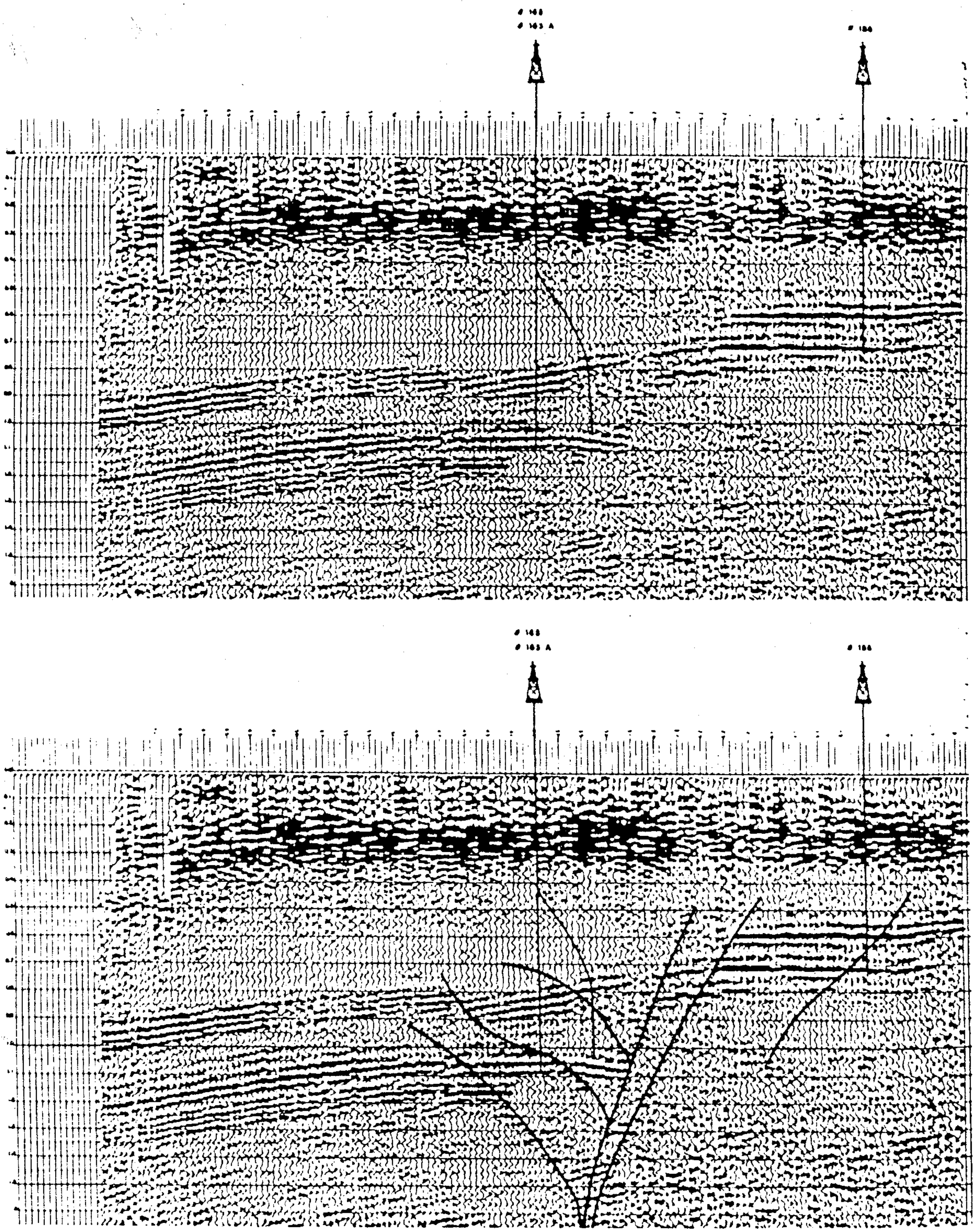
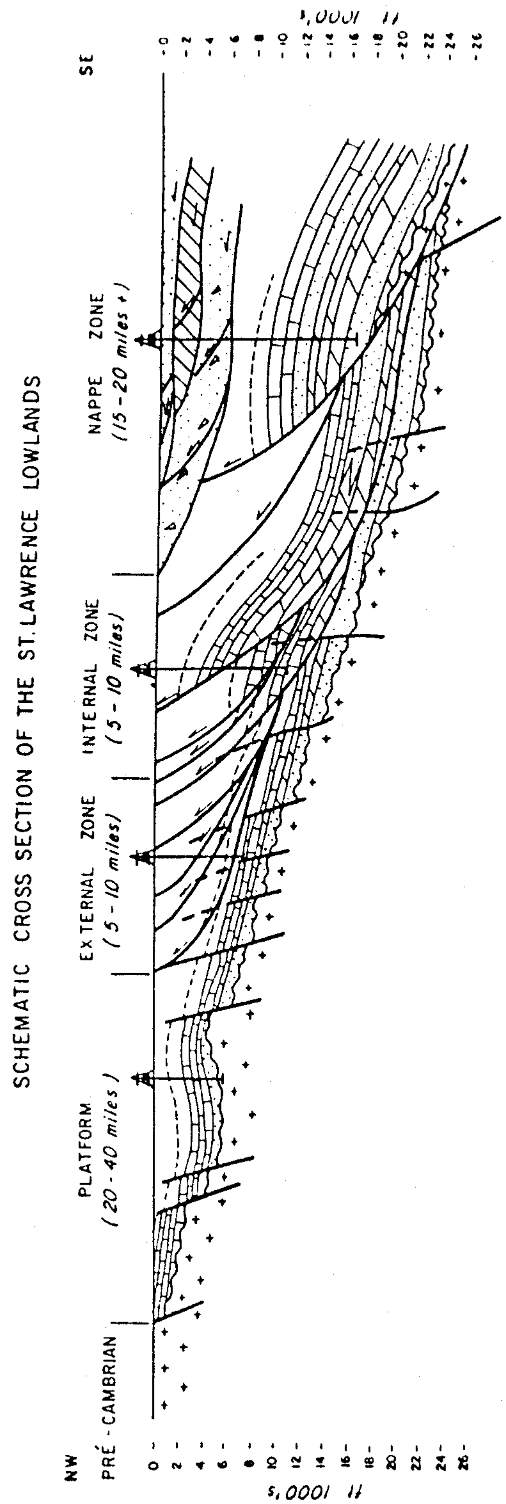


Figure 12—Seismic line 2 on the south shore of the St. Lawrence River in the Lac St. Pierre area. Line is c
perpendicular to the river, and located on Figure 1. From SOQUIP, with permission.

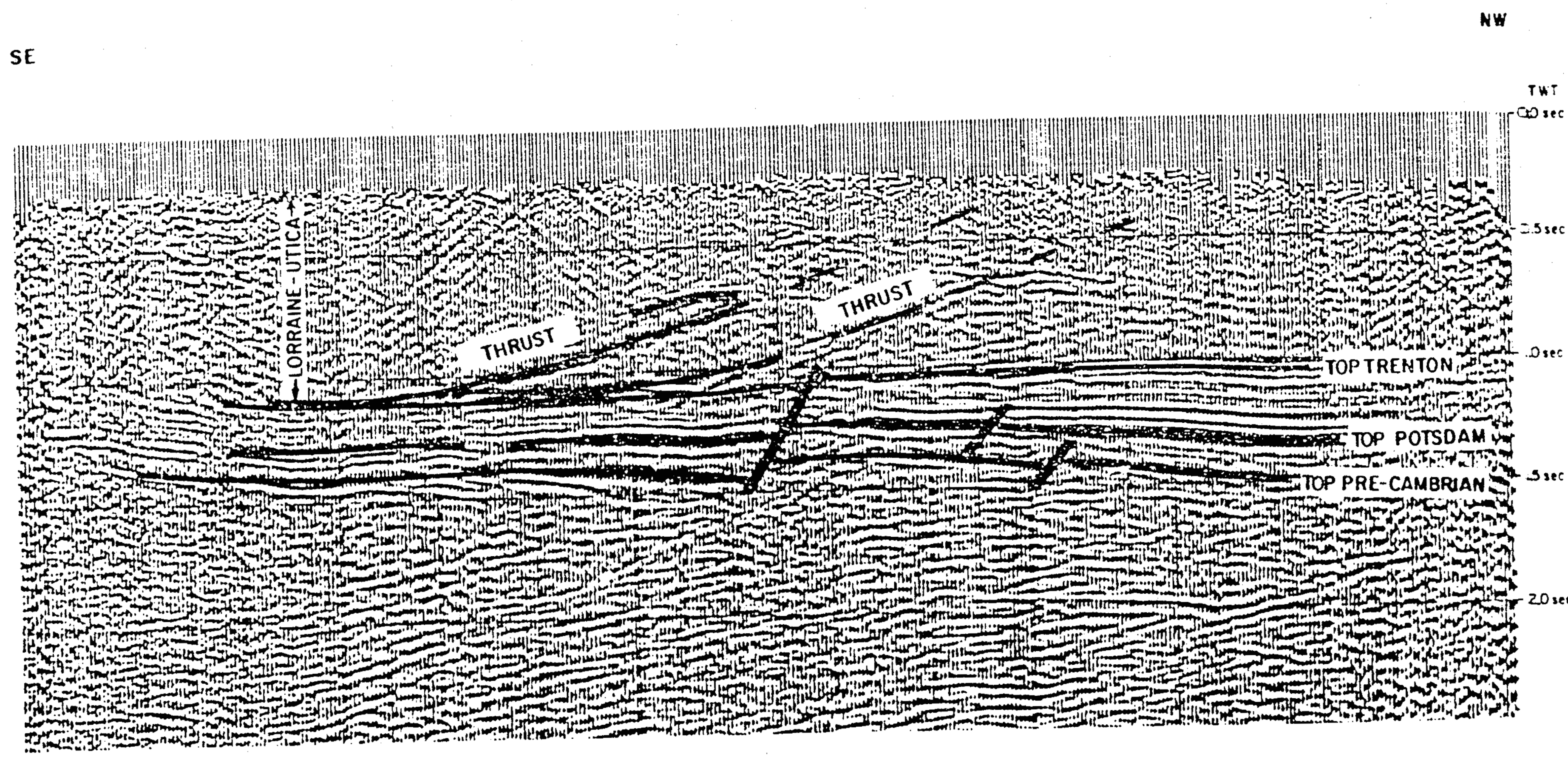
FIGURE 6



Page 11

Baiers.
Fig.3

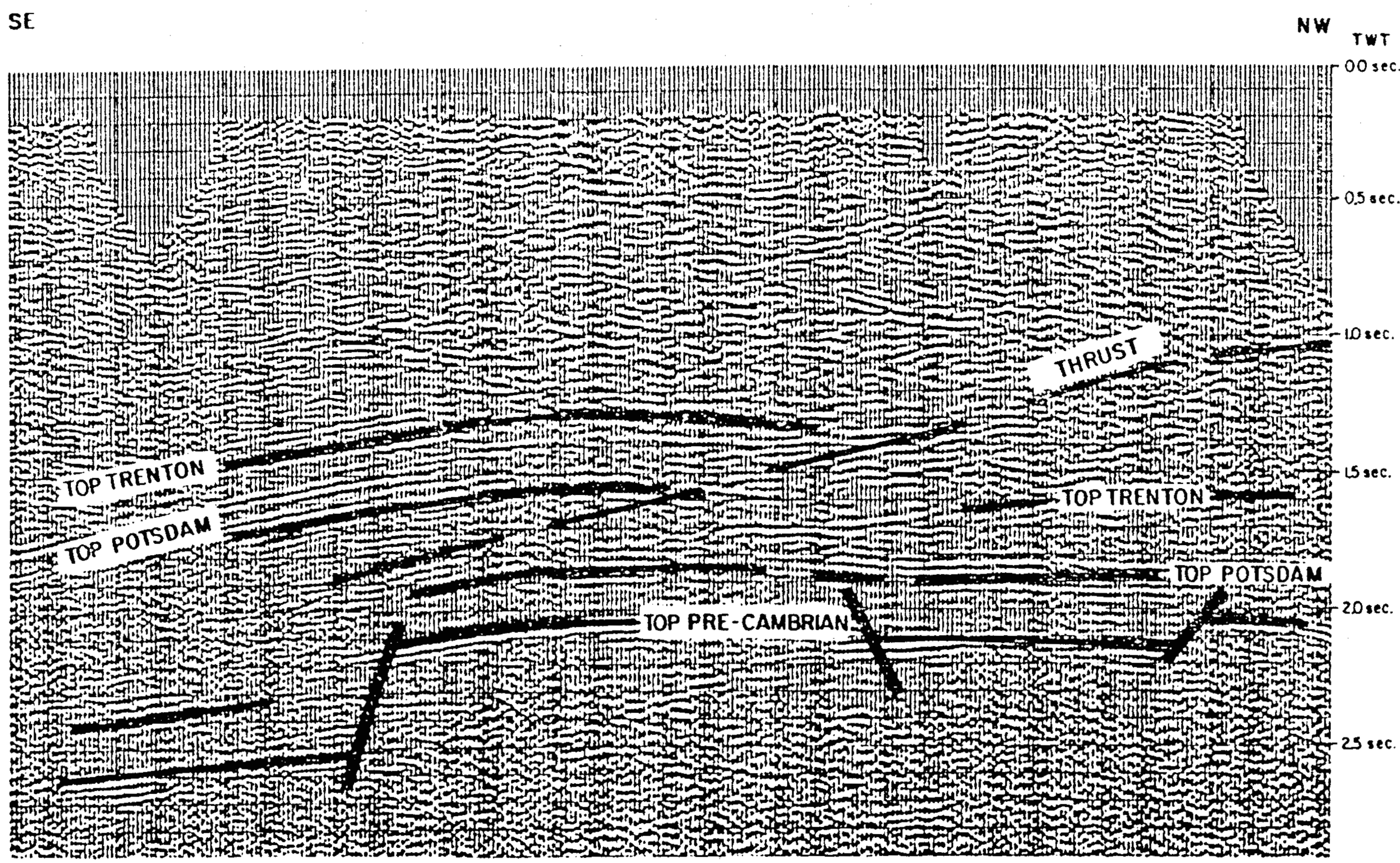
FIGURE 7



TECTONIC FEATURES IN THE
EXTERNAL ZONE
QUEBEC LOWLANDS

FIGURE 8

Beiers
Fig.8



TECTONIC FEATURES IN
THE INTERNAL AND NAPPE ZONE
QUEBEC LOWLANDS

FIGURE 9

Beiers
Fig. 10

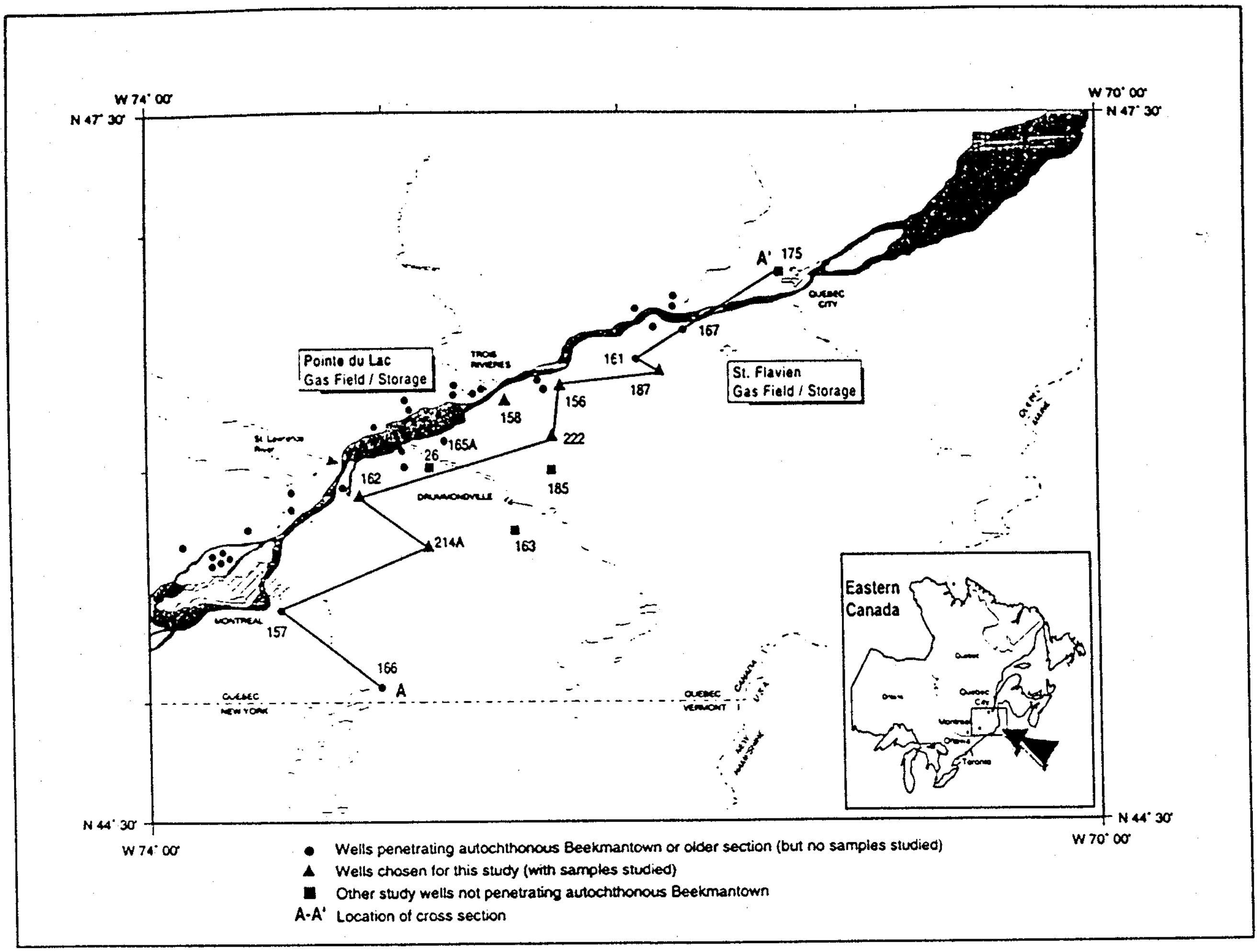
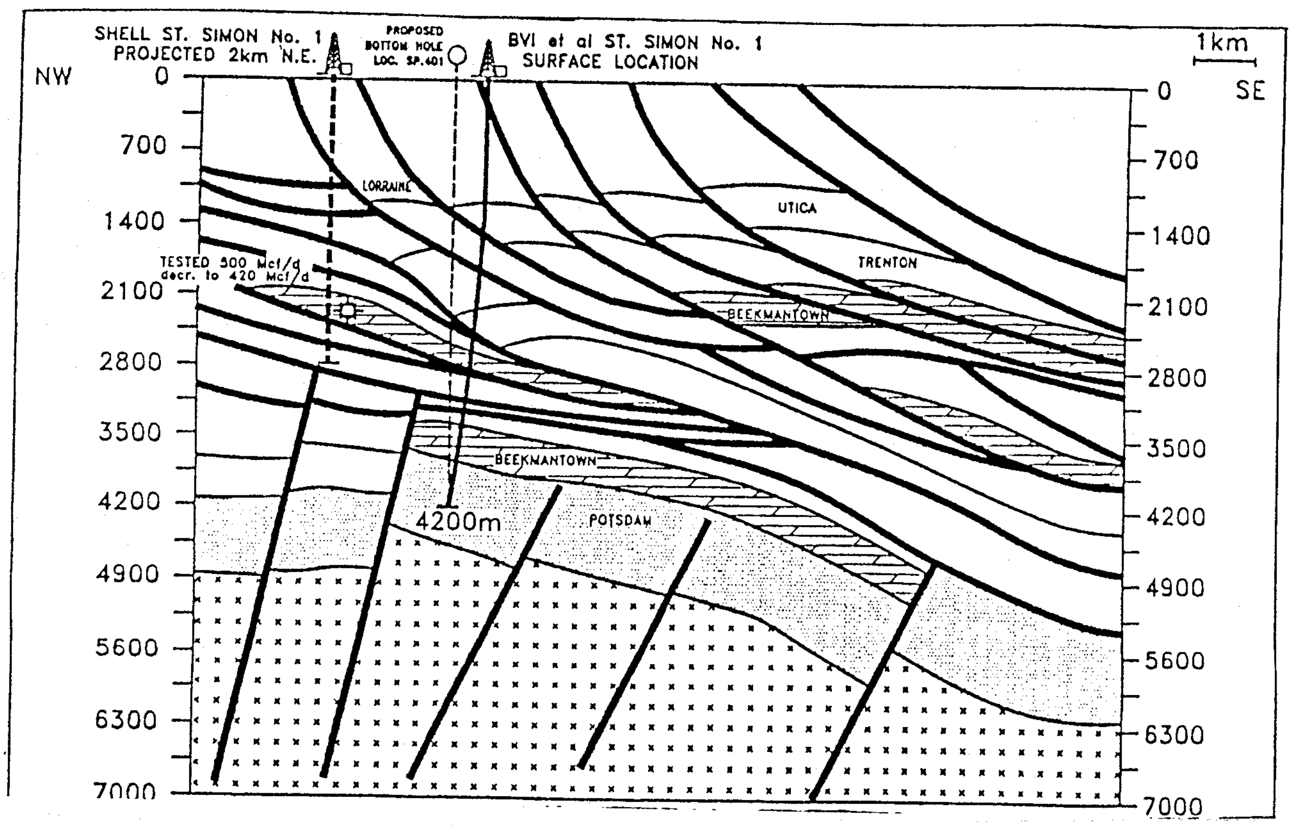


Figure 1—Distribution of wells used in this study of the autochthonous Beekmantown section in the Quebec Lowlands. Other wells that penetrated only allochthonous Beekmantown in thrust sheets are indicated with a square symbol. Line of Figure 6 cross section is shown.

(from Dykstra & Longman, AAPG Bulletin, 1995)

LINE 89 - TQ-DO1 SEISMIC PROFILE



(from Dykstra, Northeastern Geology, 1992)

FIGURE 11a

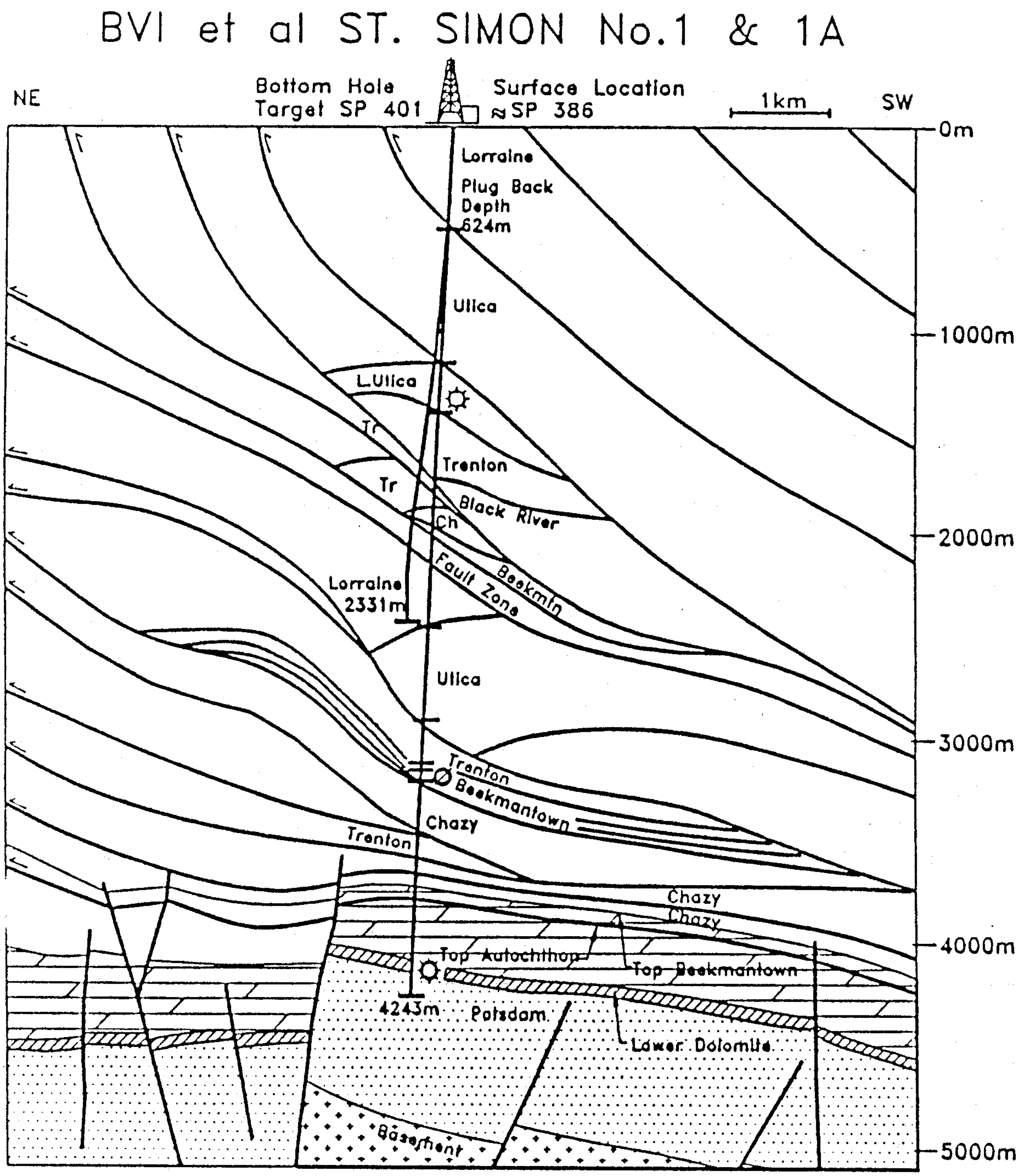
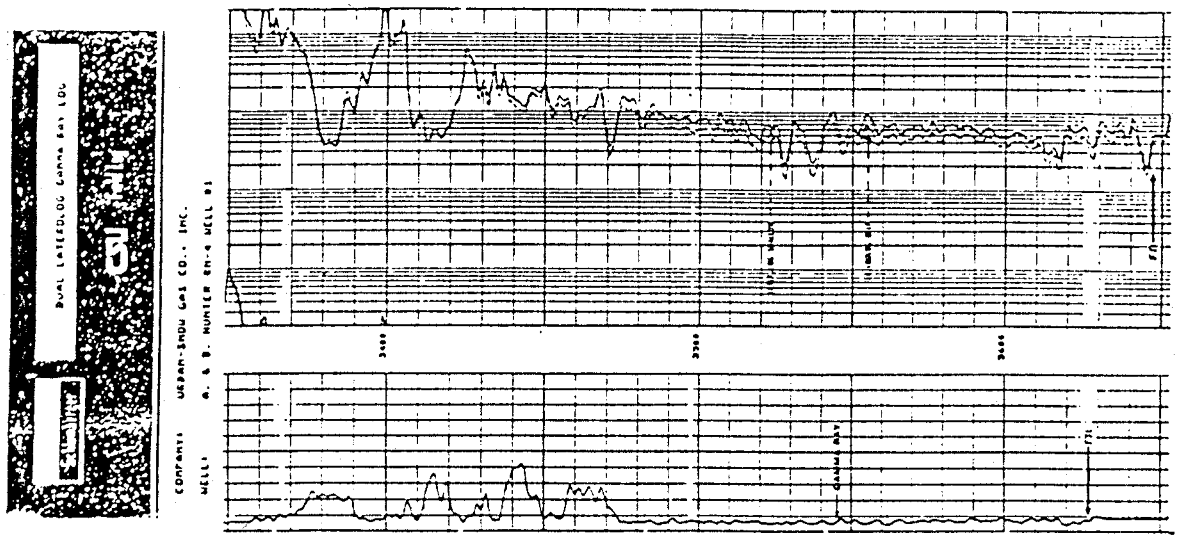
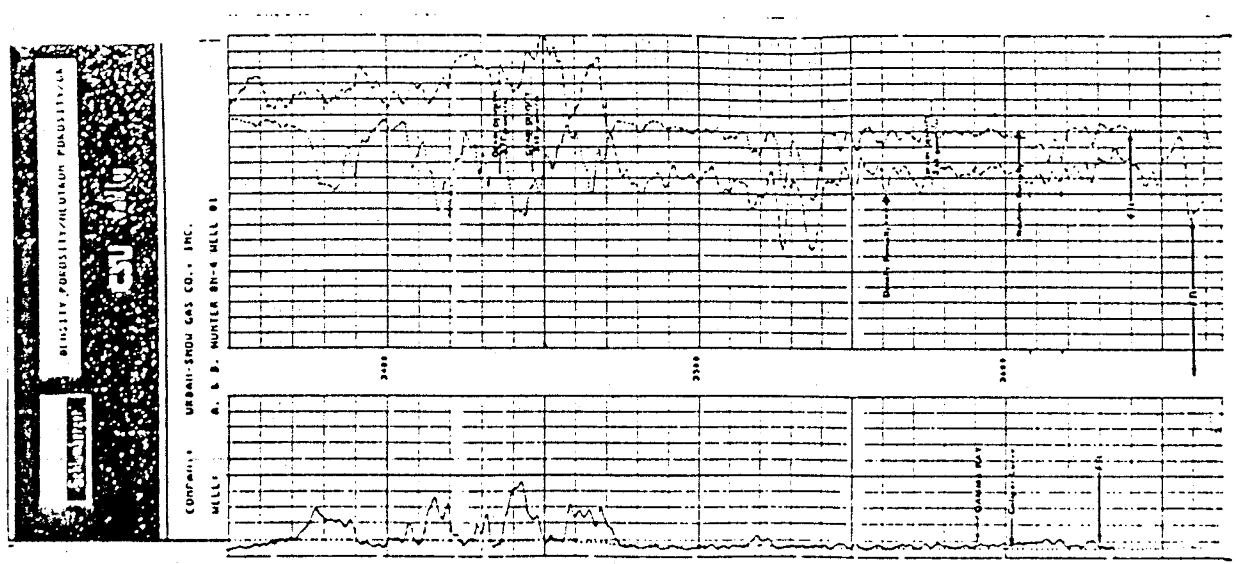


Figure 3. Seismic Profile showing the projection of the Bow Valley Industries et al St. Simon No.1 and 1A.

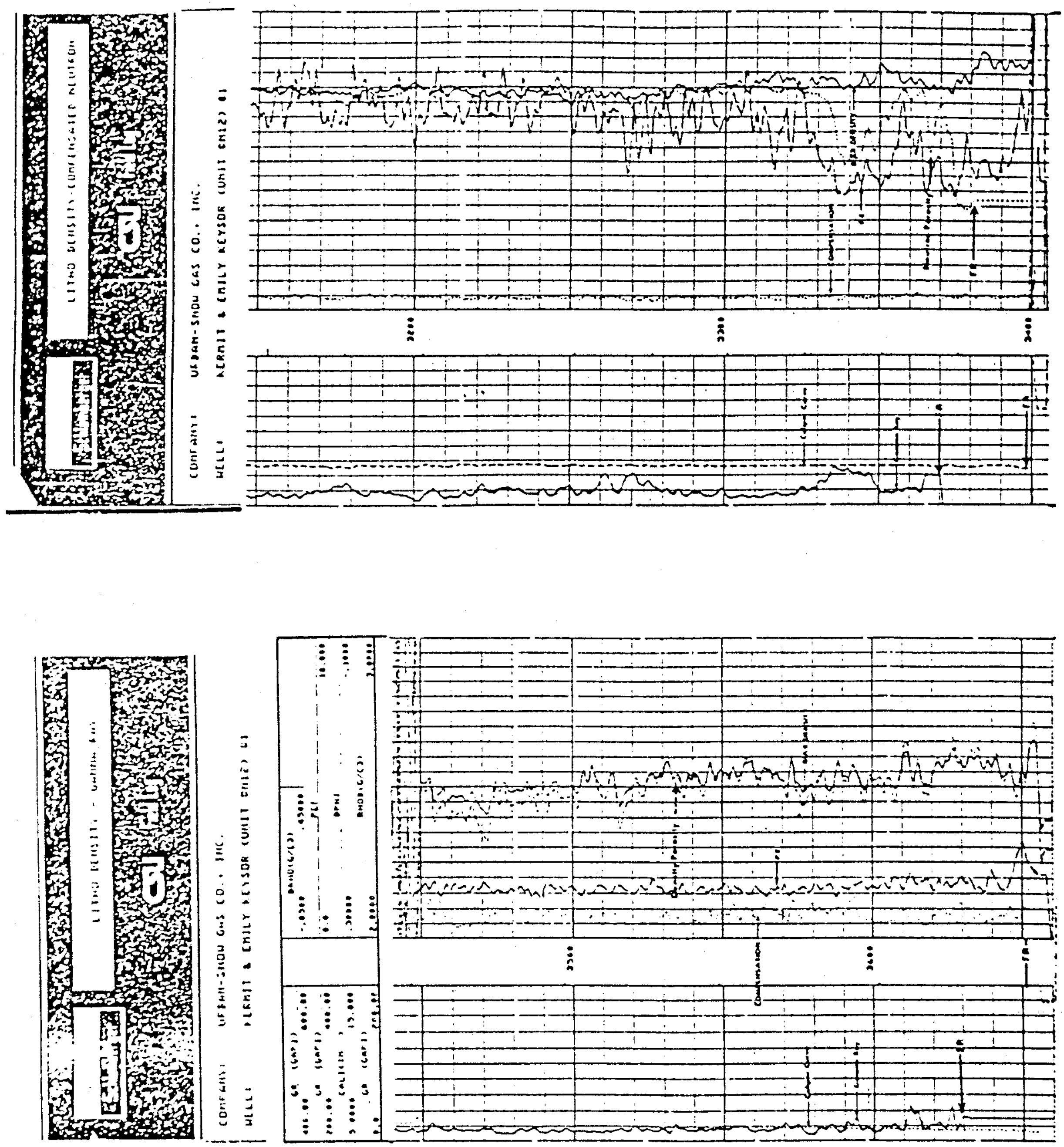
FIGURE 11b





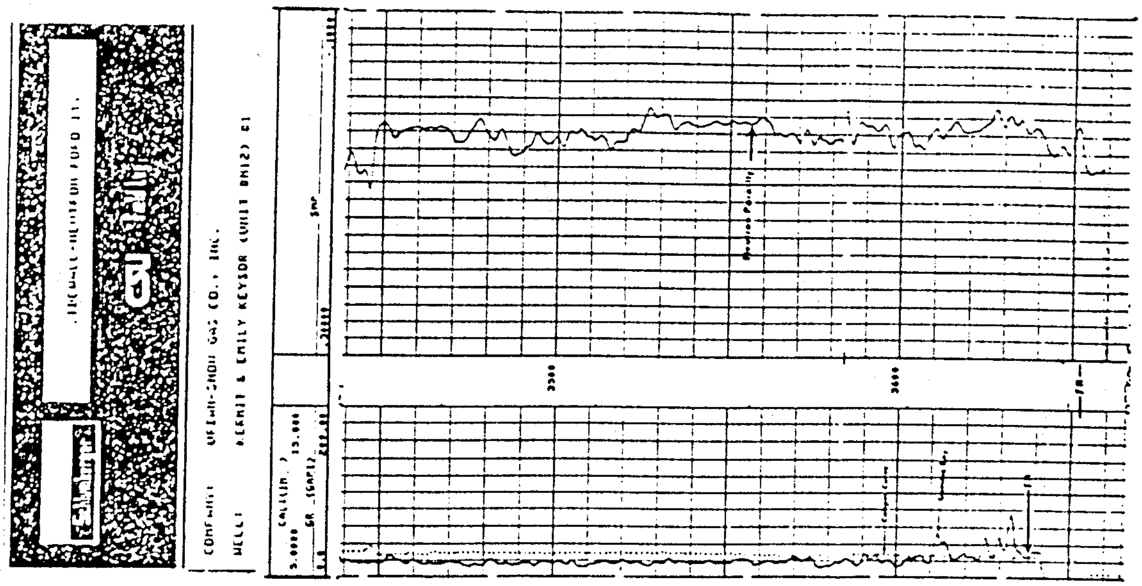
Normal Lower Paleozoic Section from a nearby Hunter Well

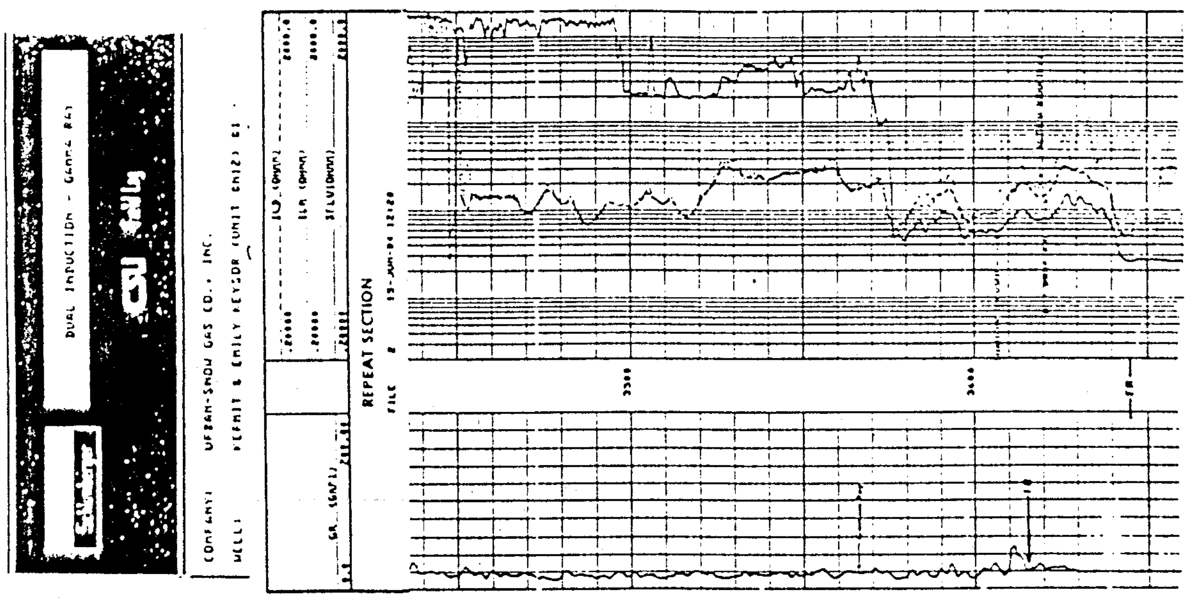
FIGURE 12



Litho Density Logs from the Keysor Well Black River and Potsdam Equivalent are shown. The anomalous section is from 3433 ft. to 3579 feet.

FIGURE 13a





Neutron Porosity and Dual Induction Logs From the Keysor Well. The anomalous section is from 3433 feet to 3579 feet.

FIGURE 13b

Eastern States Exploration Company
R.G. Stell #1A
Onondaga County, NY
31-067-21336
Gamma Ray/Density/Temperature

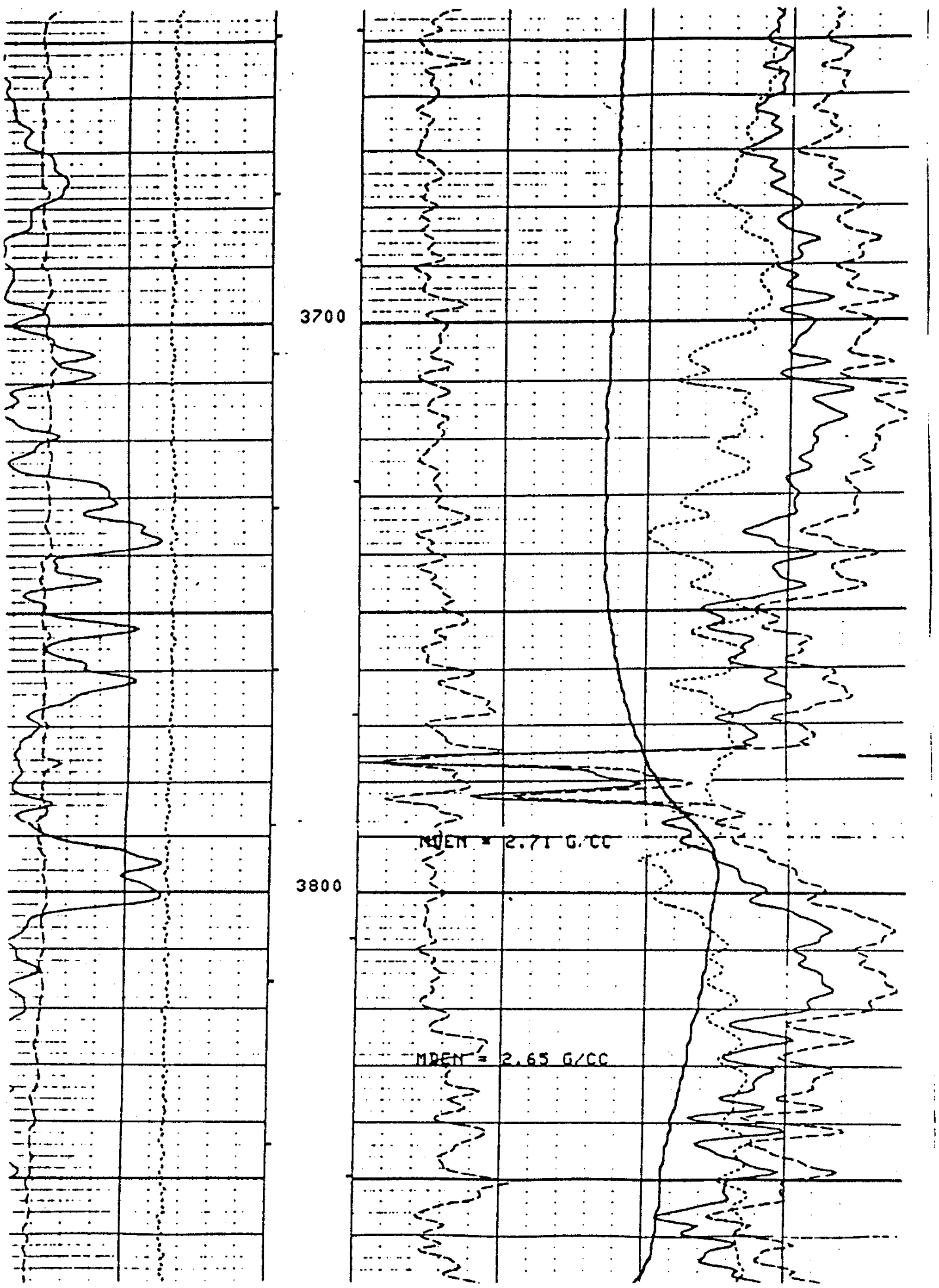


FIGURE 14a

Eastern States Exploration Company
R.G. Stell #1A
Onondaga County, NY
31-067-21336
Gamma Ray/Induction/Temperature

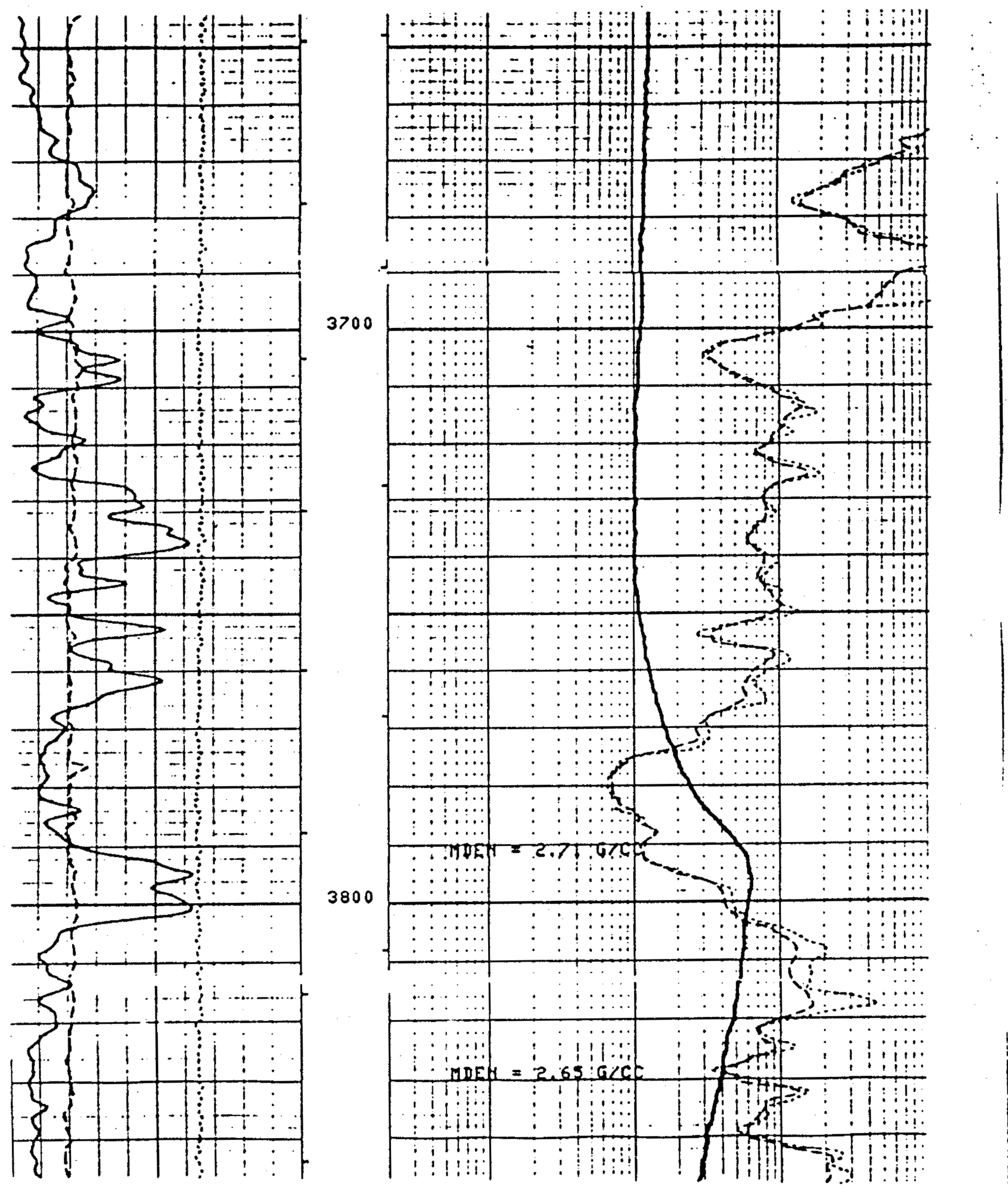


FIGURE 14b

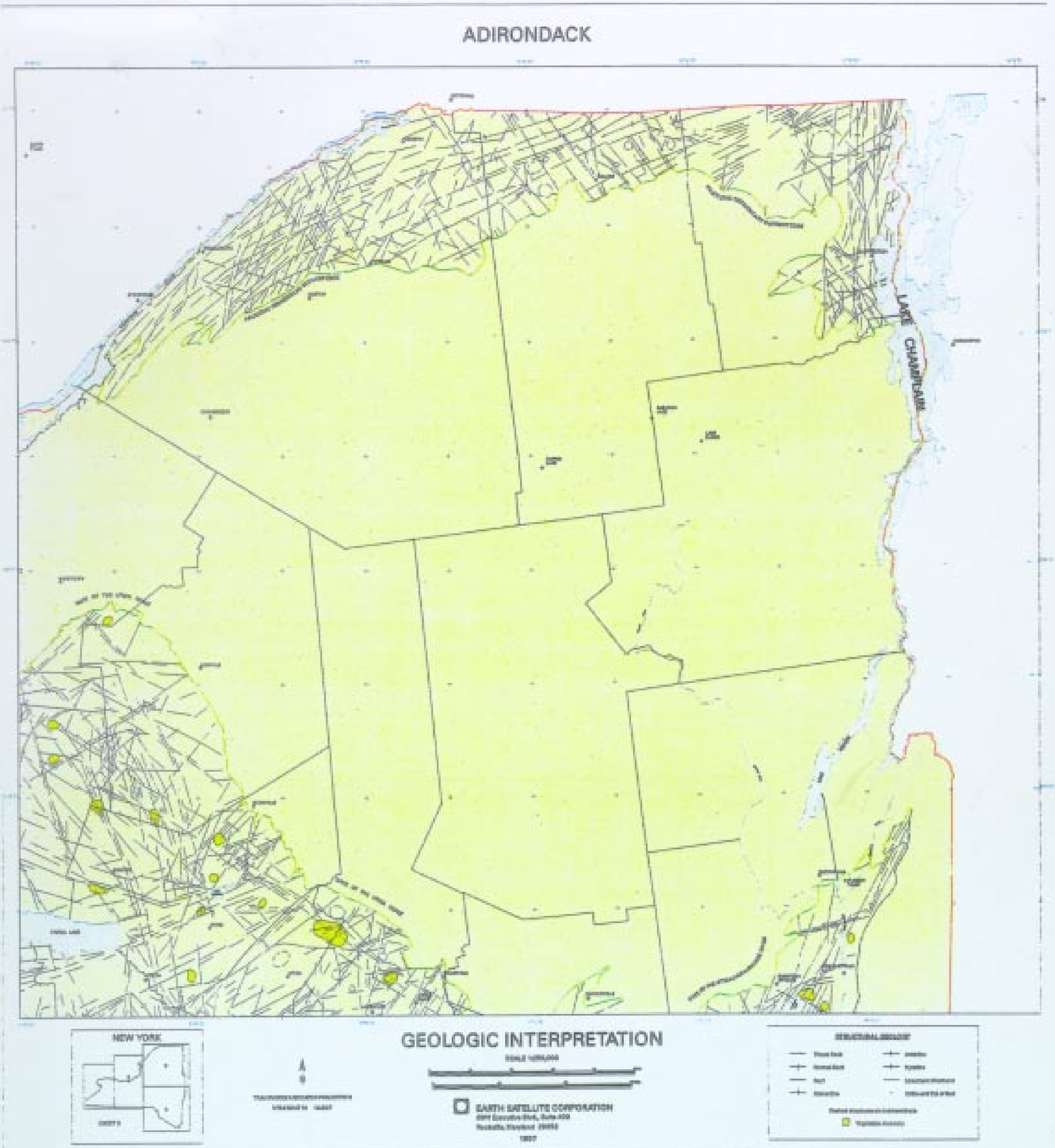

ADIRONDACK
LAKE CHAMPLAIN
NEW YORK
GEOLOGIC INTERPRETATION
EARTH SATELLITE CORPORATION

FIGURE 15

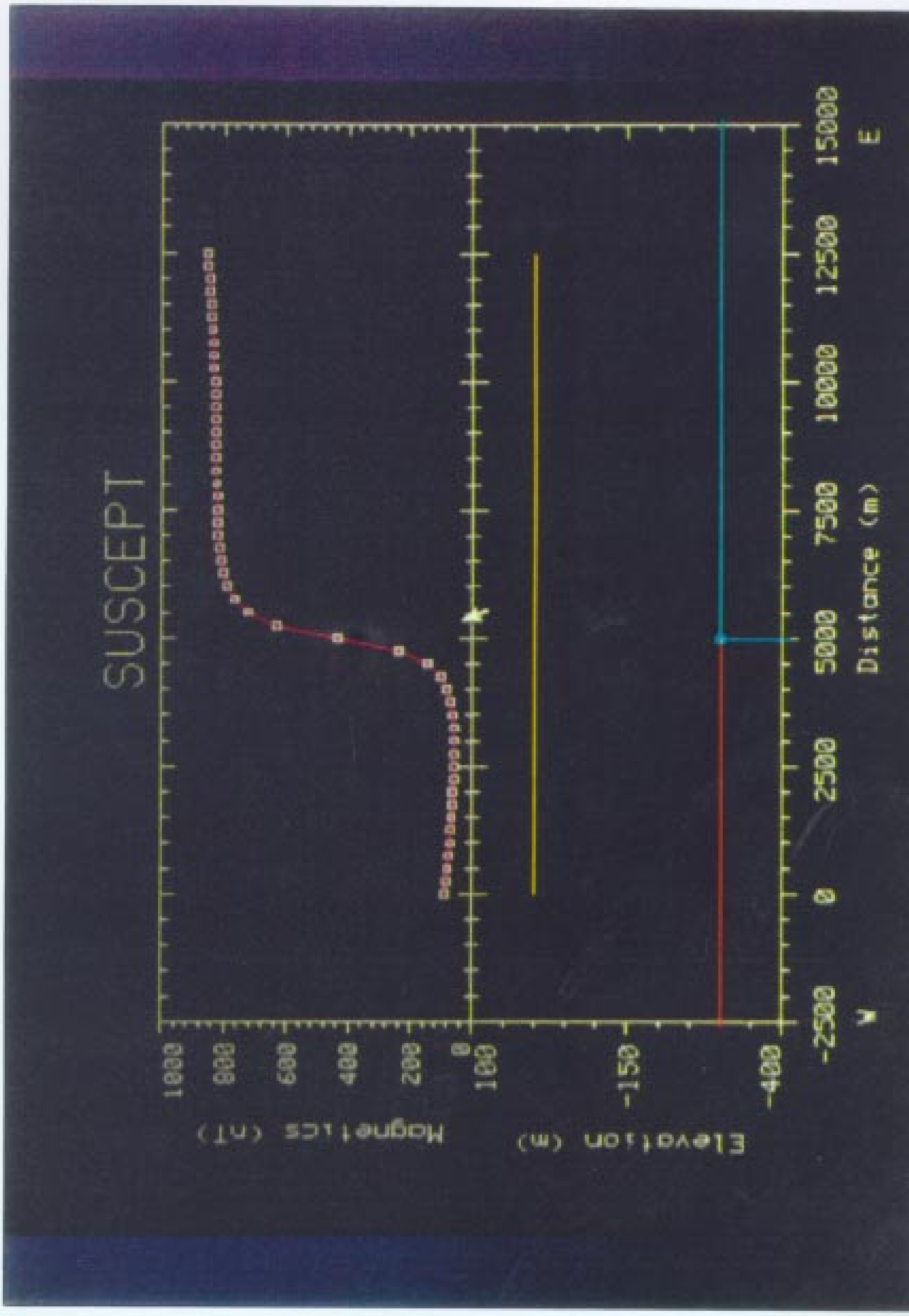

SUSCEPT
Magnetics (nT)
1000
800
600
400
200
0
100
-150
-400
Elevation (m)
-2500
0
2500
5000
7500
10000
12500
15000
W
E
Distance (m)

FIGURE 17

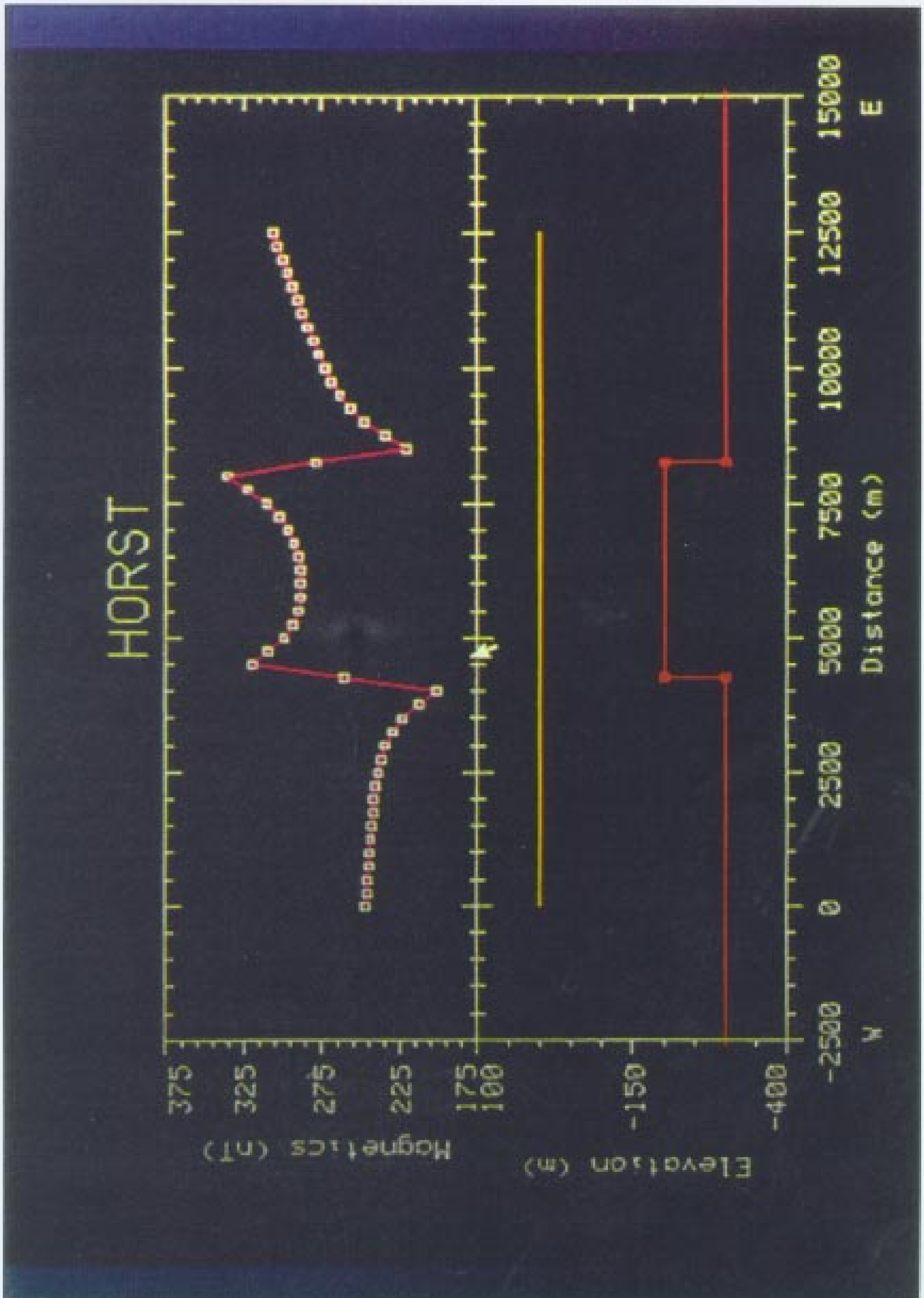

HORST
Magnetics (nT)
375
325
275
225
175
Elevation (m)
100
-150
-400
-2500
0
2500
5000
7500
10000
12500
15000
W
E
Distance (m)

FIGURE 18

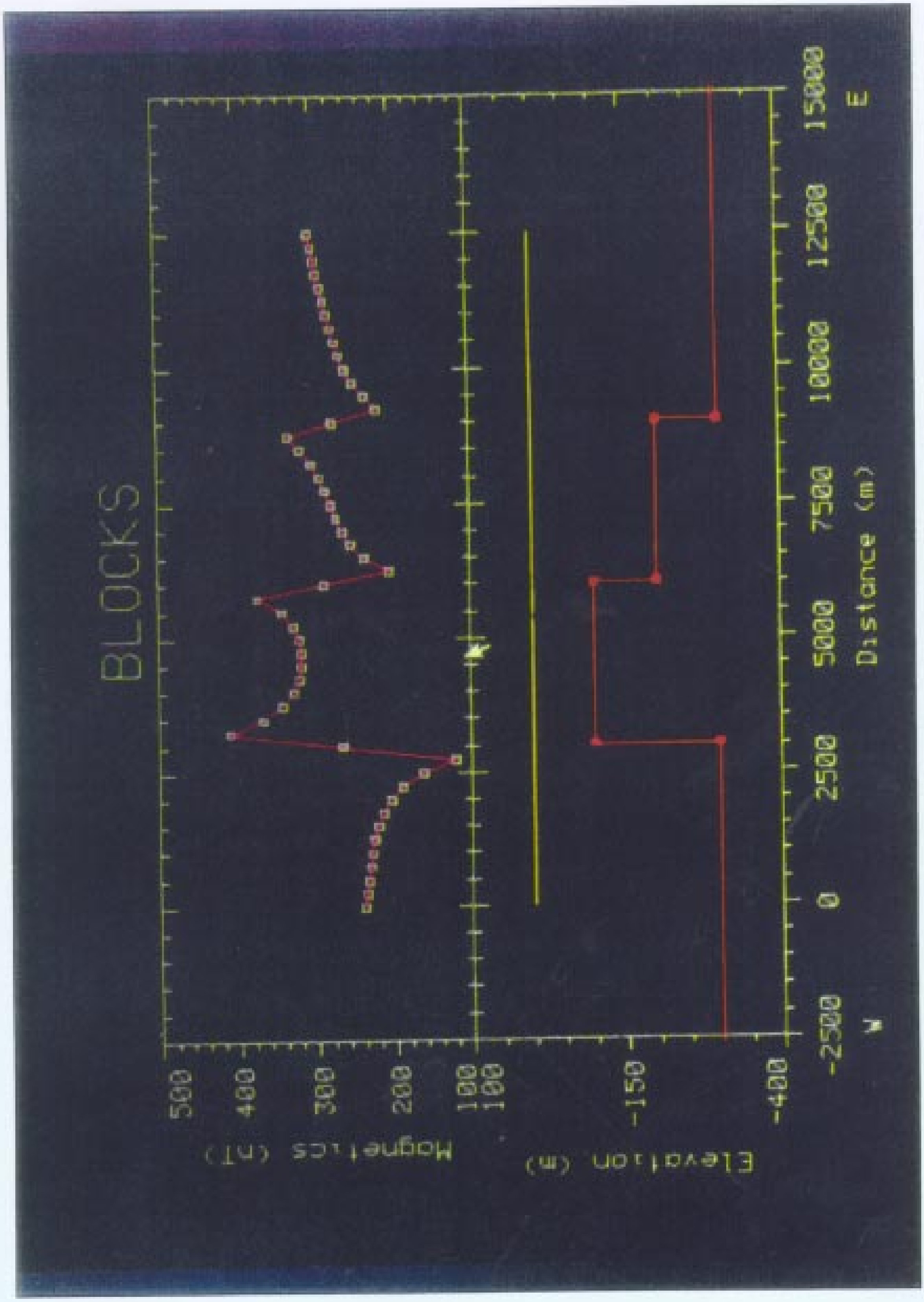

BLOCKS
Magnetics (nT)
500
400
300
200
100
100
-150
-400
Elevation (m)
-2500
0
2500
5000
7500
10000
12500
15000
W
E
Distance (m)

FIGURE 19