CHAPTER 4 CUMBERLAND AREA

INTRODUCTION

The Cumberland area in northern Nova Scotia (Fig. 1-10) is the major salt producing area in Atlantic Canada. Canada's first underground salt mine was established here by the Malagash Salt Company in 1919 and operated until 1959. Presently, two salt deposits are being exploited. The Nappan vacuum-evaporating brining operation of Domtar Chemicals Ltd., which opened in 1947, has a present annual production of approximately 100 000 short tons. The Pugwash underground mine, operated by Canadian Salt Company, opened in 1959, has a present annual production of approximately 1 000 000 short tons.

Four salt deposits and two salt occurrences are recognized in the Cumberland area (Fig. 1-4). In each case they are related to large diapiric intrusions of Windsor Group rocks in the axial areas of faulted anticlines. Bouguer gravity anomalies coincident with the anticlines indicate that salt is probably present throughout their length although only the salt relatively close to the surface has been explored. Deep drilling by petroleum exploration companies indicates that salt occurs in great thicknesses in the structures. Potash mineralized intervals have been reported from the salt at Nappan, Oxford, Pugwash, and Malagash, although from present data it appears to occur in relatively small discontinuous masses of low grade (less than 5% K_2O). Two salt occurrences recognized in the area are at Beckwith and Roslin. In addition, there are several areas where salt is strongly suggested, but has not been established by drilling.

The Cumberland area is considered to be one of the better areas for commercial deposits of potash based on its stratigraphic and structural similarities and proximity to the recently discovered New Brunswick potash deposits at Sussex and Salt Springs (Worth, 1972; Anderle et al. 1979; Kingston and Dickie, 1979; and McCutcheon, 1981). An additional favourable factor is that the presence of potash salts has already been established in the area.

In addition to their historical importance in salt mining, the salt deposits in the Cumberland area have potential for underground storage. Relatively new and continually advancing geostorage technology has been directed at the use of salt structures for the development of underground caverns through solution mining. These caverns can be used for a variety of purposes including petroleum storage and, with newly developed technology, for the possible storage of compressed air for peaking power when Fundy Tidal Power is developed. The salt deposits and occurrences in the Cumberland area are described in alphabetical order and include: Beckwith, Malagash, Nappan, Oxford, Pugwash, and Roslin.

GENERAL GEOLOGY OF THE CUMBERLAND AREA

The Cumberland area (Fig. 1-10) is located in parts of Cumberland, Pictou and Colchester Counties in northern Nova Scotia. The area is underlain by a very thick sequence of Carboniferous rocks which occurs in part of the Cumberland Sub-basin defined by Bell (1944, 1958) as that area to the north of the present day Cobequid Uplands. Although Carboniferous sediments comprise the major portion of the post-Acadian rocks in the Cumberland area, biostratigraphic data (Howie and Barss, 1975) indicate the presence of rocks as old as Middle Devonian and possibly as young as Early Permian (Pictou Group). The Carboniferous and Middle to Late Devonian rocks are confined to a deep, block faulted trough. They are bordered on the south by Early Proterozic to Middle Carboniferous aged rocks of the Cobequid Highlands and to the north, in part, by the crystalline basement of the Westmorland Upland. A smaller intrabasinal basement high occurs in the vicinity of Hastings on the northern side of the Minudie Anticline.

This summary is not intended to critically assess the validity of depositional models, stratigraphy or tectonics in the area. In the absence of more detailed and direct examination of these aspects it is only possible to restate what has already been discussed by previous workers. More detailed assessments may be found in published work by Bell (1926, 1944, 1958), Shaw (1951), Copeland (1959), Howie and Barss (1975), Poole et al. (1970), Poole (1976), Kelley (1967a), Belt (1968), van de Poll (1972), White (1972), Donohoe (1976), Wallace and Donohoe (1977), Donohoe and Wallace (1978), and in the unpublished work of petroleum exploration interests and others.

The Cumberland Sub-basin is an east-west trending sedimentary basin containing up to 8000 m of terrigenous clastic and marine evaporite sediments deposited in the waning stages of and after the Acadian (Devonian) Orogeny (Howie and Barss, 1975). It is part of a larger depositional area variously named the Fundy Basin, Fundy Epieugeosyncline, or Fundy Aulacogene that developed upon the broken Acadian Orogen in Atlantic Canada during a series of tectonic episodes collectively termed the Maritime Disturbance (Poole et al., 1970). Sedimentation in the Sub-basin was, for the most part, dominated by post-Devonian (post-Acadian) nonmarine clastic shedding from highlands (inter- and intra-basinal) although the Middle to Late Devonian terrigenous derived clastic rocks with volcanic rocks are possibly syntectonic (van de Poll, 1972). The only major marine sedimentation occurred during the deposition of the Windsor Group when basin restriction and extensive evaporite sedimentation ($CaSO_4$ and NaCl) prevailed. These thick evaporite deposits occur in the present configuration as thickened walls, ridges and domes in halotectonic (Halbouty, 1967) diapiric anticlinal structures that extend to depths of 5000 m and locally up to 6100 m according to Howie and Barss (1975). The structures appear to have the configuration of tight en echelon anticlines with longitudinal bounding faults that are locally offset by transverse faults. White (1972) concluded that the evaporites separated the basement block faulted tectonic regime from the overlying salt tectonic regime both of which occur in a rift basin setting. This assessment is an extension of the rift basin model outlined by Belt (1968).

Due to the severely deformed nature of the Windsor Group strata forming the diapiric intrusions, the stratigraphy of the Windsor Group is generally very difficult to assess and where possible, only within restricted limits. The total original thickness of the Windsor Group prior to deformation is not directly ascertainable although Bell (1958) indicated 180 m as a minimum. According to Howie and Barss (1975) the great variation in thickness of the Windsor Group is probably the result of evaporite flowage into the deeper parts of the basin due to gentle tilting, uplift and faulting shortly after deposition and/or during later tectonic or sedimentary events.

The original lateral extent of the Windsor Group deposition is not readily determinable in the Cumberland Sub-basin due to burial by the very thick, overlapping sequences of the younger nonmarine Late Carboniferous strata. The distribution of Windsor Group strata may have been strongly influenced by intrabasinal uplifts, ie. the Hastings uplift with nondeposition or subsequent erosion. Deposition of marine carbonates may not have continued beyond the C Subzone with the younger strata apparently represented entirely by terrigenous clastic rocks assigned in part to the Middleborough Formation. A similar situation has been described above the major basal evaporite cycle of the Windsor Group in New Brunswick by McCutcheon (1981). The apparent lack of younger carbonate strata may be in part a function of exposure and faulting.

Bell (1944), determined three categories for the Cumberland area Windsor Group outcrop areas:

> ... (1) elongate areas containing the loci of the main anticlinal axes of post-Pictou folds; (2) elliptical or polygonal areas, representing upfaulted blocks located upon anticlinal, post-Pictou folds; and (3) roughly elliptical areas representing subordinate dome-like folds on major post-Pictou anticlines, or similar domes partly upraised by a fault or faults.

Bell (1958) suggested that the major "salt anticlines" in the Cumberland Sub-basin probably originated as a result of post-Canso and/or post-Riversdale tectonism. He further suggested that the movement of the easily mobilized evaporite rocks was furthered by the weight of the continued accumulation of Riversdale Group and Cumberland Group rocks. The presence of angular unconformities adjacent to the Windsor Group outcrop areas is important in dating the movement history of the structures. Pictou Group rocks lie with angular unconformity on the Riversdale Group and locally, on the Windsor Group.

The stratigraphic and structural relationships outlined above together with their association with large salt structures indicate that the present outcrop distribution patterns are partly due to Pictou Group onlap onto progressively older units towards the axes of the anticlines. These anticlines were apparently faulted and diapiric in the later part of their development history. They have probably controlled, and were controlled to some extent, by sedimentation. The development sequence for each major structure may not necessarily be isochronous although major tectonic events would obviously have some control.

The hypothesis that the salt structures have developed over a period of time in response to tectonic (faulting) and sedimentary events is not new. Bell (1944) postulated that the progressive rise of Windsor Group evaporites adjacent to the Springhill coalfield (Cumberland Group) may have been controlled by increases in the sedimentary load and may have promoted the depositional conditions for coal and the local deposition of the Cumberland Group. The anticlinal salt structures themselves may have influenced, to varying degrees, local sedimentation. They appear in some instances to have pierced overlying strata and with renewed sedimentation were subsequently overlain (with angular unconformity) by still younger strata. Other structures may be related to post-Carboniferous (Late Carboniferous-Triassic?, van de Poll, 1972) faulting and subsequent evaporite intrusion. Howie and Cumming (1963) suggested that the salt-cored structures in the Cumberland area were the result of slide faulting associated with Cobequid Mountain uplift or of a combination of salt tectonics and northwestward thrusting.

Evans (1967, 1972) described the structure and stratigraphy of the Windsor Group strata exposed in the Pugwash Mine. This work revealed the highly complex and severely deformed nature of the evaporite rocks. When comparisons were made to Gulf Coast domes, the folding and orientation of the structural elements were markedly different. Evans (1967, 1972) concluded that the internal fold structures within the salt mass were modified by the folding of the Pictou Group whose major anticlinal axial plane corresponded closely with axial plane traces within the Windsor Group. Some of the structural attributes of the Pugwash structure are influenced by the lithologic inhomogeneity of the evaporite mass. The proportion of relatively competent thick anhydrite beds has no comparison in the Gulf Coast domes which are typically high purity salt. It is therefore apparent that direct comparisons regarding sedimentation and tectonics are not possible. Zechstein diapirs in northwestern Germany described by Richter-Bernburg (1972) appear to be similar in lithology (heterogeneous) and gross structural configuration to the Windsor Group diapirs in the Cumberland area.

Bidgood (1970) described the general geophysical (gravity, magnetic) aspects of the salt structures in the Cumberland area. The Bouguer gravity anomaly map (Fig. 4-1) for the area shows a number of negative anomalies coinciding with known Windsor Group outcrop areas including Malagash-Wallace, Simpson Lake (Head of Wallace Bay), Pugwash, Canfield Creek, Beckwith, Oxford, Roslin, Springhill (Black River) and Nappan areas (Fig. 1-10). Bidgood (1970) attributed these anomalies to diapiric low density salt masses that penetrated upwards along faults and into fold axes (mainly cores of anticlines), with vertical dimensions up to 3 km and widths ranging between 1.2 and 12 km. Seismic work in the Pugwash and Wallace areas yielded data on the

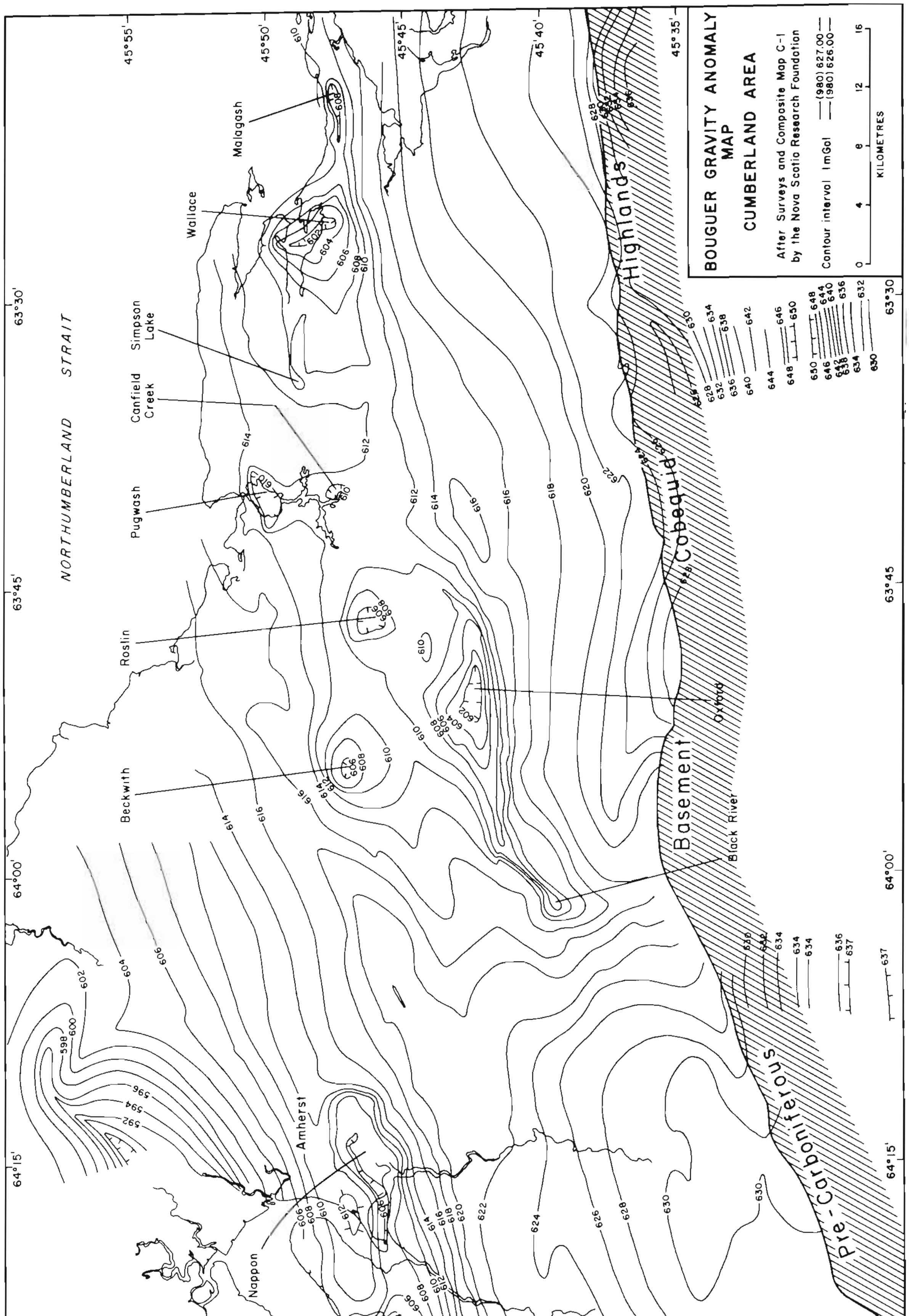


Figure 4-1. Bouguer gravity anomaly map and salt diapirs, Cumberland area.

subsurface nature and extent of the intrusions. A north-south seismic profile across the Wallace structure was interpreted by Bidgood (1970) to indicate shallow southward dips in the Windsor Group except in the immediate vicinity of the salt intrusion. He indicated a depth to the major salt of 2100 m in the south and 1800 m in the north. The intrusion is associated with a fault. A north-south seismic profile near Canfield Creek south of Pugwash showed a similar configuration, according to Bidgood (1970), with dips to the south and a depth to salt of 2400 m in the south and 2100 m in the northern end of the profile. Steep dips are indicated on the flanks of the intrusion and Bidgood (1970) suggested that the Malagash Anticline between Oxford and Malagash is salt cored and may be fault controlled. These seismic sections support the interpretation of major diapiric evaporite movement in the Cumberland area.

BECKWITH OCCURRENCE

LOCATION

The Beckwith occurrence is located in the Little River Beckwith area (Figs. 1-4, 1-10 and 4-2) approximately 6.5 km north of Oxford, Cumberland County, northern Nova Scotia (NTS 11E/13W). The area lies between the Shinimicas River and River Philip which empty into the Northumberland Strait 13 km to the northeast.

The area is readily accessible by paved Highway 204 and gravel roads connected with the Trans-Canada Highway 104 between Truro and Amherst. The main line of the Canadian National Railway between Truro and Moncton passes south of Oxford.

The terrain in the vicinity is typical of the Carboniferous Lowlands with gently rolling hills rarely exceeding 75 m in elevation.

HISTORICAL BACKGROUND

Cumberland County was investigated for its potash potential by Hayes (1931). At that time the Beckwith-Little River area was not examined due to the absence of such indicators as salt springs or seeps.

In 1966 Scurry-Rainbow Oil Ltd. undertook a sulphur exploration program in the Province with Windsor Group salt structures as the major objective. The Beckwith area was selected for drill exploration after a gravity survey by the Nova Scotia Research Foundation outlined a significant negative Bouguer gravity anomaly in the vicinity (Fig. 4-1). Although a total of five holes were drilled, only the SR27-3 hole was reported to have intersected salt, with halite veins from 313 m (1028 ft.) to total depth at 315 m (1035 ft.). This drillhole consisted of steeply dipping red shale and minor grey shale. Typical Windsor Group siltstone, gypsum and limestone were intersected in two other holes, but they were abandoned before reaching salt. Sulphur or potash was not reported in any of the drilling.

GEOLOGY

The Beckwith area was mapped by Bell (1945) as part of the Shinimicas sheet (Fig. 4-2). Strata mapped in the area belong to Windsor, Canso-Riversdale and Cumberland-Pictou Groups. The major structure present is a Windsor Group cored faulted anticline along the trend of the Minudie Anticline.

The Beckwith structure has a triangular outline with a concentric unit succession from core to margin comprising Windsor Group evaporite, limestone and shale; Middleborough Formation (Canso Group?), red sandstone, shale and minor conglomerate; Boss Point Formation (Riversdale Group), grey and red sandstone and shale, limestone-conglomerate; Cumberland Group, grey and red sandstone, grit and conglomerate, and red shale; and Pictou Group, red sandstone, shale, grit and conglomerate. The Pictou Group succession is faulted against the structure's northern border which has an east-northeast strike.

In 1966 Scurry-Rainbow Oil Ltd. drilled five sulphur exploration holes (Fig. 4-3) in the central part of the Beckwith dome (Fig. 4-2). The salt intrusion believed to be responsible for the Bouguer gravity negative anomaly outlined in a gravity survey by the Nova Scotia Research Foundation was not penetrated. A major salt mass is probably present at depth, but would require deeper drilling to establish. SR27-1, drilled near the Windsor-Middleborough contact on Purdy Brook, penetrated only steeply dipping red shales and was abandoned at 136 m. Nearby SR27-2 penetrated only gypsum (bedding dips unknown) and was stopped at 70 m in a sandstone-gypsum breccia. SR27-3, drilled approximately 1 km southeast of SR27-1, penetrated only red shales with minor salt veins at the bottom and was abandoned at 315 m. SR27-4, drilled approximately 0.6 km north-northwest of SR27-1, intersected a thick section of red shale to 173 m and then a section of interstratified limestone, green-red shale, and gypsum when the hole was abandoned at 246 m. SR27-5, drilled approximately 1.8 km north of SR27-1, penetrated a thick section of interbedded red-grey sandstone, and shale with some thin calcareous conglomerate and was abandoned at 276 m. This sequence, although in an area mapped as Windsor, is probably part of the overlying Upper Carboniferous succession. It may be assigned to the Claremont Formation and/or Boss Point Formation but possibly may be as young as Pictou Group. The presence of this sequence indicates that younger rocks occur on the southern side of the fault, but due to the scarcity of outcrop in the area the map unit boundaries and overall configuration are subject to revision (Figs. 4-2 and 4-4). The outcrop area of the Windsor Group is probably smaller and the geology more complex than that mapped by Bell (1945).

GEOPHYSICS

The Beckwith area is included on Nova Scotia Research Foundation Bouguer anomaly map 11E/13 at a scale of 1:31 680 and on a Scurry Rainbow Oil Ltd. map (Fig. 4-4). The Nova Scotia Research

Foundation (1966a) interpreted the anomaly using a spherical model with a density contrast of 0.25 g/cc, and a radius of 2073 m (6800 ft.) centred at a depth of 2316 m (7600 ft.). A good fit of computed gravity and observed gravity was indicated. In the fitting of gravity data the selection of the density contrast is based upon assumed mean density values of 2.20-2.25 g/cc for Windsor Group evaporites and 2.40-2.50 g/cc for younger clastic rocks. The density contrast value is critical and any variations from its true value will affect both the depth and size of the interpreted body.

ECONOMIC CONSIDERATIONS

The occurrence, as is presently known, comprises halite veins only and the parent salt mass has not been intersected. The presence of potash minerals is possible, but may only be tested by further deeper drilling. The depth to the main salt mass is in excess of 300 m, probably in the order of 450 to 600 m. Salt springs have not been reported in the area. The area is located within 6.5 km of the Canadian National Railway mainline between Truro and Moncton. The occurrence as presently known is not considered to be of economic importance.

MALAGASH DEPOSIT

LOCATION

The Malagash deposit is located in the Malagash-Wallace area (Figs. 1-4, 1-10 and 4-5) Cumberland County, northern Nova Scotia (NTS 11E/14). Malagash is located on the Malagash Penninsula which forms a ridge into the Northumberland Strait between Tatamagouche Bay on the south and Wallace Harbour on the north. The Malagash deposit in this report includes not only the Malagash Mine structure, but also includes the broader western extension of this structure in the Wallace area.

The area is readily accessible by paved highways (including Routes 6, 368 and 246) from Pictou, Oxford and Pugwash, and a series of unpaved roads. The Canadian National Railway line is located in Wallace Station 2.5 km south of the town of Wallace which is located on the southern shore of Wallace Harbour.

The terrane in the Malagash area is typical of the Carboniferous Lowlands in northern Nova Scotia with gently rolling hills where elevations rarely exceed 75 m. A distinct ridge coincides with the Malagash Anticline. The Northumberland Strait shoreline is characterized by broad shallow river estuaries and bays.

HISTORICAL BACKGROUND

The Malagash Salt Mine was the first underground salt mining operation in Canada. Interest in the area was sparked in the later part of the nineteenth century by discoveries of salt springs and seeps. In 1912, salt water was encountered at a depth of 25 m in a water well bored approximately 11 km northeast of Malagash Station (near the future site of the Malagash Mine). A detailed historical summary of the pre-1912 references to salt was described by Hayes (1920) and Cole (1930a,b). In 1917 Chambers and McKay were sufficiently encouraged by analyses of the well water brine to begin a churn drill exploration program for salt in the vicinity. Twelve holes were sunk with salt brine encountered in six, at depths varying from 26 to 34.4 m (85 to 113 ft.) below the surface. Based on the success of the initial drilling a diamond-drill hole was then drilled on the site to test for the presence of rock salt. Salt was intersected from 28.7 to 52.7 m (94 to 173 ft.) below the surface and a shaft was sunk 137 m east of the diamond-drill hole to further assess the salt deposit. The shaft penetrated salt at a depth of 26 m (85 ft.). Further diamond-drilling both underground and from the surface confirmed the existence of an exploitable salt deposit and commercial production of salt from the Malagash salt mine operated by the Malagash Salt Company began in 1919. Hayes (1920) described the early history of mine development and its basic geological situation.

Potash minerals in small quantities were encountered in 1919. The potash occurred in variably thick discontinuous lenses and pods of crystalline, pink and green sylvite in a halite matrix. Ellsworth (1926) analyzed samples taken over the potash mineralized intervals.

Mining, engineering and ore grade problems culminated in the closure of the operation in early 1959. By this time the operators had successfully explored and developed the Pugwash mine at Pugwash, 26 km to the west. A history of the Malagash Mine from its discovery to abandonment has been compiled by MacQuarrie (1975).

In 1965-1966 geophysical and geological programs by the Nova Scotia Research Foundation and Nova Scotia Department of Mines, funded by the Atlantic Development Board resulted in a deep diamond-drill exploration program for potash in the Malagash-Wallace area. Four holes were drilled to the west of the Malagash Mine to assess the geology and potential extension of the potash mineralized zones known to occur in the Malagash Mine. Two holes were successful in intersecting significant potash mineralized zones.

No further potash exploration drilling has been undertaken in the area since the 1966 Potash Program. Exploration has apparently been discouraged by the great depth and low grade of the mineralized interval as it is presently known. Recent discoveries of potash deposits in similar circumstances in New Brunswick may encourage a reassessment of the potash potential.

In 1973, Anschutz Corporation drilled Wallace Station No. 1 near Wallace Station, 5 km west of Wallace No. 1, in exploration for petroleum. The Windsor Group salt zone was intersected between 2506 and 3980.7 m (8222 and 13 060 ft.).

GEOLOGY

The Malagash area has been investigated by many workers since early (pre-1900) geological exploration began in Nova Scotia. The geology of

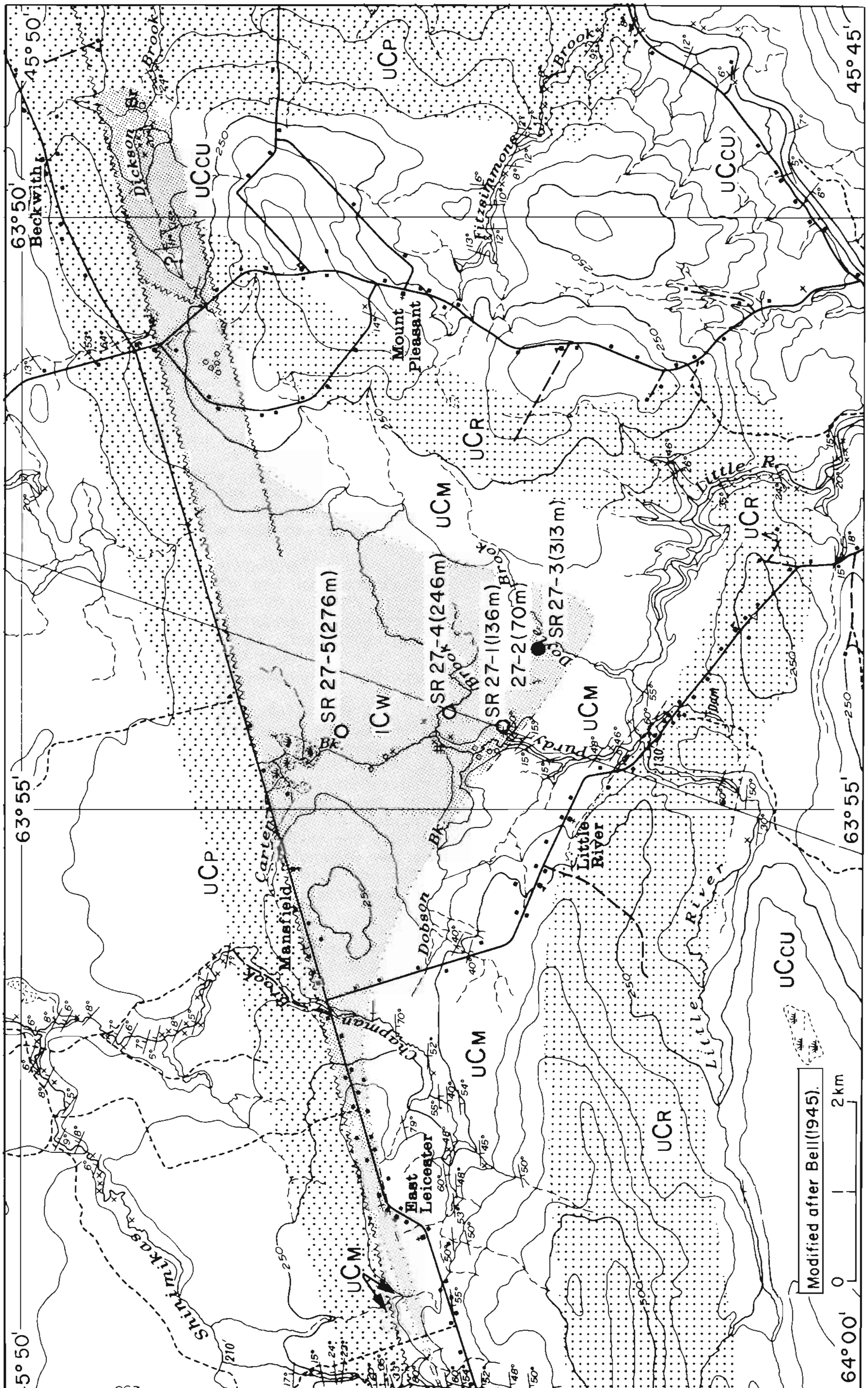


Figure 4-2. Geology in the vicinity of the Beckwith occurrence, Cumberland County, Nova Scotia.

LEGEND

UPPER CARBONIFEROUS

PICTOU GROUP
- **UCP** — Undivided sandstone, shale and congolmerate

CUMBERLAND GROUP
- **UCCU** — Undivided sandstone, conglomerate and shale
- **UCCU-U** — Upper Division: sandstone, shale and coal
- **UCCU-L** — Lower Division: conglomerate, sandstone and shale

RIVERSDALE GROUP
- **UCR** — Undivided sandstone, conglomerate and shale
- **UCR-BP** — *BOSS POINT FORMATION:* sandstone and shale
- **UCR-C** — *CLAREMONT FORMATION:* conglomerate

CANSO GROUP
- **UCCa** — Undivided sandstone and shale

- **UCM** — *MIDDLEBOROUGH FORMATION:* (may include Windsor Group or Canso Group) shale and sandstone

LOWER CARBONIFEROUS

WINDSOR GROUP
- **ICW** — Undivided shale, gypsum, anhydrite, halite and limestone

SYMBOLS

Heavily drift-covered area ....

Rock outcrop, area of outcrop ....

Limestone or dolomite outcrop (Faribault-Fletcher maps) ....

Gypsum outcrop ....

Geological boundary (defined, approximate, assumed) ....

Bedding, tops known (inclined, vertical, overturned, horizontal) .

Bedding, tops unknown (inclined) ....

Schistosity (inclined, vertical, dip unknown) ....

Gneissosity (inclined, vertical) ....

Plunge of minor fold ....

Drag fold (arrow indicates plunge) ....

Fault (defined, approximate, assumed) ....

Fault (solid circle indicates downthrow side) ....

Joint (inclined, vertical) ....

Anticline (defined, approximate, arrow indicates direction of plunge) ....

Syncline (defined, approximate, arrow indicates direction of plunge) ....

Fossil locality ....

Spore sample ....

Glacial striae (ice flow direction known) ....

Gravel deposit ....

Quarry ....

Diamond-drill hole ....

Borehole ....

Sinkhole ....

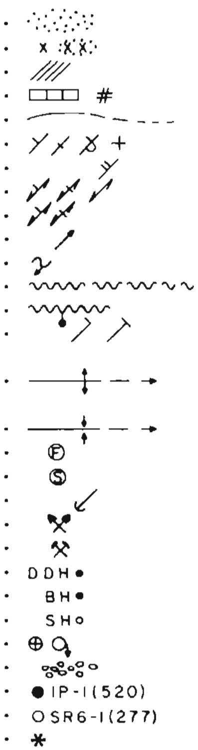
Salt spring ....

Observed karst topography ....

Drillhole intersecting salt; number (depth to salt, metres) ......

Drillhole without salt; number (Total depth, metres) ....

Drillhole location precise to 150 m ....



MINERALS

Anhydrite	ah	Limestone	lst
Gypsum	gyp	Pyrite	py
Lead	Pb	Zinc	Zn
Celestite	Sr		

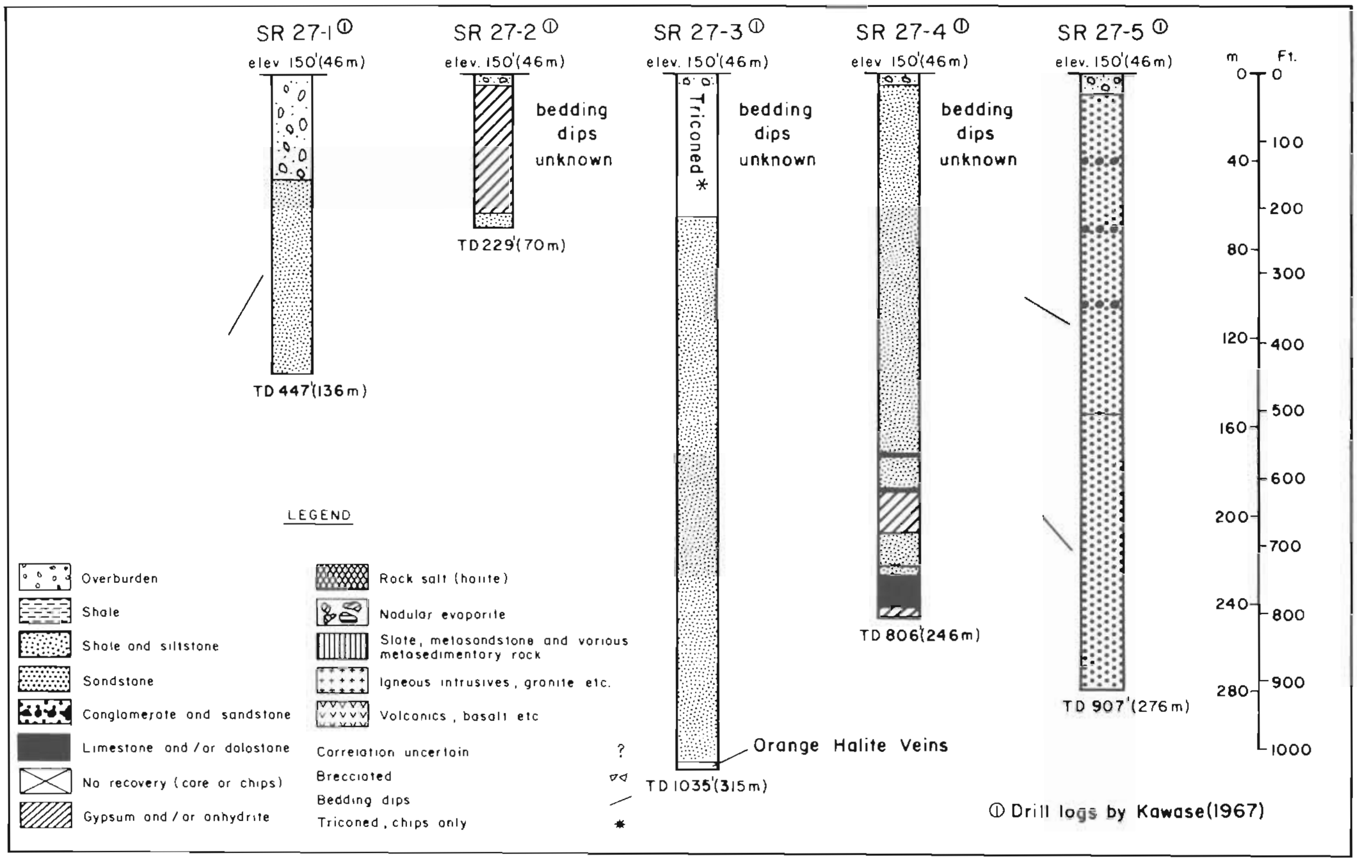


Figure 4-3. Drillhole profiles, Beckwith occurrence, with legend for Cumberland drillhole profiles.

the Malagash area (Sheets 60 and 61) was mapped by Faribault and Fletcher (1905). A torsion balance gravimetric survey of the Malagash Mine area to assess the salt was undertaken by Miller for the Dominion Observatory and the Geological Survey of Canada in 1934. The basic stratigraphy and major structural forms were outlined and indicated the Malagash Penninsula had the form of an anticline with a core unit of what was described as "Carboniferous Limestone" (Windsor Group). Cameron (1965a,b,c; and 1967) remapped and compiled the geology in the Wallace-Malagash area as part of the 1966 Potash Project. A preliminary geological map was produced and is used as a base for Figure 4-5. This map also includes data compiled from Bell's (1944) maps of the Wallace River, Lazy Bay and Stake Road areas.

The geology of the area was also studied by Hayes (1920) who described the Malagash salt deposit stratigraphy and structure. Hayes (1920) recognized three basic rock units comprising the Malagash Anticline. The oldest, that forms the core of the structure, is the conglomerate, sandstone, shale, gypsum and salt of the "Mississippian Windsor Series". The Windsor limestone and gypsum rocks are intermittently exposed along the Northumberland Strait shore to the north of the Malagash Salt Mine shaft (Fig. 4-5). At one location, Hayes (1920) reported an overturned anticlinal fold limb with 300 feet of stratigraphic section exposed. Hayes (1920) reported fossils collected from a small and poorly preserved limestone in this vicinity were provisionally identified by Kindle as Productus af. cora, Hartina anna and Aviculopecten cf. simplex. The Windsor beds trend parallel to the east-west strike of the shoreline and dip steeply (overturned) to the south. Salt with gypsum was intersected in the Malagash Mine shaft in the central part of the structure. The evaporite unit here strikes generally east-west although bedding dips are variable from 25° south to 80° north over small horizontal distances (15 m). These highly variable dips are probably due to the severe deformation associated with evaporite flowage during the development of the Malagash Anticline (Fig. 4-6).

The "Windsor Series" is overlain with unconformity by a map unit referred to by the early workers as Late Carboniferous, "Millstone Grit", comprising conglomerate, sandstone and shale (Claremont and Middleborough of Bell, 1944). Hayes (1920) reported that this unconformity is exposed along the northern shore of the Malagash Penninsula over a distance of 1 km eastwards from Grindstone Point (near Gravois Point). The Windsor rocks at this locality are reported to be overturned and dip south and are unconformably overlain by "Millstone Grit" strata dipping north. The "Millstone Grit" has a basal member, of reddish brown conglomerate of which 239.3 m

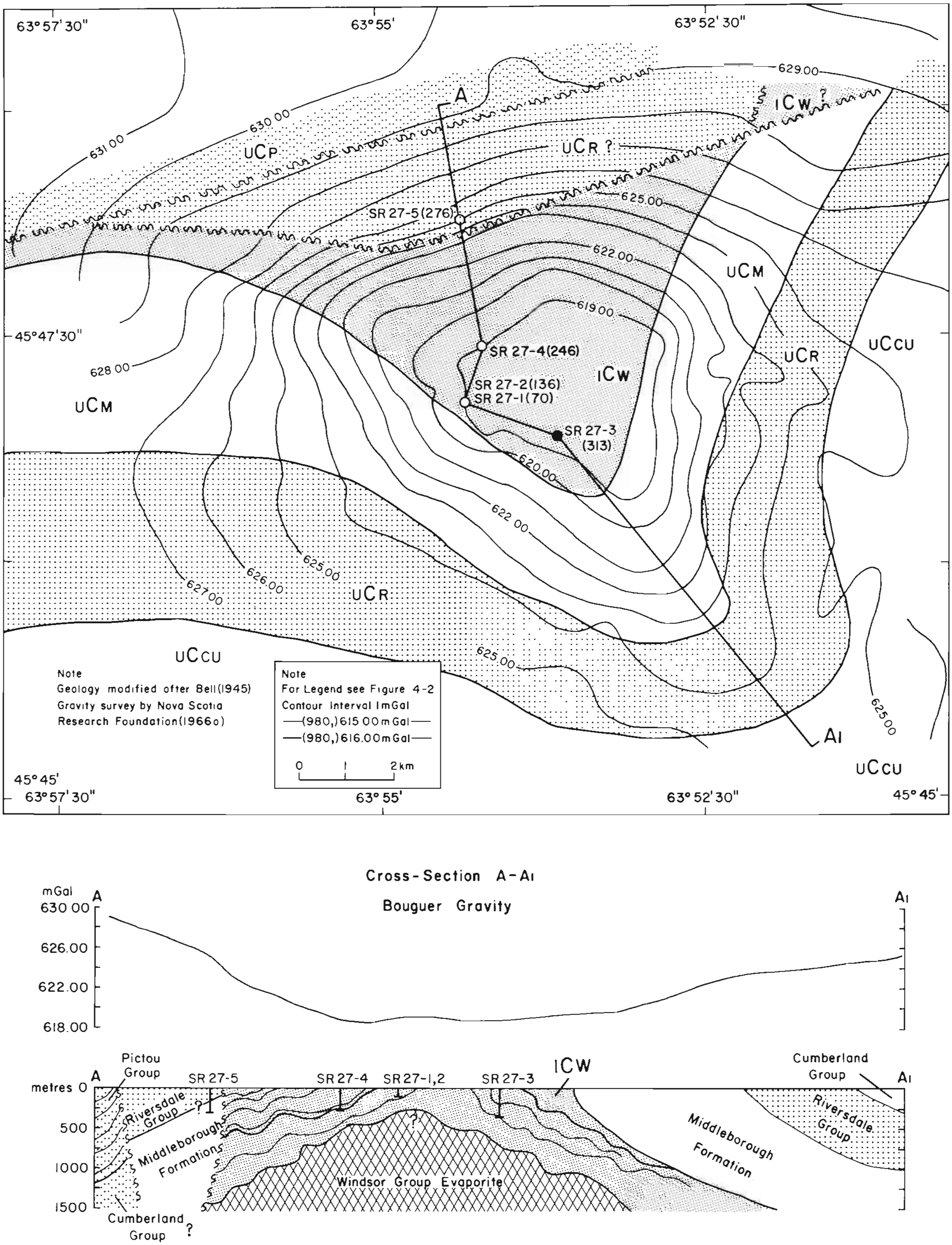


Figure 4-4. Bouguer gravity and geological map with accompanying cross-section, Beckwith occurrence.

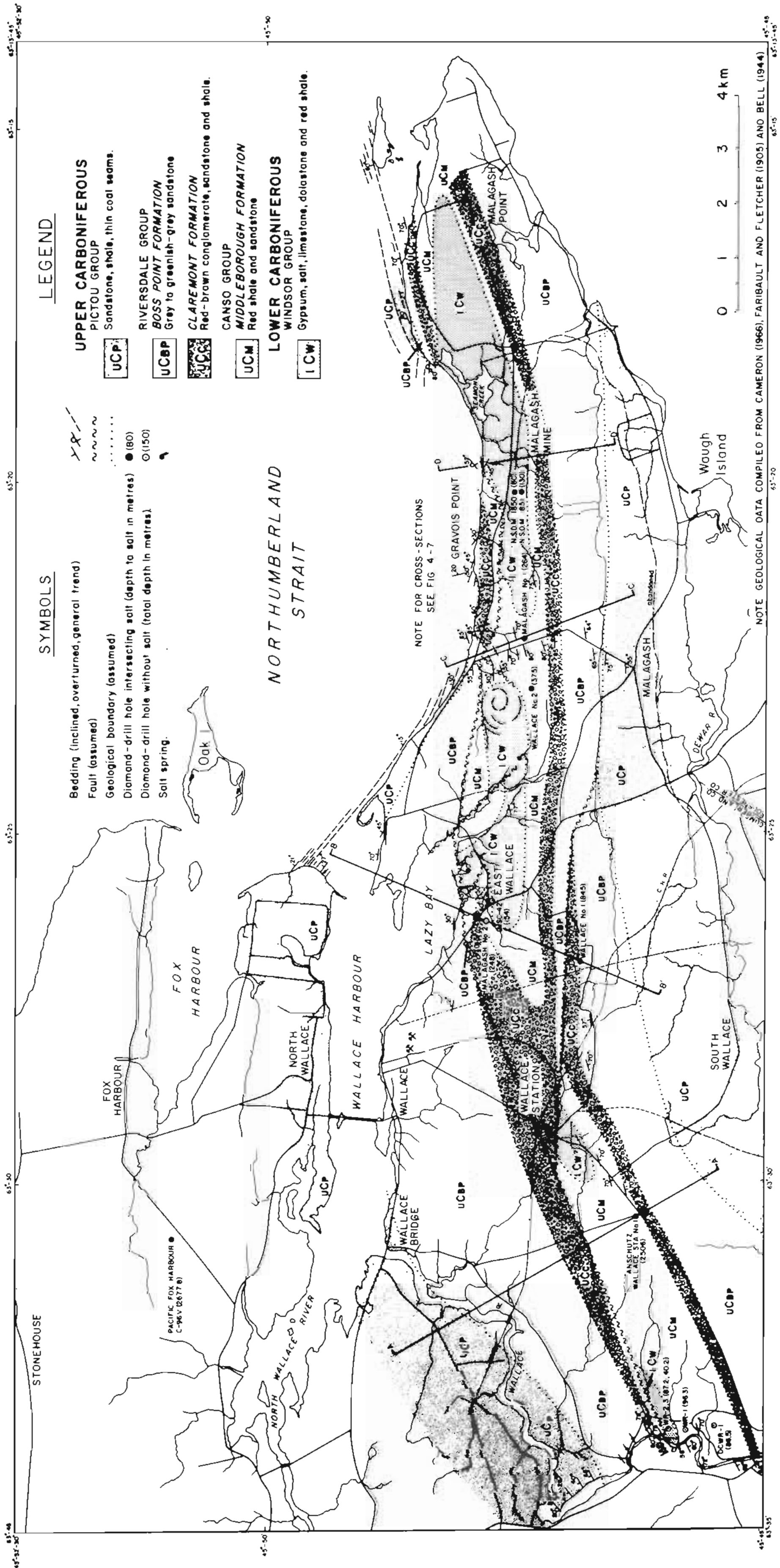


Figure 4-5. Geological compilation map, Wallace-Malagash area, Cumberland County.

(785 ft.) are exposed west of Gravois Point and 221 m (725 ft.) are exposed at Malagash Point. The younger units of his "Millstone Grit" are reported to be more variable and include thickly bedded grey-green sandstone, brown and green shale interbeds and grit-conglomerate beds. Three nonfossiliferous blue limestone beds are included in this unit. The total minimum thickness is in excess of 762 m (2500 ft.)

The "Millstone Grit", according to Hayes (1920), is overlain with unconformity by the Late Carboniferous or Early Permian "New Glasgow Series", comprising conglomerate, sandstone and shale (Pictou Group of Bell, 1944).

The Carboniferous stratigraphy of northern Nova Scotia was redefined by Bell (1944) in terms of rock stratigraphic groups related to his originally defined biostratigraphic units. This redefinition was required due to the variable nature of a given lithological succession. Bell (1944) considered his groups to represent an assemblage of strata in which no major breaks of deposition had been detected, and which contain a fossil flora and fauna of a specific time interval. Bell's (1944) terminology is the basis of the present nomenclature of the Carboniferous succession and include, from base to top, Horton, Windsor, Canso, Riversdale, Cumberland, and Pictou Groups.

Bell (1944) applied the revised nomenclature to the Malagash Anticline. The "Carboniferous Limestone" map unit of Faribault and Fletcher (1905), is referred to by Bell (1944) as the Windsor Group. The overlying conglomerate and sandstone unit Faribault and Fletcher (1905) mapped as the "Millstone Grit" is termed as two units. Bell (1944) reported that faulting brought the Windsor Group salt zone into contact on the southern side of the Malagash Anticline with Claremont Formation conglomerate; on the northern side with Claremont Formation conglomerate or Middleborough Formation; on the west, with the Middleborough Formation (Canso Group?); and on the east, with beds of the Windsor Group younger than the salt. An overturned section exposed to the north of the deposit (presumably that previously described by Hayes, 1920) Bell (1944) reported as containing Claremont and Boss Point Formations of the Riversdale Group which are unconformably overlain by northerly dipping beds of the Pictou Group ("New Glasgow Series" map unit of Faribault and Fletcher, 1905).

Structural Configuration

The structural configuration of the Malagash structure has been described and interpreted by many investigators. A summary of these will be presented in the following paragraphs. With the development of the underground workings in the Malagash Salt Mine, the three dimensional subsurface attributes of the structure were realized in greater detail. Hayes (1920) concluded:

> The salt at Malagash occurs as a stratified deposit interbedded with rocks of the Mississippian (Lower Carboniferous) period and apparently forms an integral portion of the Windsor (Carboniferous) Limestone series.
>
> The Malagash salt horizon lies along the axis of an anticlinal fold, and may, therefore, be crumpled locally and perhaps thickened by isoclinal folding and duplication of strata.
>
> The dimensions of the salt deposit can only roughly be approximated .... Assuming that the beds have not been duplicated by folding or deleted by faulting the actual thickness of the original beds is probably more than 300 feet, and less than 500 feet, measured at right angles to the dip.
>
> The salt strata are probably offset by faults at certain localities, but the regularity of the strata along the coast to the north, for a distance of about three-quarters of a mile, suggests that the salt may extend without serious interruption for an equal distance along the strike, and the sedimentary character of the salt points continuation in depth parallel to the dip of the enclosing rocks.

Ellsworth (1926) reported (extracted below) that Hayes' (1920) prediction of "local crumpling" was verified by mining operations, to a depth of 200 feet.

> The steeply inclined bed which supplies the present high-grade product has been folded almost into a horseshoe shape and minor faulting, crumpling, thickening, thinning, and duplication of beds occur in extreme degree. The structures indicate that the salt body has been subjected to at least two major external deformative forces which have acted in directions more or less at right angles: the first, due to the anticlinal folding along an east and west axis, has probably squeezed the salt up into the crest of the anticline; the second, due to transverse faulting with accompanying or subsequent compressional stress in a direction approximately parallel to the anticlinal axis, has further folded and perhaps thickened it; and finally a possible lateral movement of the fault blocks may have introduced a shearing stress as a third component of the deformational forces. As a result of the combined action of these forces, the structure of the Malagash deposit in many respects resembles that of salt domes described in the literature, though it is not intended to imply that it is necessarily circular in outline or that the mass has risen any great distance, if at all from its point of origin, as is the case in many foreign examples. The extreme deformation and duplication of beds, the steep inclination of the strata, the location in the crest of an anticline, and the capping of residual gypsiferous material ... are cited by Hahn as characterisitic of salt domes in general ... there is no proof so far that the deposit ever actually penetrated through originally overlying rock formations. If, however, the lower part at least of the gypsiferous material capping

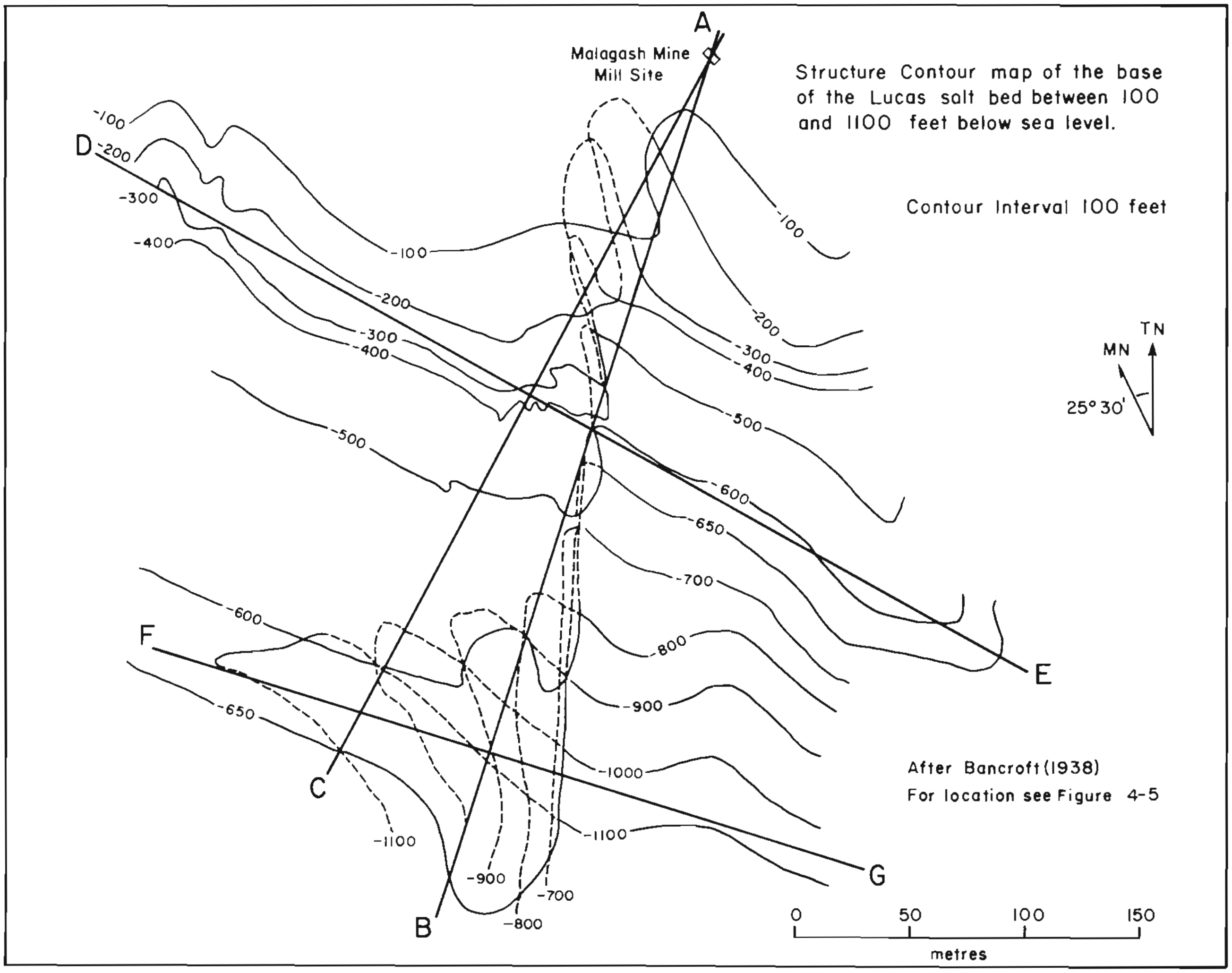


Figure 4-6. Structure contour map on the base of the Lucas seam with accompanying sections, Malagash Mine.

the deposit is regarded as being residual insoluble material resulting from the leaching away of the original upper part of the salt, there would seem to be the possibility that the mass did originally penetrate the upper formations. .... a point worth noting which seems to support the idea that the Malagash salt body is to a certain extent dome-like in structure, is the fact that the rather detailed drilling exploration carried out by Sir Alexander McGuire farther to the west on the same anticlinal axes failed entirely to locate the salt horizon.

Hayes (1920) indicated that Sir Alexander MacGuire of London, England, was actively drilling in exploration for salt in the vicinity of Wallace in 1919.

Bancroft (1938) produced a structure contour map and cross-sections illustrating the structure encountered in the Malagash Mine (Fig. 4-6). The mapping was based on surveys of the Lucas salt bed which has a general strike of 115° and an average dip of 45° south. Minor folds occurring as welts and corrugations are found on the general strike and dip of the beds. Folds transverse to the trend of the beds are prominent in the structural mapping by Bancroft (1938). The folds are characterized by marked attenuation on the limbs and thickening in the hinge area. Cross-sections through this folding in the Lucas seam (Fig. 4-6) indicate the curvilinear fold axes trend approximately parallel to the general dip direction of the seam and vary in closure from open to subisoclinal and isoclinal.

Bell's (1944) discussion of the structure and stratigraphy of the Malagash deposit follows:

> It is sufficient to state that the salt deposit with its accompanying interbedded anhydrite lies in a fault block. G. W. H. Norman considers that the two faults that bound the deposit on the north and south respectively are thrust planes that "strike parallel to the anticlinal axis and dip inwards to converge towards one another at depth, as in many other typical salt structures. Many salt structures have an hourglass structure in which bounding walls converge for some distance with depth and then diverge" (Norman, 1941; personal communication).

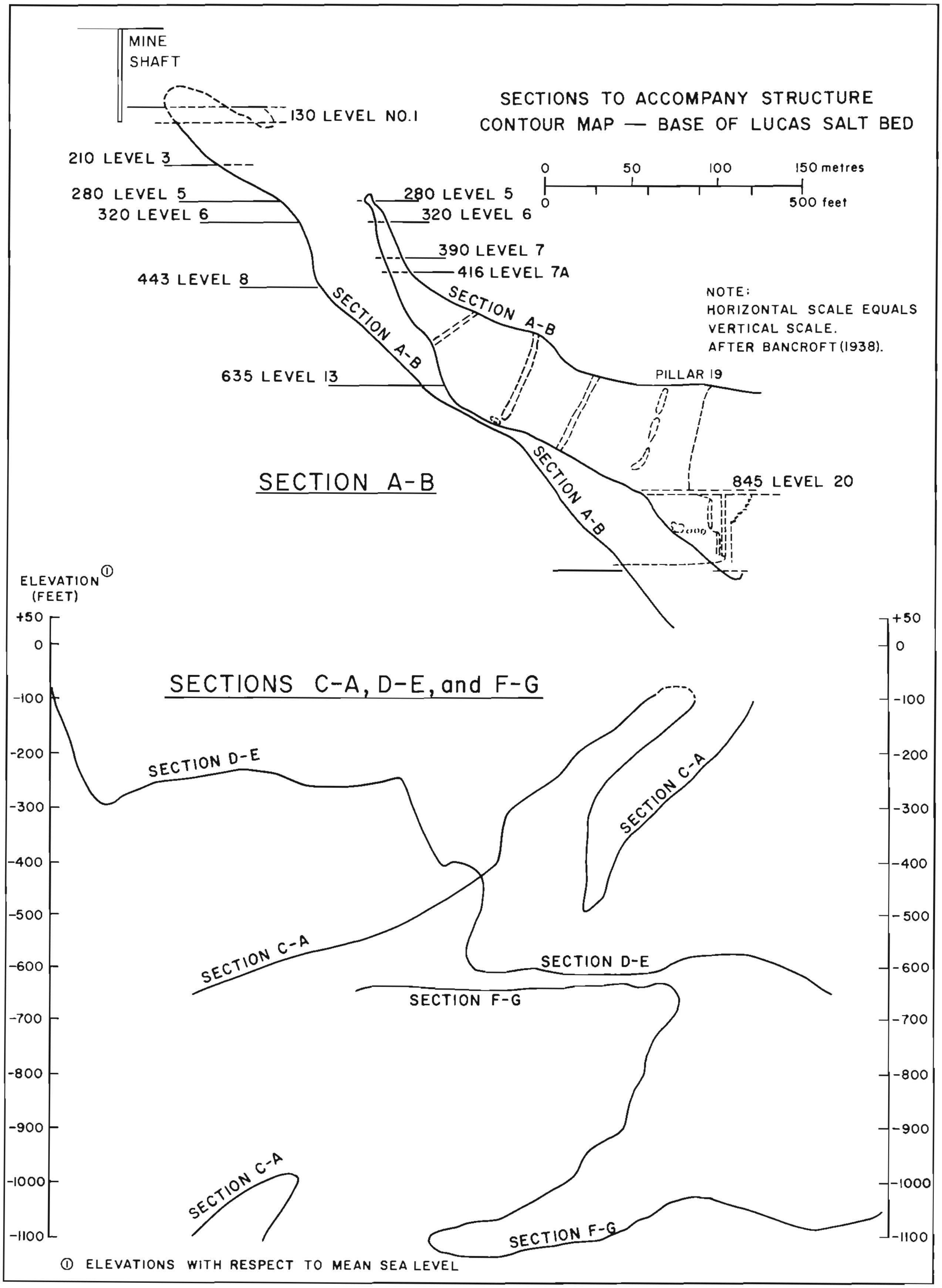


Figure 4-6. Continued.

It is inferred that the western boundary of the salt deposit is the transverse fault that may be seen at the shore about 450 feet northwest of the salt mine. The fault there is a normal fault with stratigraphic upthrow on the east side according to Norman, of 500 feet or more. The eastern boundary of the salt deposit is unknown, although it is seemingly also a fault.

The general structural configuration of the Malagash structure is illustrated in the "Stake Road Section" of Bell (1944) (Figs. 4-5 and 4-7). The Stake Road trends roughly north-south and has outcrops of the major rock units which define a cross-section through the Malagash Anticline. Bell (1944) indicated the following stratigraphic sequence in the southern limb of the Anticline in descending order:

PICTOU GROUP: brownish red sandstone and shale; 1300+ feet thick

- - - - - - - - - - - - fault - - - - - - - - - - - -

RIVERSDALE GROUP Boss Point Formation: grey sandstone, massive and flaggy, minor quartz-pebble conglomerate; 1500+ feet thick.

Claremont Formation: brownish red arkose, arkosic sandstone and conglomerate with limy and kunkur nodular beds near base; 1800 ± feet thick

- - - - - - - - - - disconformity - - - - - - - - - -

Middleborough Formation: finely micaeous and crossbedded, brownish red sandstone, siltstone, and shale; 1900± feet thick.

- - - - - - - - - - - - fault? - - - - - - - - - -

WINDSOR GROUP: brownish red sandstone, siltstone, mudstone, and shale (based upon the presence of a gypsum? sinkhole, Fig. 4-5, Section C-C_1).

Bell (1944) expressed some reservation about the certainty of the presence of Windsor strata along the Stake Road (based upon a small sink hole). He stated, however, that on the evidence of large (gypsum) sinkholes, it is definitely present one half mile southwest of the smaller suspected sinkhole. Gypsum is also reported by Bell (1944) to outcrop one half mile farther west. To the east of the Stake Road, Bell (1944) reported the Middleborough Formation overlain unconformably by Pictou Group strata. Windsor strata have not been established at surface in the area to the east of the Stake Road except for the western end of the Malagash Salt Mine area. Middleborough Formation strata apparently occupy the axial area between the eastern and western Windsor outcrop areas.

In 1966 the Nova Scotia Department of Mines and Nova Scotia Research Foundation undertook a potash exploration survey in the Malagash-Wallace area. The potash assessment involved geological mapping (Fig. 4-5) and geophysical surveys including detailed gravity (Fig. 4-8) and total intensity magnetometer (Fig. 4-9). These surveys were followed by diamond-drill exploration of selected targets. The first hole, Malagash No. 1 (Fig. 4-10), was drilled at the western end of the Malagash Mine, eastern Windsor Group outcrop area. The hole collared in the Middleborough Formation penetrated Windsor Group gypsum at 224 m (734 ft.) and intersected salt from 264 m (865 ft.) to a total depth of 306 m (1004 ft.). The overlying Middleborough Formation, comprising red shale and sandstone, are very steeply dipping (65° to 80°) and are extensively brecciated. The Windsor Group gypsum is indicated to be less steeply dipping (20°-40°) and is apparently in fault contact at a depth of 224 m with the Middleborough Formation.

The Windsor outcrop area south of Wallace was explored with four drillholes. Wallace No. 2 (Fig. 4-11) was drilled near the eastern terminus of the Windsor outcrop area and penetrated two separate salt intervals, 372-542 m (1221-1778 ft.) and 756-798 m (2482-2618 ft.), before it was abandoned at a depth of 798 m (2618 ft.). Bedding dips in the cored intervals of the hole are reported to be moderate (20-40°). Since only the salt intervals were cored, the dips of the sandstone and shale intervals are not known, and the effects of brecciation and faulting are not determinable. It is probable that faulting and possibly folding are responsible for the occurrence of two salt horizons. Numerous thin low grade potash mineralized intervals are found in the salt-shale breccia intervals of Wallace No. 2 (Fig. 4-11). The western terminus of the outcrop area was tested by the Malagash No. 2 diamond-drill hole. Malagash No. 2 intersected brecciated Windsor Group gypsum, anhydrite, and green-grey brecciated mudstone-siltstone to a depth of 171.3 m (562 ft.) where sandstone and siltstone were penetrated to a final total depth of 248 m (814 ft.) (Fig. 4-10). These lower sandstones are reported to be similar to the rocks of the Middleborough Formation exposed on Wallace River. If this is the case, then the section is stratigraphically out of order, and is attributable to either overfolding and/or thrust faulting. Bell (1944), in a possibly analogous situation, indicated overthrusting of Windsor in the Wallace River section to the west (Figs. 4-5, 4-7). He described the geology in East Wallace area from exposure on the southern shore of Lazy Bay and nearby stream outcrops (Fig. 4-12) as follows:

> This area lies west of the Stake Road to East Wallace settlement. It is crossed by Wade Brook, in the lower part of which the presence of the Windsor group is attested by gypsum sinks. It contains also the outcrop of gypsum east of Wade Brook already noted in discussion of the Stake Road section. From this outcrop northwesterly almost to the shore at East Wallace, a distance of about 8000 feet, there are no known outcrops of Windsor strata. The gypsum east of Wade Brook dips at a high angle (up to 65 degrees) southerly and obviously lies in the south limb of the Malagash anticline. Overlying strata of the Middleborough formation, consisting of brownish red, finely micaceous sandstone, siltstone, and shale, outcrop on Wade Brook southwest of the gypsum, striking about 15 degrees south of east and dipping 75 degrees south. Whether they overlie the gypsum unconformably or are separated by a fault is unknown.

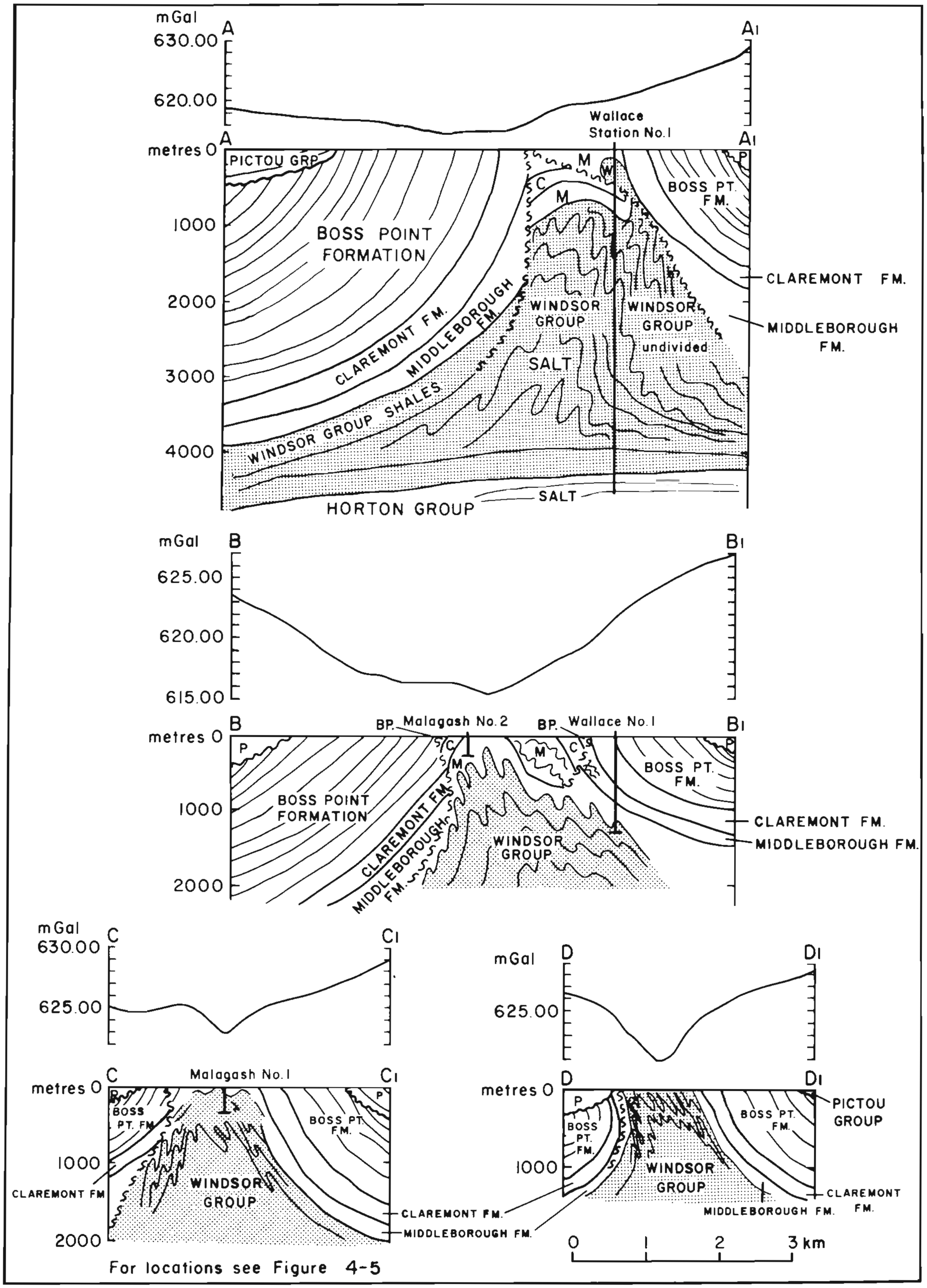


Figure 4-7. Geological and Bouguer gravity cross-sections, Malagash deposit.

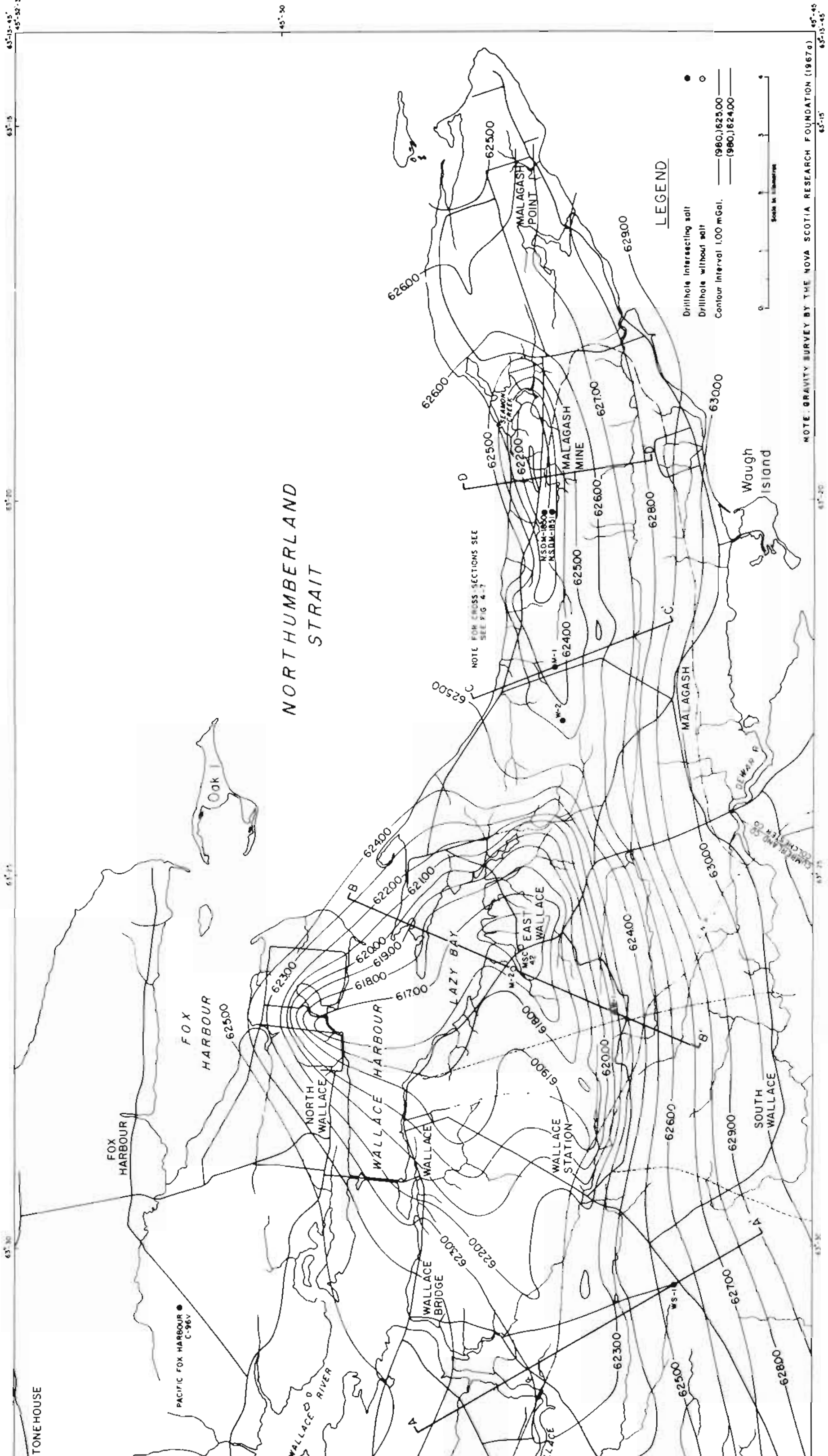


Figure 4-8. Bouguer gravity anomaly map, Wallace-Malagash area, Cumberland County.

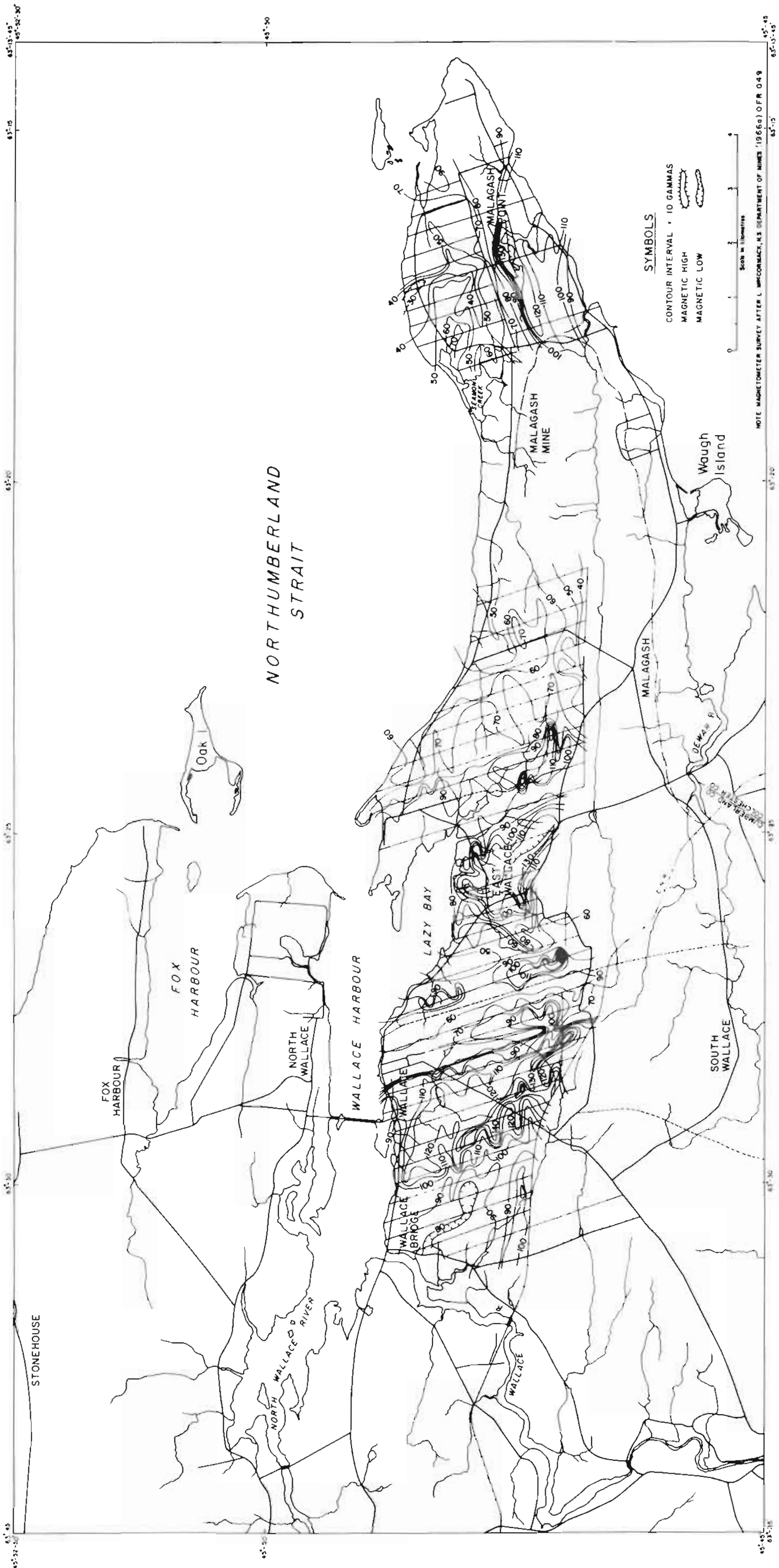


Figure 4-9. Total intensity magnetometer survey, Wallace-Malagash area.

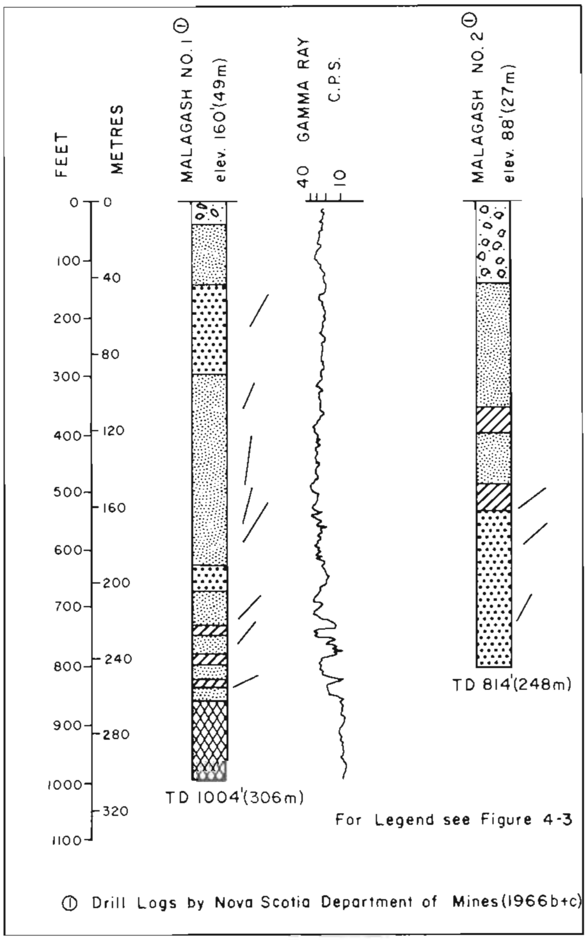


Figure 4-10. Drillhole profiles Malagash Nos. 1 and 2, Malagash deposit. (For locations see Fig. 4-5).

Outcrops on the shore west of Wade Brook near East Wallace show the strata there belong to the northern limb of the anticline. The Windsor group is interpreted to lie in a fault block upthrust into the Boss Point formation. Two main faults, which bound the Windsor group, are believed to be present at the shore. The main one strikes roughly parallel to the shore in a direction north 81 degrees east, from which a branch diverges in a direction south 60 degrees east. If these faults extend eastward to meet the southwesterly trending fault in the northern part of the Stake Road section the Windsor strata in the East Wallace area lie in a wedge shaped fault block, obliquely transversing the Malagash anticline.

Windsor rock exposed in the vicinity of East Wallace is mainly gypsum, which, near the faults, carries large amounts of secondary selenite. One band of calcareous or dolomitic shale, overturned at a high angle southwestward, carries Productus lyelli Verneuil, Leptodesma dawsoni (Beede), Modiola dawsoni (Bell), and cephala of a xiphosurid, indicative of a Lower Windsor age. The Boss Point strata into which the Windsor beds have been thrust consist of grey sandstone, much shattered near the faults, brownish red shale, and at least one bed of quartz-pebble conglomerate. These strata are underlain near the main highway (route 6) by beds of the Claremont formation, comprising brownish red, arkosic conglomerate, red sandstone, and shale, dipping 40 to 60 degrees northeasterly.

It is evident from Bell's (1944) descriptions that the rocks in the structure have been subjected to extensive deformation involving faulting, folding and overturning.

Wallace No. 1 (Fig. 4-11) was drilled 1.9 km south-southwest of Wallace No. 2 on a structurally separate block (Fig. 4-5). This block is apparently separated from the Wallace-Malagash block by an east-west trending fault (Cameron, 1967). Wallace No. 1 penetrated a thick section of conglomerate and sandstone from 43 m (140 ft.) to approximately 633 m (2077 ft.) (Claremont Formation); an interval of reddish brown, and grey green siltstone and sandstone with dips of 30-45° was intersected to 823 m (2700 ft.) (Middleborough Formation); grey shale was intersected to 845 m (2772 ft.) where the Windsor Group salt was penetrated. The hole was stopped in salt at a depth of 1222.6 m (4011 ft.) and potash mineralized intervals were associated with the salt. Wallace No. 1 intersected 29.9 m (98.2 ft.) of 5.05% K_2O at a depth of 1180 m (3870 ft.). Dips in the salt interval are moderate to steep in the range of 45° to 60°.

Wallace No. 1 was apparently drilled on the southerly dipping flank of the anticlinal structure (Fig. 4-5) and does not appear to have any repetition of strata (overlying the salt) by faulting or folding. Since most of the upper section was not cored, overturning and repetition may occur. The nature of the fault separating the blocks is not certain although both steeply dipping strike and dip slip (reverse) movements are inferred, but dip direction is not discernible and may change with depth.

Bell (1944), described the section exposed on the Wallace River approximately 4 km west of Wallace Station No. 1 as the best exposed section through the Malagash-Claremont Anticline. The sequence in descending order is summarized as follows:

PICTOU GROUP (may include some Cumberland)

North limb

brownish red sandstone, siltstone, brownish red and some grey arkosic grit and conglomerate; 1500 feet underlain by brownish red and mottled red and grey sandstone and grey quartzite-pebble conglomerate. Thickness: 825 feet.

South limb

lower half, grey and brownish red quartzite-pebble conglomerate and sandstone; and upper half, mainly brownish red, arkosic conglomerate, sandstone and grit. Thickness 1785 ft.

disconformity

RIVERSDALE GROUP

Boss Point Formation

grey and brownish red sandstone, lenticular limestone conglomerate beds. Thickness: 3600 feet, north limb; 4350 feet, south limb

Claremont Formation

brownish red to brick red arkosic conglomerate, some red sandstone and kunkur bearing shale.
Thickness: 450-500 feet.
Fault in north limb, disconformity in south limb

Middleborough Formation

brownish red sandstone, siltstone and shale. Thickness: 275 feet, north limb; 3175 feet, south limb. Fault in north limb, possible fault or disconformity in south limb.

WINDSOR GROUP

Poorly exposed, yellowish brown and grey, calcareous sandy shale, shaly limestone. Thickness: uncertain.

This section (Fig. 4-12) is probably typical of a higher erosional level, or lower level of intrusion in the Malagash Anticline with the mobile Windsor core not fully exposed. The Wallace River section was generally confirmed in later drilling along strike to the east near Wallace station.

In 1973 Anschutz Corporation drilled Wallace Station No. 1 in exploration for petroleum, 2.5 km southwest of Wallace Station and 5 km west-southwest of Wallace No. 1 on the Wallace structural block of the Malagash Anticline (southern limb) (Figs. 4-5, 4-13). The following is the generalized stratigraphic succession reported in the well: surface to 134 m (440 ft.) Middleborough Formation; 134-491 m (440-1610 ft.) Windsor Group; reverse fault; 491-613 m (1610-2010 ft.) Claremont Formation; 613-792 m (2010-2600 ft.) Middleborough Formation; 792-2455 m (2600-8056 ft.) Windsor Group C? Subzone; 2455-2506 m (8056-8222 ft.) Windsor Group B? Subzone; 2506-3981 m (8222-13,060 ft.) Windsor Group A? Subzone (salt); 3981-4267 m (13,060-14,000 ft.) Windsor Group shale and chert; 4267-4536 m (14,000-14,883 ft.) Horton Group. The interval 4432-4536 m (14,540-14,883 ft.) in the Horton Group is reported to contain 51% salt. Drilling difficulties required multiple directional redrilling resulting in a rather complex well history.

A southward dipping thrust fault was postulated by MacDonald (1973) to explain the Middleborough Formation-Windsor Group section to 491 m overlying the younger Claremont Formation. Anomalous K_2O measurements are indicated in several intervals of the salt although analyses of sidewall core from these intervals did not indicate a correlation with potash minerals.

Malagash Mine

The geology of the Malagash Mine site has been described by various workers including Hayes (1920, 1931), Ellsworth (1926), Chambers (1924), Norman (1932b), Bancroft (1938), Messervey (1950) and MacQuarrie (1975). Detailed descriptions of the mine are found in these reports and only a general description is summarized in the following paragraphs.

The Malagash Mine shaft is located 550 m south of the Northumberland Strait Shore on the southern limb of the Malagash Anticline (Figs. 4-5, 4-6, 4-14 and 4-15). The salt occurs as complexly deformed, variably thick, steeply dipping beds interstratified with gypsum and anhydrite. The rock salt is reported to have a distinct 5 cm thick banded structure with colours ranging from pure white to very dark grey with bands of red occurring locally. Insoluble material such as anhydrite, gypsum and clay occur as broken beds, stringers and irregular patches that originally were probably interstratified with the halite, but through deformation became broken and mixed in the mass. The mine is reported to have operated on three main salt seams, the MacKay, the Chambers, and the Lucas seams. The major salt production in the mine has come from the Lucas seam which is made up of three beds: a lower one consisting of pure white crystalline halite, a middle bed of interstratified salt, gypsum and anhydrite, and an upper bed of crystalline white halite with interstratified dark salt bands. The MacKay seam is reported to have inconsistent salt quality. The Lucas seam bed has a general strike of 115° and has an average dip of 45° south.

Extensive plastic deformation involving complex folding was prevalent in the mine (Fig. 4-6). Hayes (1920) postulated that strata duplication by folding or deleted by faulting probably existed in the salt mass. Later mine development substantiated that local crumpling, attenuation and thickening accompanied by complex isoclinal folding was present. Folding of the deposit is responsible for variations in the salt seam thicknesses making mine workings somewhat erratic (Fig. 4-14 and 4-15) because they had to follow the salt in the deformed beds. A large number of diamond-drill holes were drilled to explore and develop the Malagash Mine deposit (Fig. 4-16).

The Malagash Salt Mine was worked using an open stope system. A longwall cutting machine undercut the salt seam before blasting. This method was used until the dip of the seam became too steep at depth, and the undercutting procedure was abandoned. Mining width averaged 1.8 m (6 ft.) and had a maximum width of 3.7-4.3 m (12-14 ft.). Drilling underground was done with both electric and compressed air drills. The salt that required beneficiation was treated through flotation and fusion processes. Brining operations involving water sprayed on the salt were carried out on part of the MacKay seam. More detailed descriptions of the mining methods and development history are found in Hayes (1931), MacQuarrie (1975) and in Nova Scotia Annual Reports on Mines for the period in which the mine operated.

GEOPHYSICS

Miller and Norman (1936) published the results of a torsion balance gravimetric survey of the Malagash salt deposit. A substantial gravity

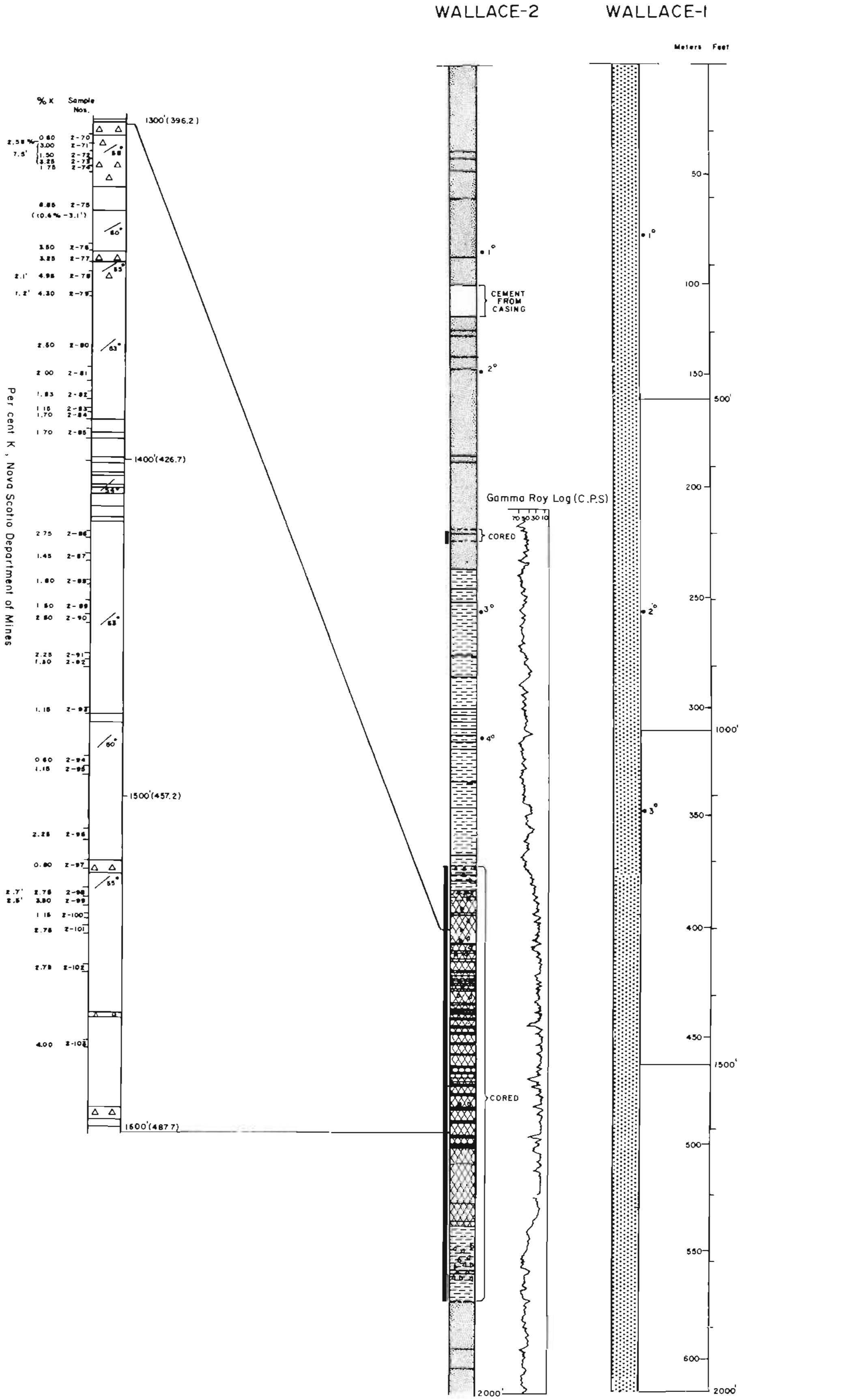


Figure 4-11. Drillhole profiles, Wallace Nos. 1 and 2, Malagash deposit. (For locations see Fig. 4-5).

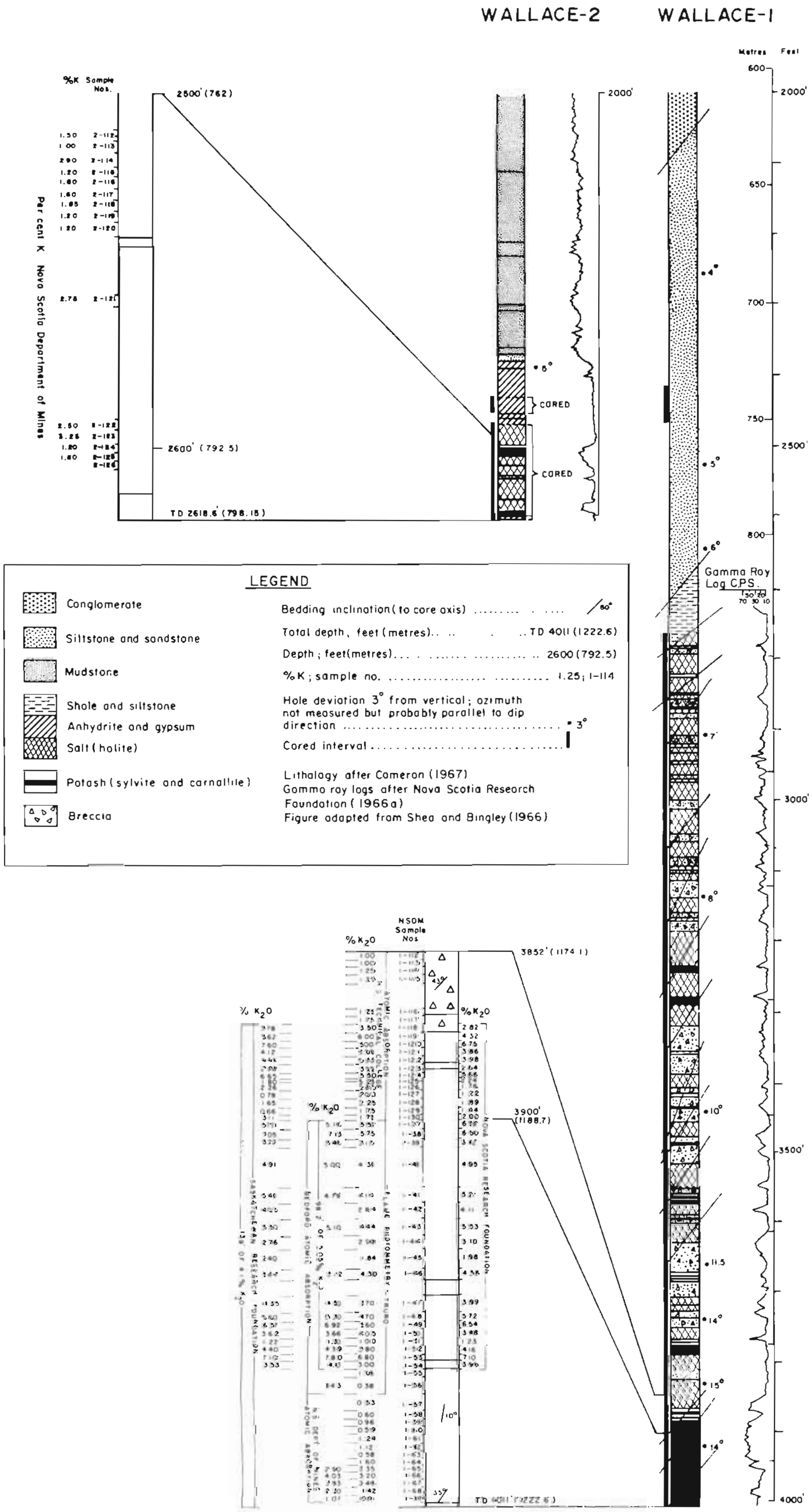


Figure 4-11. Continued.

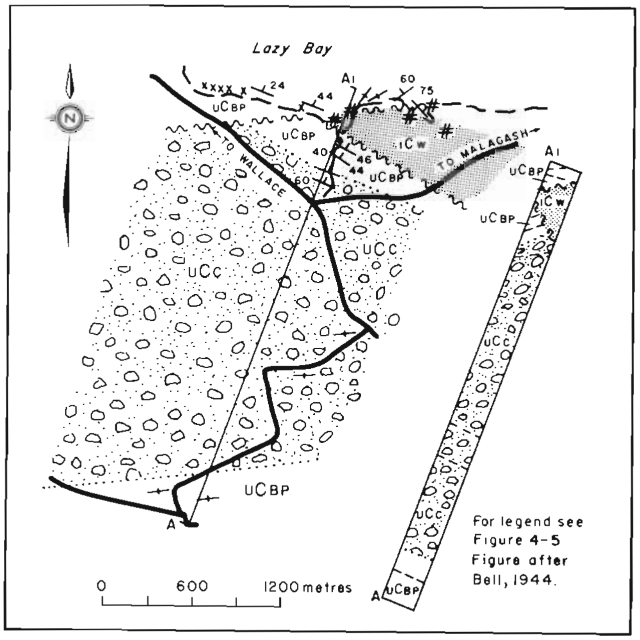


Figure 4-12. Geological map and cross-section, Lazy Bay.

anomaly was outlined, but geological models were not attempted.

Detailed gravity surveys were conducted on the Malagash and similar structures in Cumberland County by the Nova Scotia Research Foundation as part of the 1966 Potash Project. The survey in the Malagash-Wallace area outlined a large elongated Bouguer gravity low coincident with the Malagash-Clairmont Anticline (Fig. 4-8). A triangular outlined Bouguer gravity anomaly is evident in the Wallace Harbour area to the west. The southern (East Wallace-Lazy Bay) side of the triangle parallels the Malagash Anticline and is itself an elongate gravity low. This trend is not indicated as completely closing, but apparently opens to the north and connects with a smaller low centred in Wallace Harbour. The elongate Bouguer gravity low centred in the Malagash Mine area to the east coincides with the Windsor Group containing salt in the axis of the Anticline. Gravity model interpretations of the Wallace anomaly have been published by Bidgood and Blanchard (1967).

A total intensity magnetometer survey by the Nova Scotia Department of Mines (1966a) (Fig. 4-9) was conducted over the same area as the Nova Scotia Research Foundation gravity survey. These surveys indicate a strong correlation between magnetic high anomalies and Bouguer gravity low anomalies in the axial area of the Malagash Anticline. The magnetic anomalies are small scale, and low amplitude features concentrated along the southern flank of the gravity anomalies. A similar coincidence was described at the Roslin occurrence by the Nova Scotia Research Foundation (1967a). A study of the Roslin structure concluded the anomalies were produced by small bodies of magnetic material near the upper surface of the gravity feature. This material was speculated to be rinneite ($FeCl_2 \cdot 3KCL \cdot NaCl$).

In addition to the gravity and magnetic surveys, a reflection seismograph survey was undertaken by Beaver Geophysical Services Limited for the Nova Scotia Department of Mines and Pacific Petroleums Ltd. in 1965. Structural complications have hindered attempts to contour a structural map based on the Windsor Group (Fig. 4-17). Several major features of interest including fold axis and faults were outlined. Interpretation of the seismic data indicates a major high angle fault on the northern side of the Windsor outcrop area and a similar fault on the southern side. This evidence was used in constructing the cross-sections in Figure 4-7.

POTASH

Potash mineralized zones were first encountered in 1919 during the early stages of the development of the Malagash Salt Mine. The geology and chemistry of the potash horizons were investigated by Ellsworth (1926). He described the potash as almost pure sylvite (pink to yellowish green) occurring most commonly as disseminations and small lenses. The sylvite was associated with red coloured salt with the colouration attributed to the presence of microscopic hematite. The potash seams appear to have undergone some leaching of the soluble potassium salts because of their hygroscopic nature and extreme solubility. Chambers (1924) suggested that cracks in a zone of yellow clay filled with salt and potash minerals might indicate a period of complete drying of the depositional basin waters and sediment dessication. Leaching and small scale unconformities were also reported in banded salts associated with the potash zones. The potash was not considered to be of economic interest at that time because of low grade and uncertain continuity.

Messervey (1950) indicated that although the potash occurred mainly as small isolated lenses, three well-defined zones bearing small, persistent quantities were observed in all levels of the mine. The potash occurs over widths ranging from 10 cm to 1.5 m. On the 24th level of the mine a potash zone was proven by diamond drilling and crosscutting over a length of 300 m (1000 ft.). The reported analyses from chip sampling range from 0.51% to 11.41% KCl. Approximately 72 000 t (80 000 tons) averaging 8% KCl were proven with an additional 131 500 t (145 000 tons) of similar grade possible.

Two deep drillholes, Wallace No. 1 and No. 2, intersected steeply dipping (55°) subeconomic grade potash salts mixed with halite and mudstone. Maximum grades reported are 4.1% K_2O over 42.2 m (139 ft.) or 5.05% over 29.9 m (98.2 ft.).

Evans (1970c) described the genesis of sylvite and carnallite bearing rocks from the Wallace Nos. 1 and 2 drillholes in the Malagash structure. He indicated that although sylvite was reported to occur with halite and minor carnallite in a dense clay and mudstone breccia it was probably a secondary product from leaching of carnallite.

In a petrographic examination of the mineralized core, Evans (1970c) reported the following

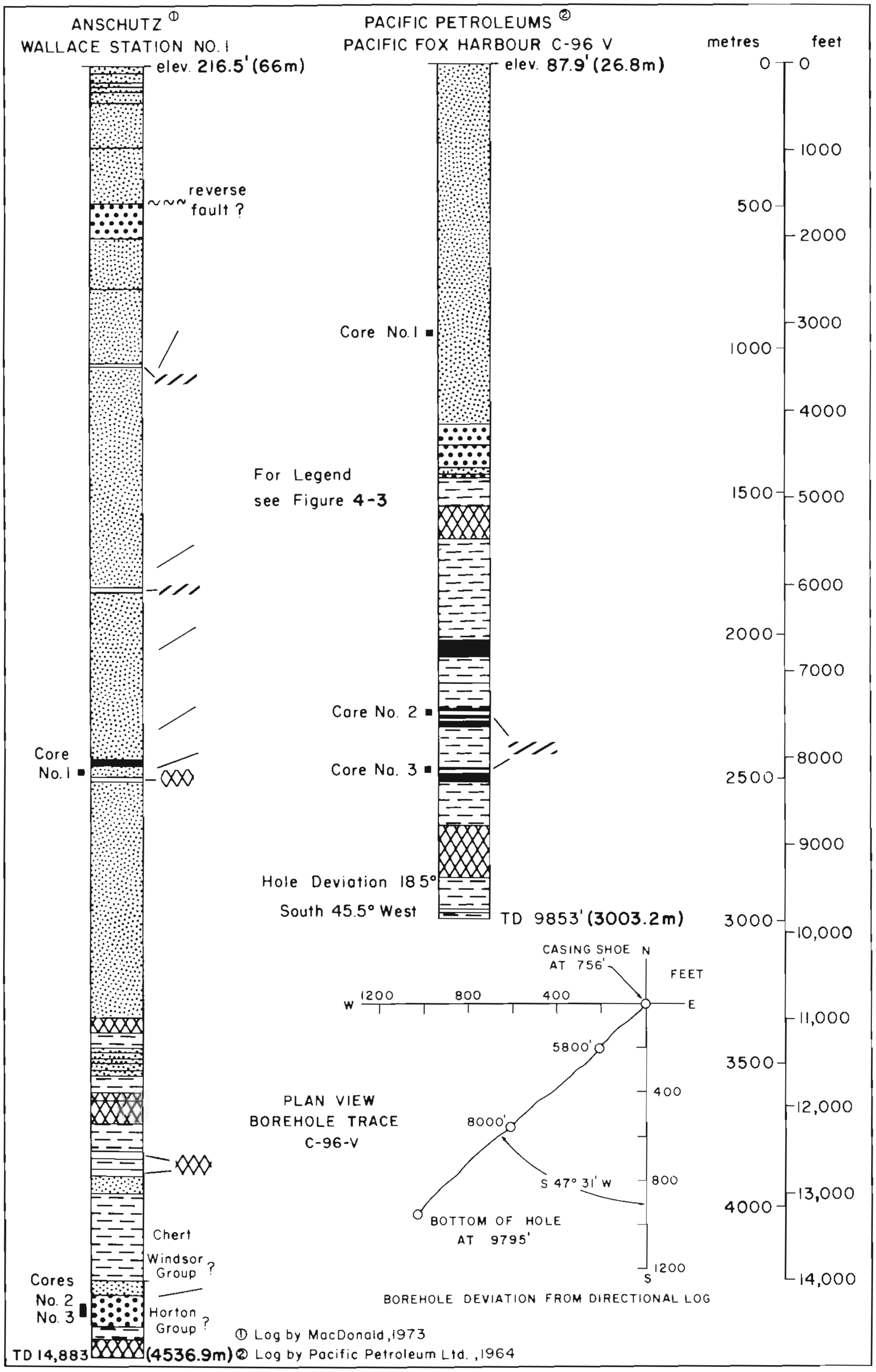


Figure 4-13. Drillhole profiles, Anschutz, Wallace Station No. 1 and Pacific Fox Harbour C-96-V, Cumberland County. (For locations see Fig. 4-5).

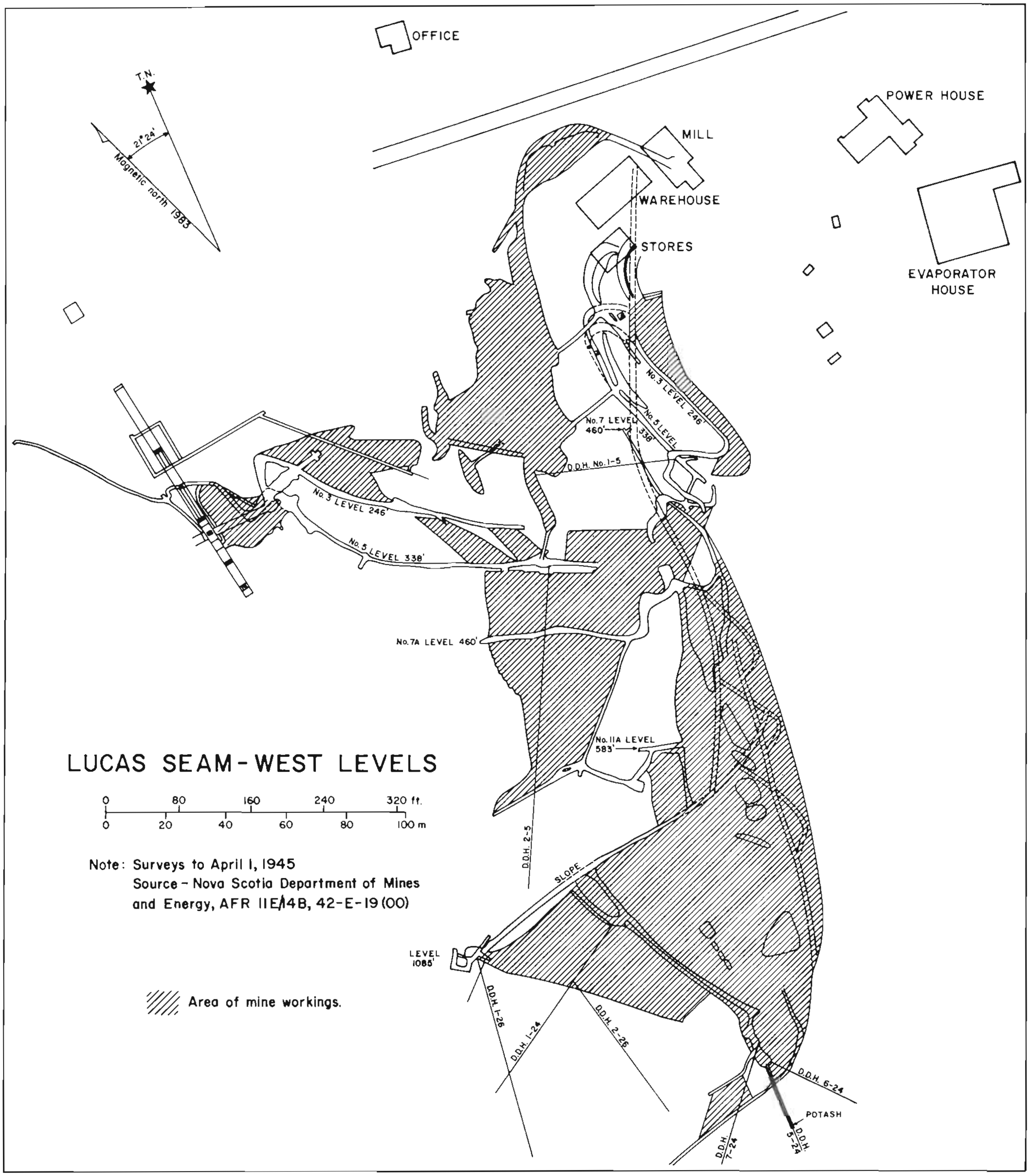


Figure 4-14. Malagash Mine plan, Lucas seam, west workings.

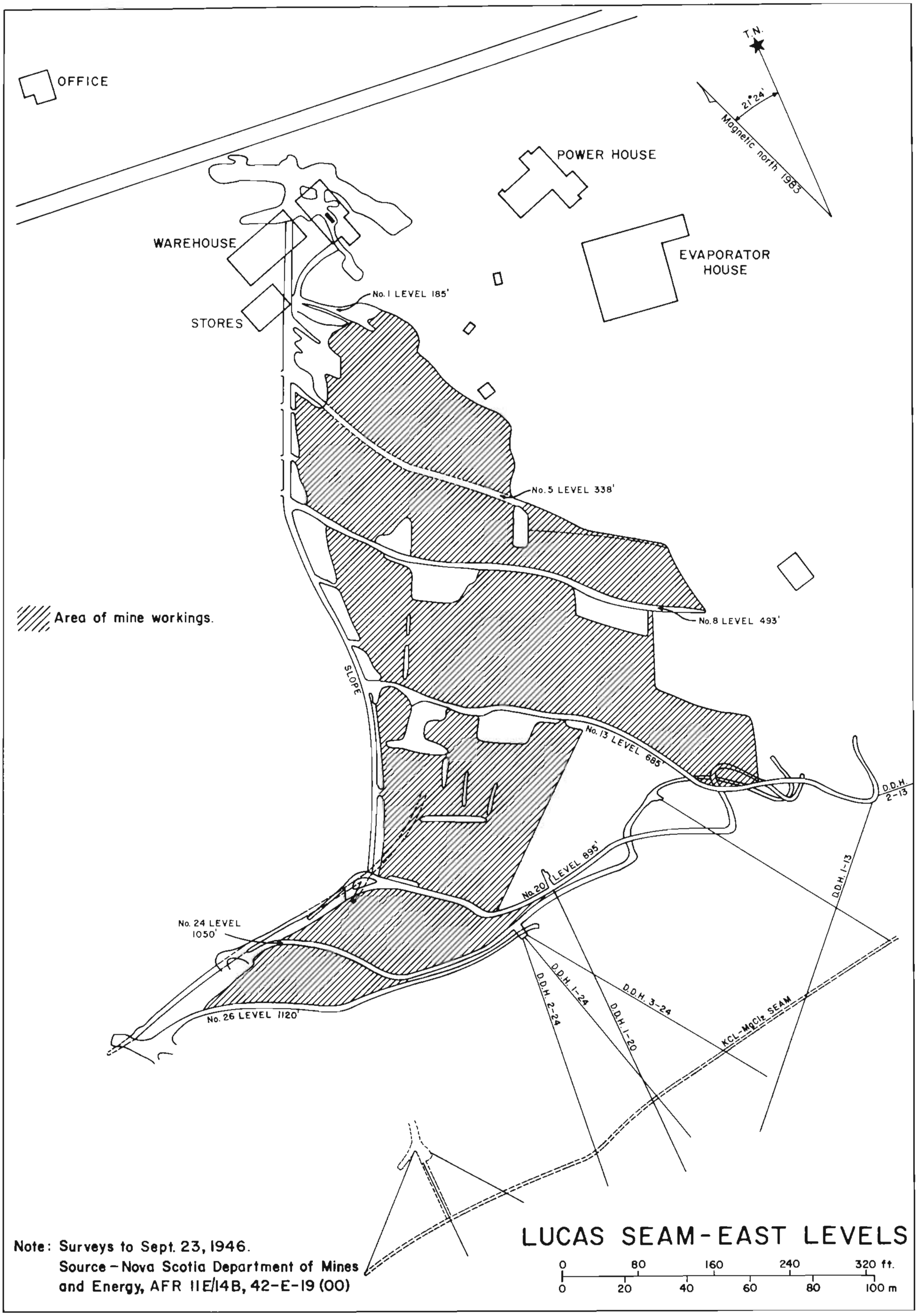


Figure 4-15. Malagash Mine plan, Lucas seam, east workings.

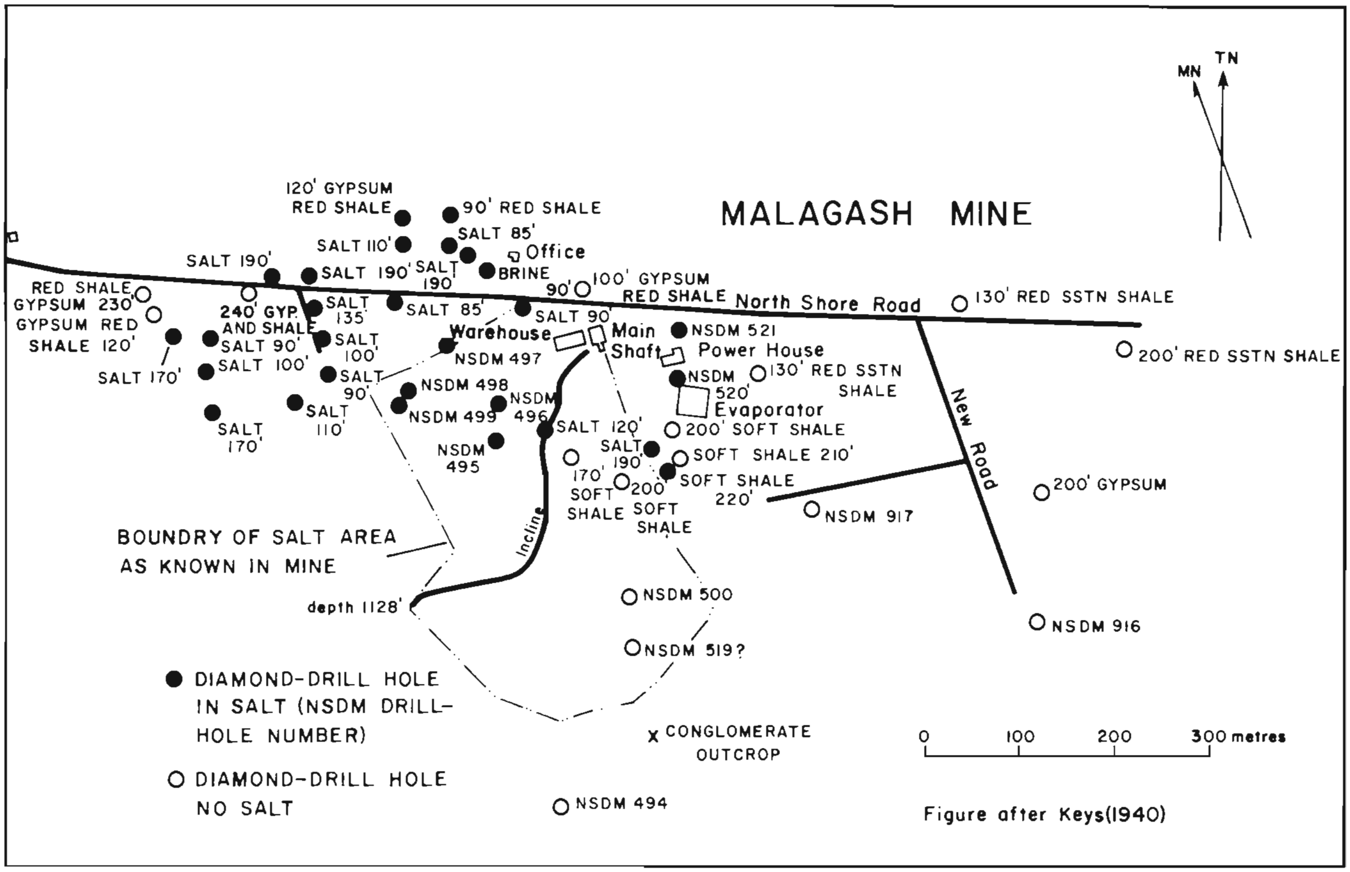


Figure 4-16. Drillhole location map, Malagash Mine.

paragenetic sequence: sylvite after carnallite, halite pseudomorphs after carnallite, and halite after sylvite after carnallite. Byproducts of the latter reaction include hematite, quartz and talc. The talc occurs as reaction rims and the hematite and quartz as hexagonal flakes and euhedra. Evans (1970c) concluded that the original sediment was a carnallite and halite rich clay which, through deformation was associated with salt intrusion, metamorphosed into the present assemblage.

GEOCHEMISTRY

A sample of water taken from a "waterspring at peak of active salt dome South Wallace" by Cameron (1965a) had the following analyses compared with analyses of the brine from Peter Murphy's well reported by Cole (1930a) (Table 4-1). The salt spring sampled by Cameron is dilute and has a high content of $CaSO_4$ indicating a probable gypsum and halite source. The salt brine analyzed by Cole (1930a), in contrast, is relatively strong and low in $CaSO_4$.

A substantial number of chemical analyses have been performed and reported by workers including Ellsworth (1926), Cole (1930a), Chambers (1924) and Hayes (1920). The most detailed study was that by Ellsworth (1926) who compiled much of the previous data and investigated in some detail the chemistry of the potash zones as exposed in the Malagash Mine. Table 4-2 (Appendix 2) contains analyses of salt samples collected from the Malagash Mine and compiled by Ellsworth (1926).

Table 4-3 (Appendix 2) contains the results of potash analyses made by Ellsworth (1926) on samples collected in 1919 during early mine development. Series A, B, C and E were sampled from a 5 cm (2-inch) channel cut normal to the dip, with each successive number representing a 30 cm (1-foot) interval of the channel from top to base. Sample A-1 was reported by Ellsworth (1926) to represent the uppermost part of the "red zone" and C-6 the lowest part accessible at that time. Series D consists of samples obtained from drilling the same interval as the B series. Series E is supposedly the same interval as series A only taken on the opposite side of the drift. In addition more detailed determinations were made by Ellsworth (1926), on composite samples of the A, B, C and D sections and the results are presented in Table 4-4 (Appendix 2). Tabulations of chemical analyses of core samples from the 1966 Potash Project drill program are also presented in Appendix 2.

ECONOMIC CONSIDERATIONS

The Malagash deposit consists mainly of halite with thin, but significant zones of low grade

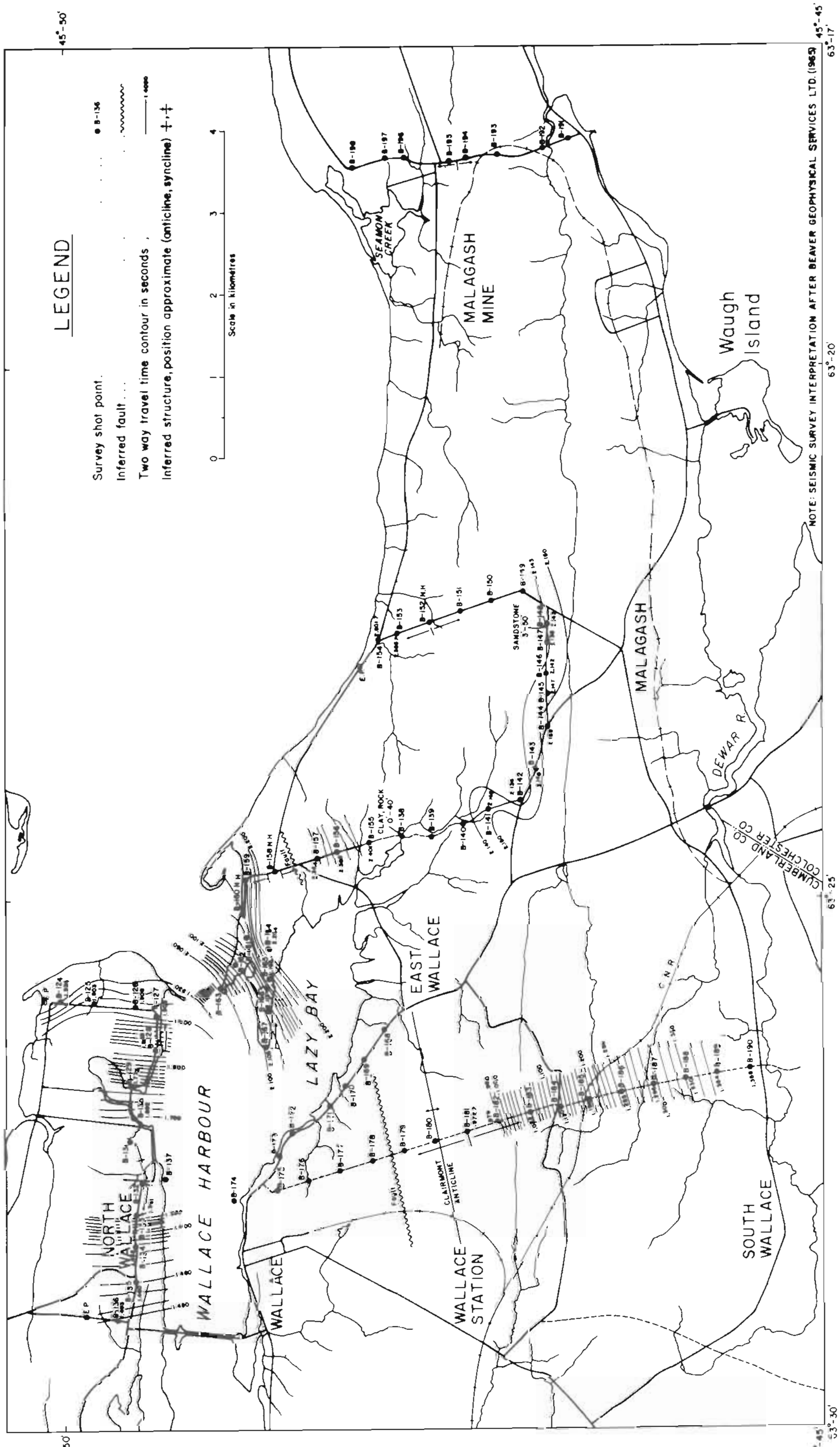


Figure 4-17. Reflection seismic survey showing structural contours on a Windsor Group horizon, Malagash-Wallace area.

Table 4-1. Analyses of salt brines, South Wallace and Malagash.

	South Wallace Cameron (1965a) (parts per million)	**Peter Murray well, Malagash Cole (1930a) (milligrams per litre)**
Sodium	500+	99 500
Potassium	20.0	550
Iron	n.d.	70
Calcium	810.0	1 370
Manganese	63.2	220
SO_4	n.d.	3 110
Chloride	250+	Chlorine 154 700
Ph	7.3	n.d.
Conductance (mhos x 10-5)	1800	n.d.
Sg	n.d.	1.200 (15.5°C)

Hypothetical Combination
(parts per thousand)

NaCl	252.90
KCl	1.04
$MgCl_2$	0.86
$CaCl_2$	0.22
$CaSO_4$	4.42
Fe_2O_3	0.10

potash minerals associated with brecciated mudstone. Part of the deposit was mined for salt in the Malagash Salt Mine which operated on the eastern end of the deposit between 1919 and 1959. Potash, mainly sylvite, was encountered in several variable, but continuous low grade zones as well as in scattered lenses in the mine. Potash was intersected in the Wallace No. 1 drillhole 10 km to the west of the mine and in Wallace No. 2 drillhole 4.25 km west of the mine on the same structure. Much of the deep exploratory drilling was concentrated on the southern limb of the steeply dipping structure.

The area is readily accessible by paved highways, gravel roads and railway lines. The Northumberland Strait shore and Wallace Harbour are within easy reach of most of the area and could potentially be developed for tide water shipping facilities. The deposit is not being used at present and the area will require further exploration to determine if economic salt and potash deposits are present.

NAPPAN DEPOSIT

LOCATION

The Nappan deposit is located in the vicinity of Nappan 5 km south of Amherst (NTS 21H/16), northwestern Cumberland County, northern Nova Scotia (Figs. 1-4, 1-10 and 4-18).

The area is readily accessible by paved highway from the Trans-Canada Highway 104 that runs between Truro through Amherst to New Brunswick. The mainline of the Canadian National Railway between Truro and Montreal passes within 1.5 km of the Sifto Salt Company brining mine. The area is located approximately 8 km south of the Cumberland Basin where potential tidal power installations are being evaluated.

The area is located near the lowlands of the Chignecto Isthmus which lie between Nova Scotia and New Brunswick. These marshy lowlands rarely exceed 30 m in elevation and are generally at or near sea level. The highland area to the south is characterized by undulating hills with elevations of up to 150 m.

HISTORICAL BACKGROUND

The Nappan deposit is located in the Minudie Anticline that was explored for potential petroleum deposits by Imperial Oil Limited between 1926 and 1932 and by Sun Oil Company Limited between 1945 and 1947.

The Minudie structure has been known in geological literature for over 100 years. Logan (1845) described and measured in detail the strata of the coastal section from the crest of the Minudie Anticline to the middle of the adjoining Cumberland coal basin syncline. He reported a section, in excess of 1500 m thick, of conformable Pennsylvanian sediments containing an upright standing coal forest. Dawson (1868) elaborated on the paleontology of the section.

A reconnaissance survey of Nova Scotia in 1926 by International Petroleum Company (Imperial Oil Limited) outlined the Minudie structure as having good petroleum potential which warranted further investigation (Roliff, 1932).

Pohl in Hayes (1931) reported that salt water was encountered in a water well near Upper Nappan. Fresh water used in the 1927 drilling operation returned salty between 70 and 85 m (230 and 280 ft.). This indicated that at least part of the structure contained salt although its precise configuration was unknown.

In 1928 Imperial Oil drilled six test holes near Nappan, south of Amherst, to confirm the nature of the anticlinal structure. Four additional holes were drilled in 1929. Early in 1931 a wildcat test well, Amherst No. 1, was drilled to a total depth of 1260 m (4134 ft.). The hole was stopped in the Windsor Group gypsum, anhydrite and salt without completely penetrating the sequence, establishing that the structure was not just a simple anticline, but rather has a dome or diapiric configuration with accompanying thickening of the core evaporites.

In late 1942 the Nova Scotia Department of Mines studied the Nappan area in connection with a proposed drilling program to check the possible extension of the salt beds encountered in the Imperial Oil Amherst No. 1 hole. The test area was located approximately 1.5 km west-southwest of the Imperial Oil hole. Although the first hole was abandoned, the second and third holes intersected salt. Based on the success of the Nova Scotia Department of Mines investigation and the Imperial Oil Amherst No. 1 well, Maritime Industries Ltd. began boring brine wells for the production of evaporated salt at Nappan in late 1945. In the same year Sun Oil Company spudded Sunoco No. 1 exploratory well for petroleum. The Sunoco well intersected salt but had to be abandoned at 1981 m (6499 ft.) due to drilling problems. In 1946 this well was relocated 46 m north and redrilled as Sunoco No. 1A. It reached Horton Group strata at approximately 1850 m and was finally abandoned at a depth of 3506 m in 1947. The section reported as Horton is now known to belong to the Canso-Riversdale Group based on spores (Howie, personal communication, 1982). By 1947 the Maritime Industries Nappan operation was in production. The company took over the abandoned Sunoco Nos. 1 and 1A oil wells and used these for brine production. The Nappan operation is still in production and is now owned by Domtar Chemical Ltd. Sifto Salt Division.

In 1975 Gulf Oil Canada Limited et al. drilled Hastings No. 1 in exploration for petroleum near Hastings, approximately 9 km east of Amherst. This well which intersected Upper Carboniferous strata was reported to have been abandoned in "Older Paleozoic" metamorphic rocks that were first encountered at 2783 m (9130 ft.). Rocks of the Windsor Group were not identified in this borehole.

GEOLOGY

The geology in the Nappan area was described and mapped by geologists with Imperial Oil Ltd. A simplified version of this map is presented in Figure 4-18. In general form the structure at Nappan is that of an eroded east-west trending anticline (Fig. 4-18). This anticlinal structure, known as the Minudie Anticline or Anticlinorium, extends from Shepody Bay in New Brunswick on the west, to near Brookdale, approximately 3 km southeast of Amherst, on the east. Geologically the Minudie Anticlinorium is defined by Lower and Upper Carboniferous units with the oldest, Windsor Group occurring in the axial region and the successively younger Middleborough Formation, Boss Point Formation, and Pictou Group rocks on the flanks.

The Windsor Group consisting of red shale, gypsum, and anhydrite rocks in the core area, was assigned by previous workers such as Roliff (1932) to the A Subzone. These rocks, where exposed, are reported to be highly folded and contorted. They exhibit flow structures and form a series of small and large complex antiforms and synforms within the larger Minudie Anticlinorium. The northern and southern limbs of the Anticlinorium are characterized by relatively consistent strikes and moderate dips, in contrast to the more variable attitudes in the core region. On the northern flank of the Anticlinorium, Roliff (1932) reported red shales of the Windsor Group Subzone A overlying the gypsum, but the overlying Subzone B limestone succession is apparently concealed by the overlapping Pictou Group. In many areas the Windsor Group is overlain by chocolate red shale and siltstone of the Transition Formation of Roliff (1932) which appears to be equivalent to the Maringouin or Shepody Formation of Shaw (1951) or the Middleborough Formation of Bell (1944). The Middleborough Formation is overlain by a sequence of sandstone and shale called the Boss Point Formation (Riversdale Group).

The Boss Point Formation is in turn overlain with apparent angular unconformity by sandstone, shale, and conglomerate of the Pictou Group. On the northern flank of the structure in the Maringouin Peninsula, New Brunswick, gently dipping Pictou Group rocks rest upon highly inclined beds of the Boss Point Formation (Roliff, 1932).

The stratigraphy of the Windsor Group outcrops in the area were described by Bell (1944, 1958). The lower evaporite succession (A Subzone) of the Windsor Group is overlain with uncertain relationship by red shales and fossiliferous B Subzone limestone. The limestones are exposed at several localities around the Minudie Anticlinorium in particular on its southern limb. Hayes (1931) described the section at Lower Maccan on the southern limb of the structure as having 18.3 m (60 ft.) of red and grey shale overlain by a 27 m (90 ft.) bed of limestone similar to that at Lime-kiln Brook (Fig. 4-19). The strike exposure of the limestone yields good collecting of the fauna that he indicated is dominated by abundant *Diodoceras avonensis*, the B Subzone guide fossil. Sinkhole topography reported to stratigraphically overlie the limestone by approximately 76 m (250 ft.) was interpreted as a gypsum horizon. According to Hayes (1931) the gypsum occurred as a lens, because gypsum was known only to occur stratigraphically below the Subzone B limestones. The sinkhole topography may, however, be related limestone karst. Hayes (1931) reported that 366 m (stratigraphic) (1200 ft.) of fine grained ripple marked sandstone (Middleborough Formation?) are reported to overlie the B Subzone limestone section.

Bell (1958) studied the Maccan River section in more detail and interpreted the succession somewhat differently. His section has a total exposed thickness of 88 m (290 ft.). He recognized a two part subdivision instead of a single limestone unit in which a limestone of the

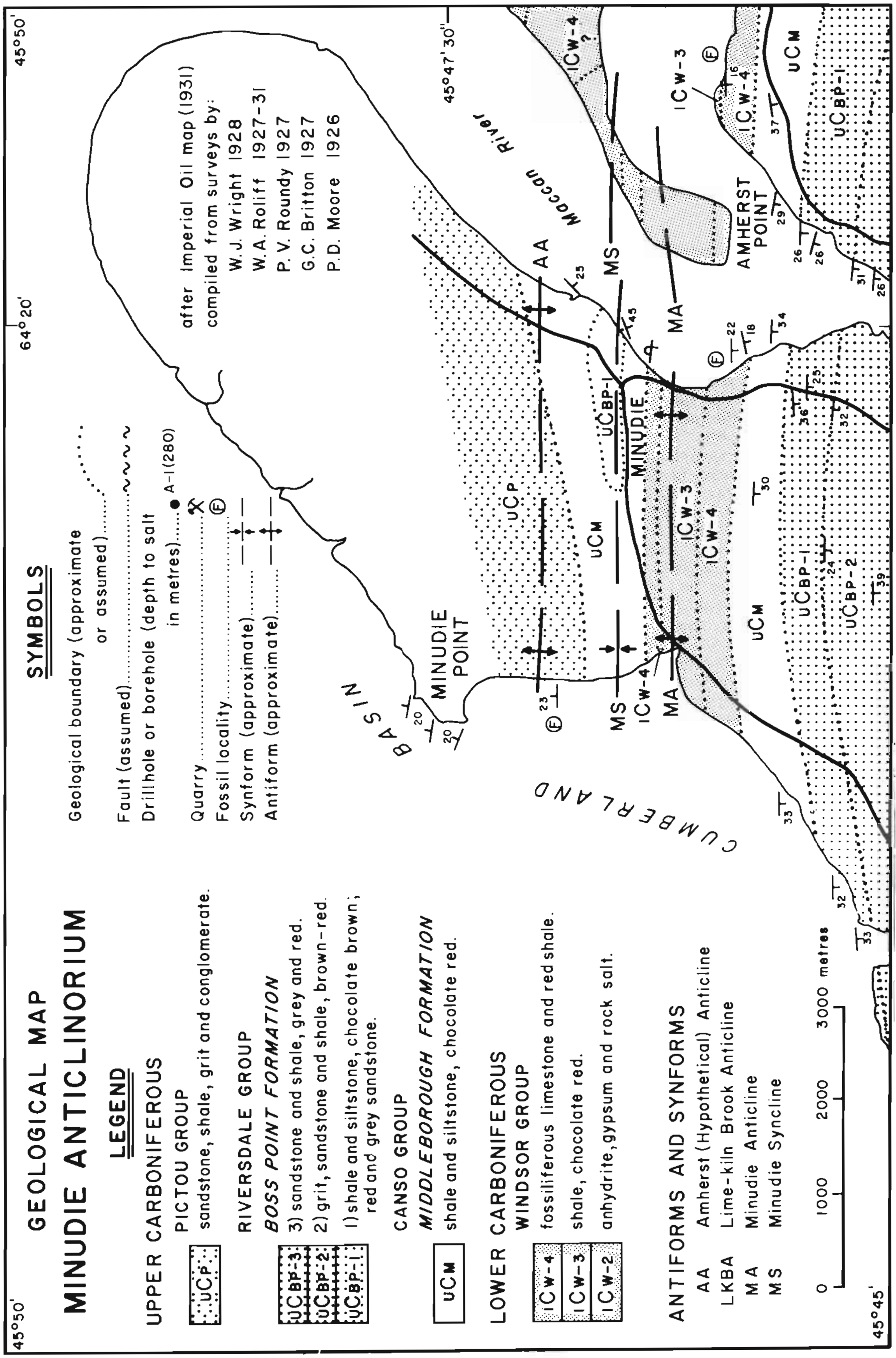


Figure 4-18. Geology in the vicinity of the Nappan deposit, Minudie Anticline.

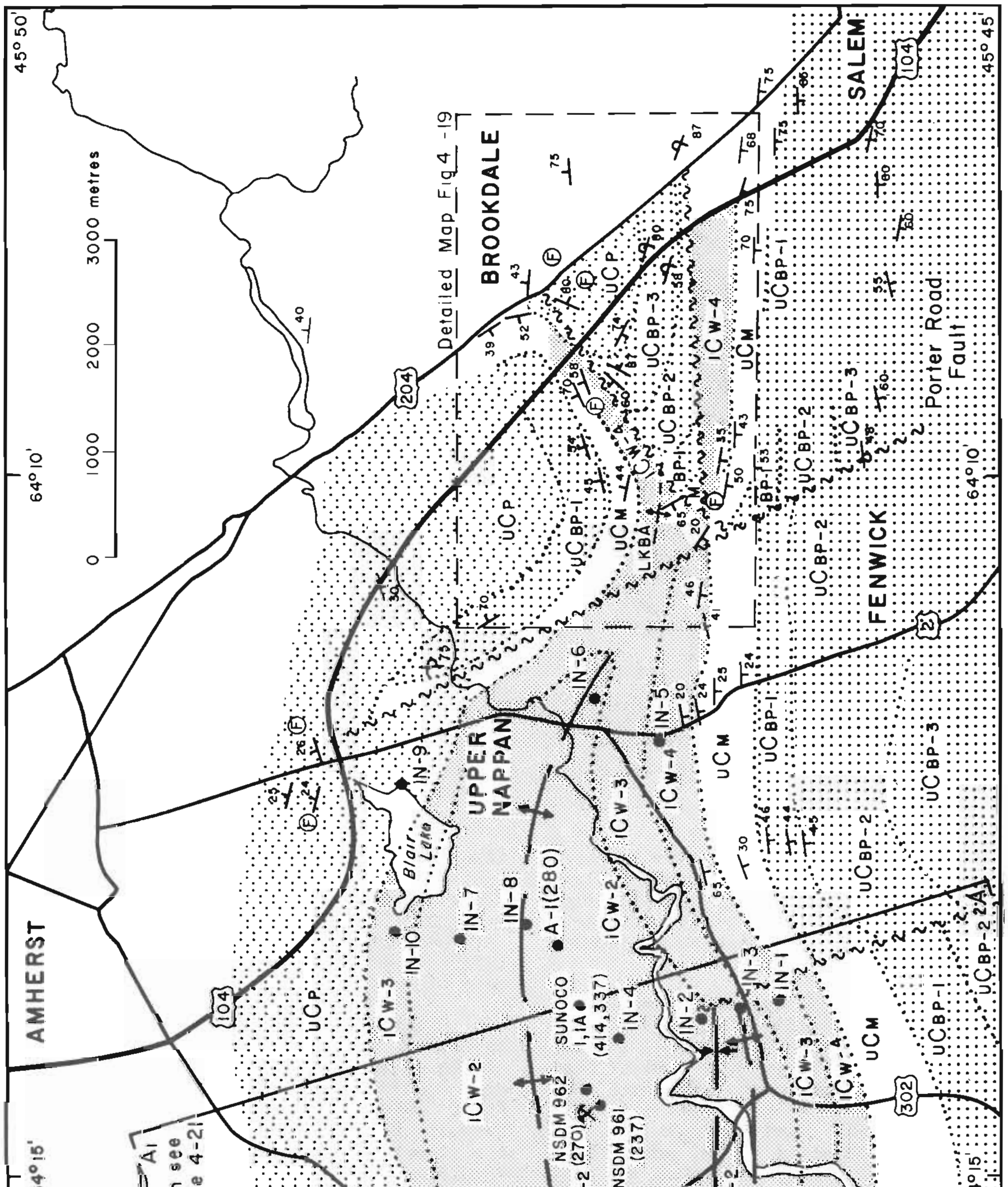


Figure 4-18. Continued.

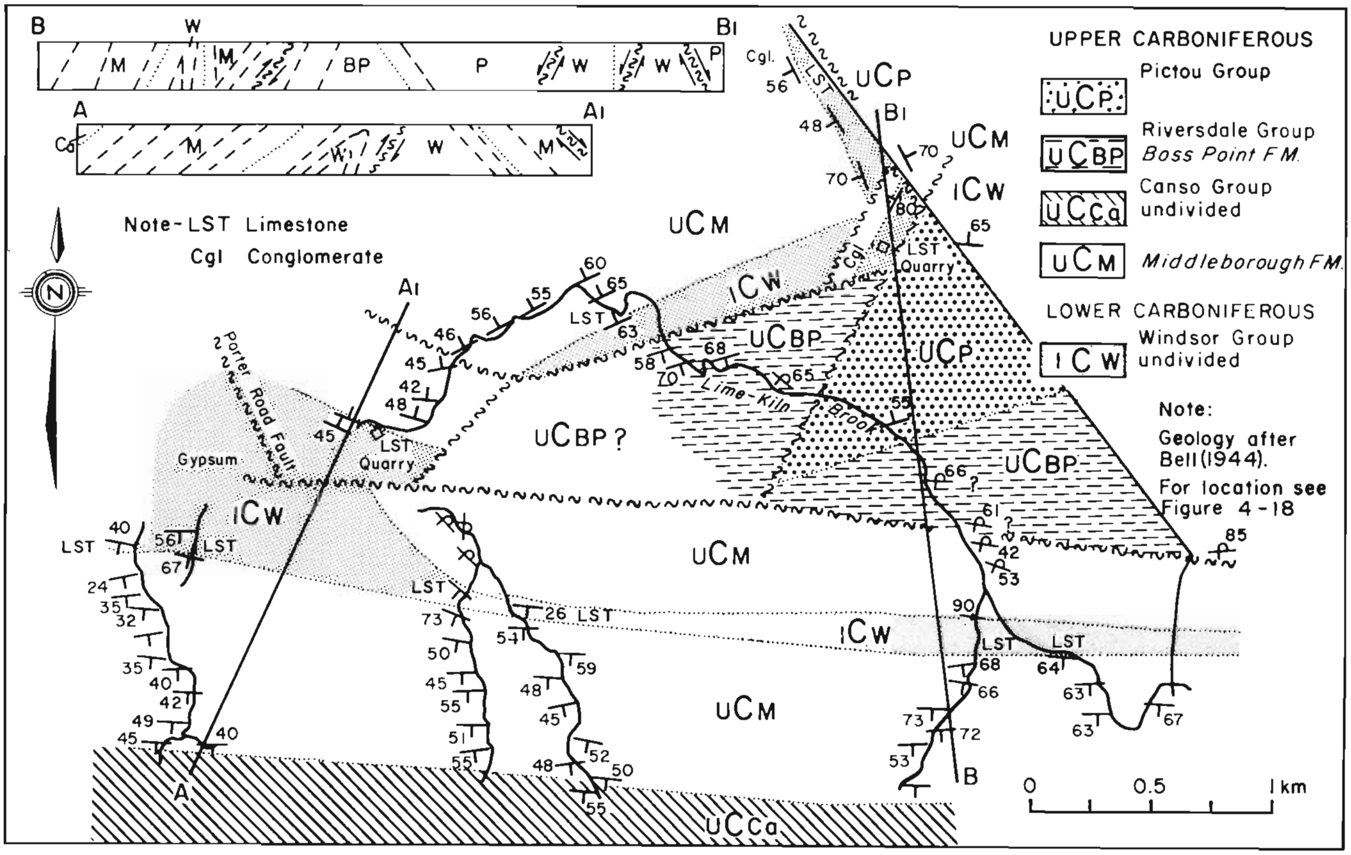


Figure 4-19. Lime-kiln Brook area, geological map and cross-section.

B Subzone (units 13, 14) is overlain by a thicker C Subzone limestone (units 17-26). Unfortunately, the fossils he reported from the C limestone are not specifically diagnostic to this Subzone. Moore and Ryan (1976) indicated a longer range for these forms.

The Minudie structure narrows drastically from the Maccan area westward (Fig. 4-18). B Subzone limestone strata mapped by Roliff (1932) in the Minudie area on the northern limb of the structure are indicated as being overturned and dipping southward (Fig. 4-18). Bell (1958) described this section, located south of the Minudie wharf, as consisting of at least four Windsor Group limestone beds separated by red siltstone, having a total section thickness of greater than 44.3 m (145.5 ft.).

Roliff (1932) postulated the Minudie Anticlinorium consisted of two major internal folds. These folds are, from south to north, the Minudie Anticline, Minudie Syncline and Hypothetical (Amherst) Anticline, in which the northern limbs are generally steeper than the southern limbs (Fig. 4-18). The dips of these fold limbs vary at different locations along the strike of the major Minudie structure, being nearly vertical near Maringouin Peninsula and approximately 22° in the southern limb at Minudie. The northern limb at Minudie is overturned. In the Nappan Station and Upper Nappan area, the southern dips are moderate and the Minudie and Amherst Anticlines begin to merge. Here they are separated by a tightly folded syncline. At this location the inferred northward dips are concealed and Roliff (1932) reported that shallow drilling indicated dips of about 45°.

Numerous minor faults transverse to the structural strike are reported along the length of the folds. The only fault of major displacement Roliff (1932) reported is the Porter Road Fault (Figs. 4-18, 4-19). It is important because it forms part of the eastern closure of the structure. Bell (1944) described the Porter Road Fault as a transverse upthrust (reverse fault), but limited its southerly extent by terminating it against an east-west (longitudinal) trending thrust fault (Fig. 4-19). The geological situation in the eastern end of the Minudie Anticlinorium is more complex than that described in the western area (Fig. 4-19). Bell (1944) reported that the Middleborough Formation lies conformably upon a "limestone zone" of the Windsor Group. This sequence is exposed in the Lime-kiln Brook quarry area. The Middleborough Formation comprising brick-red sandstone, siltstone, and shale, is indicated to have a total thickness of 480 m (1575 ft.). The Middleborough Formation was reported by Bell (1944) to be overlain conformably, in the Fenwick area, by

Canso Group comprising grey and red sandstone and red shale.

The Lime-kiln Brook section was described by Bell (1944, 1958). It is noteworthy that Bell (1958) reconsidered his earlier assessment and indicated that the Windsor Group-Middleborough Formation contact might be a disconformable rather than conformable contact.

The fauna of bed 3 of the Lime-kiln Brook section indicates an upper part of Subzone B of the Windsor Group. The presence of Nodosinella priscilla (in bed 18) probably indicates Subzone C (Bell, 1944).

Upstream in Lime-kiln Brook approximately 1 km east-northeast from the quarry, the uppermost limestone unit from the "quarry section" is exposed. In this exposure, Bell (1944) reported that the limestone section was overlain by Middleborough Formation arkosic grit. The same limestone unit is again exposed farther east near Brookdale, where it was reportedly quarried for manganese. Here again Bell (1944) reported that it is overlain by red grit and conglomerate at the base of the Middleborough Formation. The limestone was considered by Bell (1944) to be probably C Subzone. The upper units of this limestone section he equated with the upper units in the Maccan River section to the west. The Lime-kiln Brook area is extensively faulted according to Bell's (1944) map (Fig. 4-19). He indicated that the southern limb of the Minudie Anticline was folded back upon itself. The upper beds of the limestone section and conglomerate at the base of the Middleborough, he reported to be poorly exposed in the axial area of the subordinate fold. This fold apparently accompanies an east-west trending thrust fault where Middleborough Formation strata are thrust against the Boss Point Formation. The Boss Point Formation and the sometimes unconformably overlying Pictou Group strata are down faulted against the Windsor Group limestone section or against Middleborough Formation strata on the northern limb of the Minudie Anticlinorium.

Lower Windsor A Subzone gypsum outcrops in the central region of the Minudie Anticlinorium, and was quarried to a small extent, near Nappan. Bell (1944) stated that the Windsor limestone section (B and C Subzones) is underlain by a section of brownish to brick red mudstone, sandstone, shale, and then gypsum. He further indicated that if the lowest Windsor limestone outcropping in the brook west of Lime-kiln Brook is continuous in section with the gypsum intersected in the Imperial Oil drillhole located approximately 425 m to the north, then the interval comprising red siltstone and shale is in the order of 245 m. Hayes (1931), using similar reasoning, indicated this interval to be approximately 275 m thick.

Deep exploration drilling has provided a better understanding of the geology of the Minudie Anticlinorium. The early uncomplicated anticlinal model was proven to be invalid when more than 1000 m of evaporites were intersected. Deep drilling for petroleum in the Nappan area was under taken in three holes: the first, Amherst No. 1 was drilled by Imperial Oil Limited in 1931, and two were drilled by Sun Oil Company, Sunoco No. 1 and No. 1A between 1945-1947 (Fig. 4-20).

Prior to the drilling of the Amherst No. 1 well, Imperial Oil Ltd. drilled ten shallow holes with depths ranging between 32 and 243 m to evaluate the configuration of the structure (Fig. 4-18). Gypsum was penetrated as bedrock in six of these. The four remaining holes penetrated younger strata flanking the structure. Roliff (1932) reported that in planning the Amherst No. 1 test, it was estimated that the Windsor Group gypsum, salt and limestone would not extend beyond the depth of 300 m. It was estimated that a sequence of 600 to 1200 m of red and chocolate shales and conglomerate would be found, followed by the Horton Group Albert Formation.

Amherst No. 1 first penetrated salt at 280.4 m after intersecting an interbedded (collapse brecciated) sequence of gypsum, sandstone, conglomerate, limestone, and dolostone. Between 280.4 and 488 m, seven salt intervals were intersected with an aggregate thickness of 52 m. From 488 m to the total depth at 1260 m, 8 salt beds totalling 384 m were intersected with major thick gypsum and anhydrite interbeds. The major salt intervals intersected are: 527.3-554.7 m, 664.5-716.3 m, 734.6-759 m, 777.2-868.7 m, 923.5-1063.8 m (981.5-984.5 m is reported to be similar in appearance to the Malagash potash mineralized zone), and 1207-1237.5 m. The salt is described from drill cuttings as being mostly white to clear white with some pink and reddish coloured salt locally abundant.

The stratigraphic and structural configuration of the salt units encountered in the drilling was not precisely known. Cross-sections drawn by Imperial Oil Limited to accompany their geological map portray the evaporite succession in the core area of the Minudie Anticlinorium as being tightly folded and probably highly contorted. This severe deformation appears to be due to the mobile nature of the evaporites produced by their flowage and has resulted in a great thickening in this part of the section (Fig. 4-21). This situation is not unlike that encountered in the Pugwash and Malagash Mines and probably occurs in all the Windsor Group outcrop areas in the Cumberland area.

In early 1943 the Nova Scotia Department of Mines began diamond drilling approximately 1500 m west-southwest of the Amherst No. 1, in the vicinity of an old gypsum quarry. Salt was penetrated at 237.4 m (779 ft.) in NSDM 961 and was abandoned in salt at 273 m (895 ft.). NSDM 962, drilled 194 m northeast, penetrated salt at 270.7 m (888 ft.) and was abandoned at 340 m (1114.5 ft.). The depth to salt in both drillholes is similar to the 280 m (920 ft.) depth to salt in the Amherst No. 1 well. Maritime Industries Limited began boring brining wells for the production of evaporated salt in 1945.

In 1945 Sun Oil Company drilled Sunoco No. 1 (Fig. 4-20) in search of petroleum approximately 800 m east of the NSDM 962 and 600 m west-southwest of Amherst No. 1. Salt was first pene-

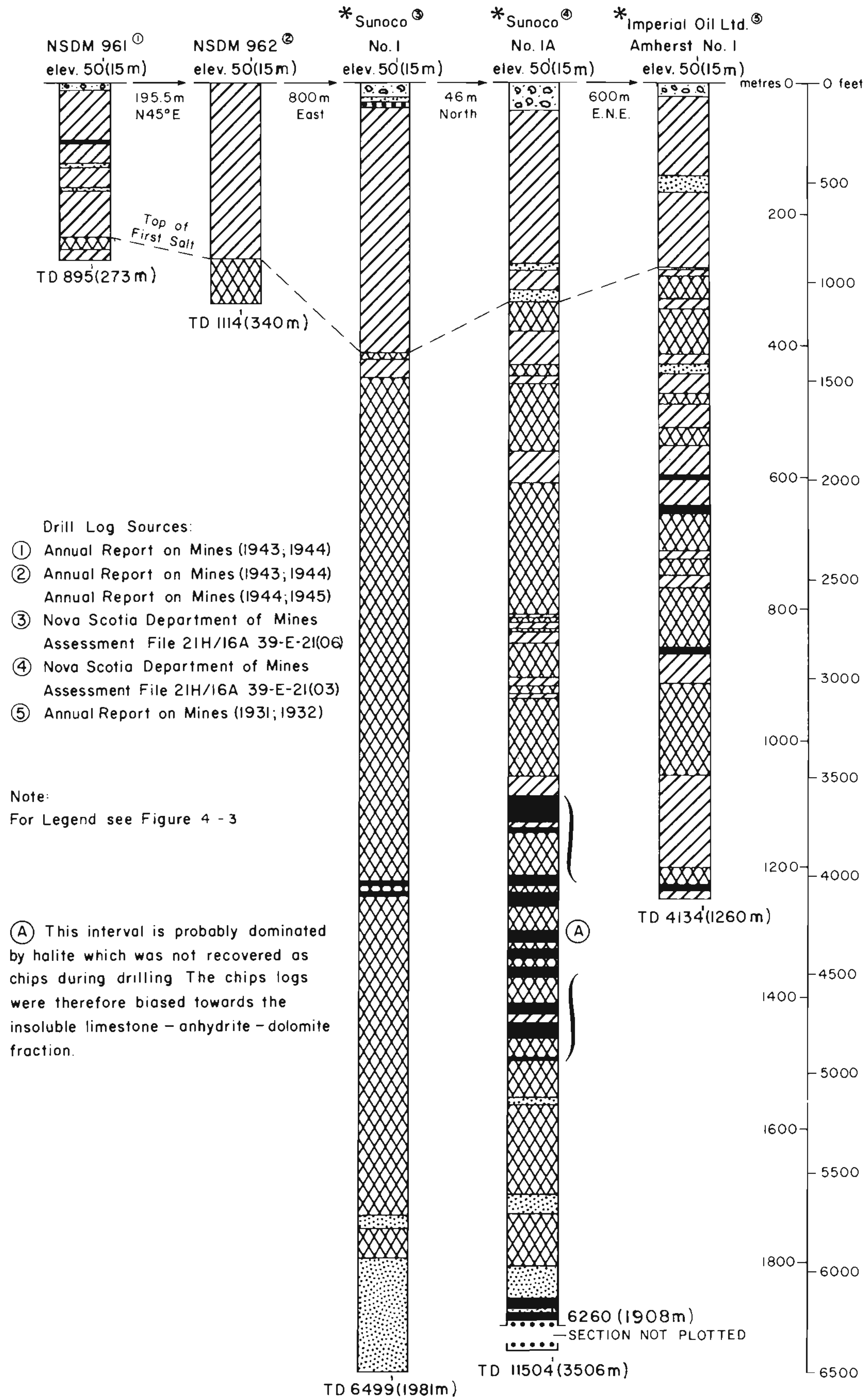


Figure 4-20. Drillhole profiles, Nappan deposit, Cumberland County. (For locations see Fig. 4-18).

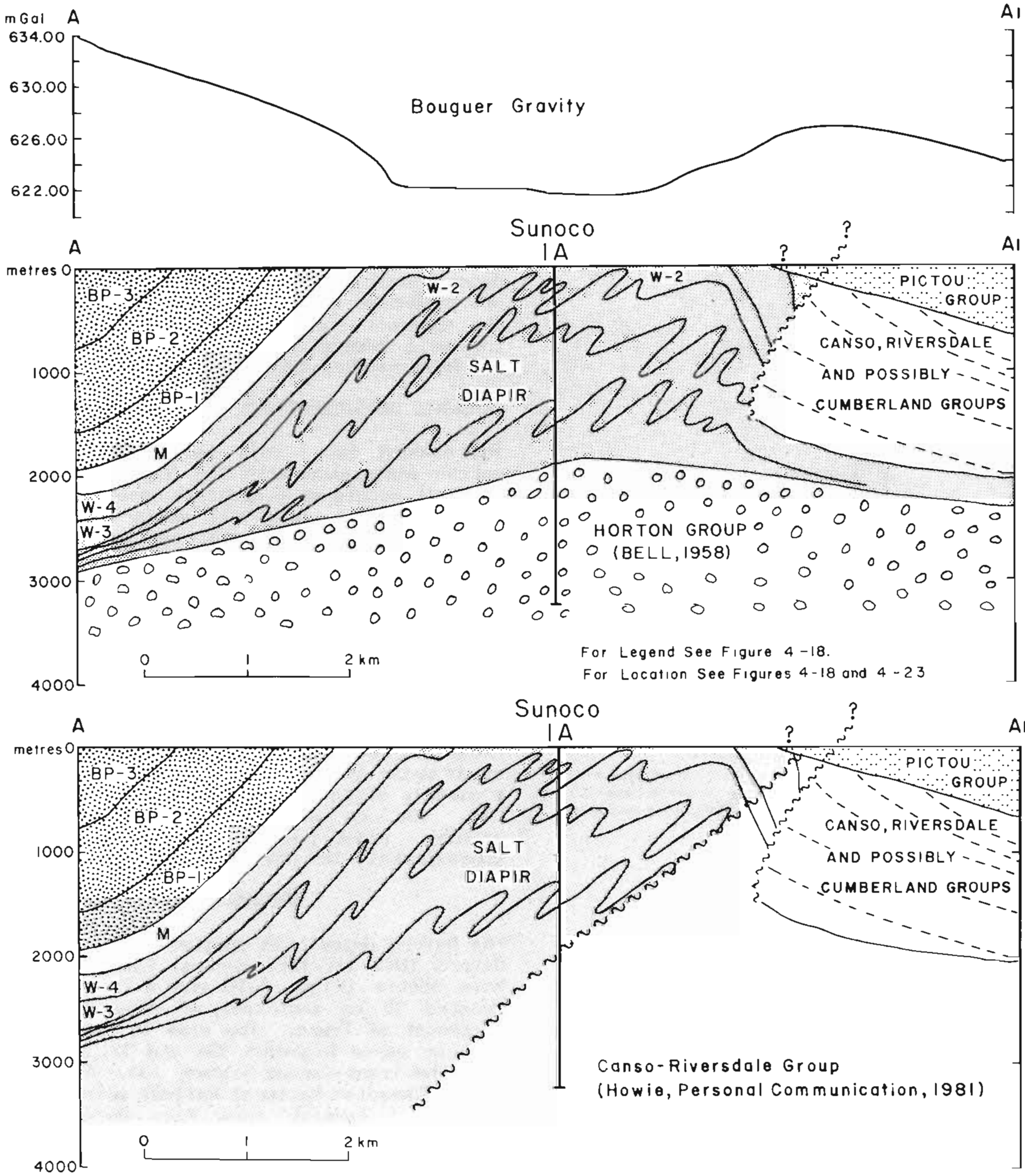


Figure 4-21. Geological and Bouguer gravity profile, Nappan deposit.

trated at 414.5 m (1360 ft.) and was bottomed at 1809.3 m (5936 ft.). The hole was lost at 1981 m (6499 ft.) and Sunoco No. 1A was drilled 46 m north. Salt was first penetrated at 336.8 m and was bottomed at 1818.1 m. In both holes the salt intervals alternated with gypsum, anhydrite, limestone, and dolomite. The Sunoco No. 1A test was abandoned in 1947 at 3506 m, in strata reported to be part of the Horton Group (Bell, 1958). Howie (personal communication, 1982) reported that Canso-Riversdale Group spores were recovered from this section indicating a reverse or thrust fault with Windsor Group evaporites over younger rocks (Fig. 4-21). It should be noted that the drillhole plots for Sunoco No. 1 and No. 1A (Fig. 4-20) are based upon chip logs which often are multicomponent descriptions and precise correlations are not apparent even though the hole separation is less than 50 m (Goodman and Pendle, 1955).

The latest drilling in the area by Gulf Oil Canada Ltd. in 1975 (Fig. 4-18) penetrated the entire Carboniferous section present (Fig. 4-22), but did not intersect salt. In this area the Windsor Group is apparently not present because of onlap by younger Carboniferous rocks onto pre-Carboniferous basement.

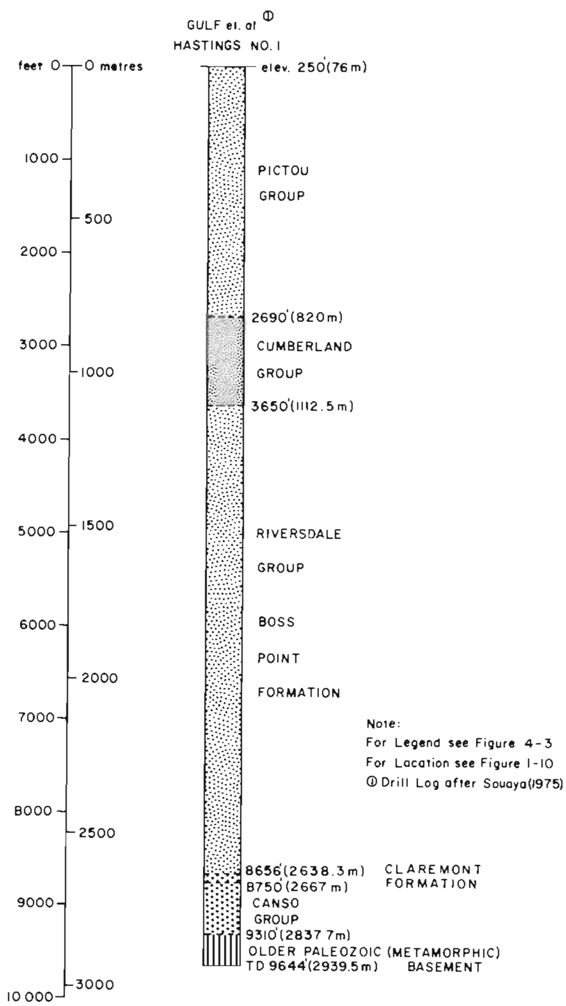


Figure 4-22. Drillhole profile, Gulf et al., Hastings No. 1, Cumberland County.

GEOPHYSICS

The area in the vicinity of the Nappan deposit is included on portions of the Nova Scotia Research Foundation Bouguer anomaly maps 21H/09 and 21H/16 at a scale of 2 inches equals one mile (Fig. 4-23). A high amplitude Bouguer gravity low coincides closely with the Windsor Group outcrop area and it is apparent that these abnormally thickened low density rocks are producing the anomaly. Unfortunately, downhole geophysical logging was not available at the time the oil wells were drilled by Imperial Oil and Sun Oil Company for they probably would have fascilitated more confident interpretations of the lithologic succession.

GEOCHEMISTRY

Several samples from the Amherst No. 1 well were analyzed by Imperial Oil Ltd. and the results are presented in Tables 4-5 and 4-6.

Baar (1966) studied the bromine geochemistry of salt deposits in Nova Scotia as part of the 1966 Potash Project. Cutting samples available from Sunoco No. 1A were analyzed to determine the weight per cent Br/NaCl which were used as indicators of the degree of concentration of the depositional brines. The results of the analyses are presented in Figure 4-24. He concluded that the apparent increase of bromine with depth in the well indicated concentration degrees which may have reached potassium salt precipitation.

ECONOMIC CONSIDERATIONS

The Amherst No. 1 well indicates there is some potash associated with the Nappan salt deposit. The salt occurs as a diapiric core in the Minudie Anticlinorium. Deep oil wells drilled in the area indicate a total salt section thickness in the order of 1400 m. Analyses of borehole cutting samples from Amherst No. 1 yeild NaCl contents of approximately 96.6% at depths below 600 m, however the salt is not as pure in the shallower intervals. The lateral extent of the deposit has not been fully defined, but the gravity data and inferred geology, indicate the salt probably underlies the broad portion of the core area. Salt springs are not common in the area, but salt water has been reported in some water wells (Hayes, 1931). The Nappan deposit is presently being exploited by Sifto Salt Company Ltd. who is operating a vacuum-evaporating brining plant with annual production of approximately 100 000 short tons.

OXFORD DEPOSIT

The Oxford deposit is located in the vicinity of Oxford (NTS 11E/12), central Cumberland County, Nova Scotia (Figs. 1-10 and 4-25). Oxford is located 35 km southeast of Amherst and 90 km northwest of Truro. The area is readily accessible by paved highways 204 and 321 that connect with the Trans-Canada Highway 104. A branch line of the Canadian National Railway mainline between Truro and Amherst runs from Oxford Junction through to Oxford, 4 km to the north.

The terrain in the vicinity is characterized by gently rolling hills with elevations rarely exceeding 75 m in the Carboniferous Lowlands of northern Nova Scotia.

HISTORICAL BACKGROUND

Very saline salt springs and salt ponds were reported on the southern outskirts of the town of Oxford by Hayes (1931) and Bell (1944). Bell (1944) reported that Black, Slade, Vickery, and Park Lakes are due, in large part, to the dissolution and subsequent collapse of the water soluble Windsor Group evaporites such as gypsum, anhydrite, and salt which apparently underlie a large part of the area south of Oxford.

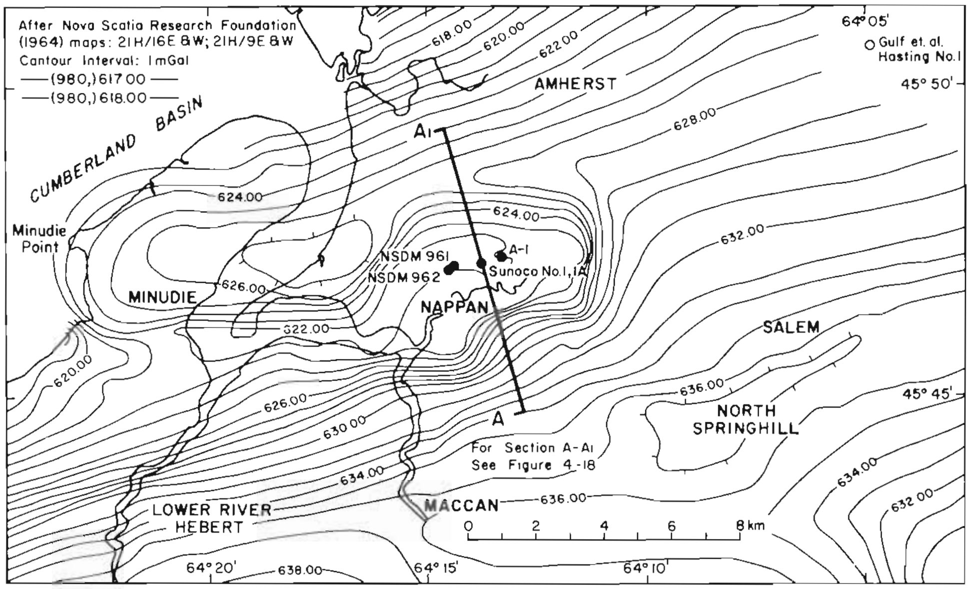


Figure 4-23. Bouguer gravity anomaly map, Nappan deposit.

Table 4-5. Analyses of salt samples, Amherst No. 1, Nappan deposit (in per cent)*

Depth (ft.)	Na	K	Ca	Mg	Cl	Si	Fe_2O_3 + Al_2O_3	SO_4	Moisture
1731-61	36.10	0.58	1.41	trace	56.30		trace	3.43	2.04
1820	32.20	0.19	4.34	trace	52.10	-	0.32	7.83	2.56
1980	35.90	0.64	1.81	trace	56.20	-	trace	4.35	0.63
2223	37.50	0.30	0.25	trace	58.40	-	trace	0.95	0.14
2280	38.24	0.16	0.14	trace	58.99	-	trace	0.81	1.29
2330	38.10	0.28	0.54	trace	59.33	-	0.19	1.50	0.18
2440	37.97	0.23	0.74	trace	59.13	-	0.23	2.00	0.10
2640	38.05	0.40	0.78	trace	59.23	-	0.21	1.90	0.25
3230	36.36	0.62	2.07	trace	57.50	0.66	0.24	3.23	-
3240	38.10	0.83	0.22	trace	59.92	0.17	0.31	0.38	-
3250	38.14	0.76	0.38	trace	59.60	0.13	0.09	0.84	-

*Imperial Oil (1932)

Several diamond-drill holes (NSDM 463, 464, 489, and 490) were drilled for a private concern near Oxford Station. According to Hayes (1931) the drill penetrated nearly vertical dipping interbedded gypsum and red-grey sandstone-shale which are typical of the Windsor Group. Salt water obtained from the drilling was analyzed by the Canadian Government Department of Health (Hayes, 1931). NaCl and $CaSO_4$ were the dominant components.

The Malagash Salt Company Ltd. explored the Oxford area for salt in 1953. Two diamond-drill holes were spudded approximately 3 km southeast of Oxford. The first hole MSC-43 reached a total depth of 125 m (410 ft.). Small amounts of salt in reddish veins and as crystals were reported from 79 m (260 ft.) to the bottom of the hole. A second hole MSC-44, drilled 150 m southwest of MSC-43, to a total depth of 114 m did not contain salt.

Salt intermixed with mudstone and anhydrite was intersected in drillholes AOP-1 and AOP-2 drilled by Amax Potash Ltd. in 1979. These holes were located near the Malagash Salt Company Ltd. drillholes. Potash of unknown grade was reported in association with salt in AOP-1.

GEOLOGY

The geology in the vicinity of the Oxford deposit was mapped by Norman and Bell (1938). Due to the apparent scarcity of outcrop, the precise configuration and relationships of the rocks near the axis of the structure were not known.

In general, the Windsor Group rocks occur in the axial area of the western extension of the Malagash Anticline which trends slightly north of east-west. West of Oxford, it hooks into a northeast-southwest trend near Springhill (Fig. 1-10). A north-northeast trending fault offsets the structure 8 km east of Oxford (Fig. 4-25). This fault apparently extends northward to form the southeastern border of the Roslin structure (Figs. 1-10 and 1-4).

The Oxford portion of the Malagash Anticline is bordered on the south by the Tatamagouche

Table 4-6. Mineral assemblage by conventional combination, Amherst No. 1 (in per cent)*

Depth (ft.)	$CaCO_3$	Na_2SO_4	NaCl	KCl	$CaSO_4$	$CaCl_2$	$MgCl_2$	Fe_2O_3 + Al_2O_3	SiO_2	K_2SO_4	Moisture
980-990	3.00	3.40	73.94	-	6.33	-	-	0.48	13.40	-	0.32
1050	-	-	-	4.50	-	-	-	-	-	-	-
1100	-	-	-	4.42	-	-	-	-	-	-	-
1731-61	-	-	91.82	1.11	4.89	-	trace	trace	-	-	2.04
1820	-	-	81.80	0.36	11.09	3.00	trace	0.32	-	-	2.56
1980	-	-	91.40	1.22	6.17	-	trace	trace	-	-	0.63
2223	-	-	95.30	0.57	0.85	-	trace	trace	-	-	0.14
2280	-	-	97.20	-	0.48	-	trace	trace	-	0.71	12.9
2330	-	-	96.80	0.53	1.84	-	trace	0.19	-	-	0.18
2440	-	-	96.50	0.44	2.52	-	trace	0.23	-	-	0.10
2640	-	-	96.70	0.76	2.65	-	trace	0.21	-	-	0.25
3052	-	-	-	trace	-	-	-	-	-	-	-
3230	-	-	92.25	1.18	4.58	2.00	trace	0.24	0.66	-	-
3240	-	-	96.70	1.58	0.54	0.17	trace	0.31	0.17	-	-
3250	-	-	96.72	1.45	1.19	0.08	trace	0.09	0.13	-	-
3275	-	-	-	trace	-	-	-	-	-	-	-
3460	-	-	-	trace	-	-	-	-	-	-	-
4000	-	-	-	none	-	-	-	-	-	-	-

*Imperial Oil (1932)

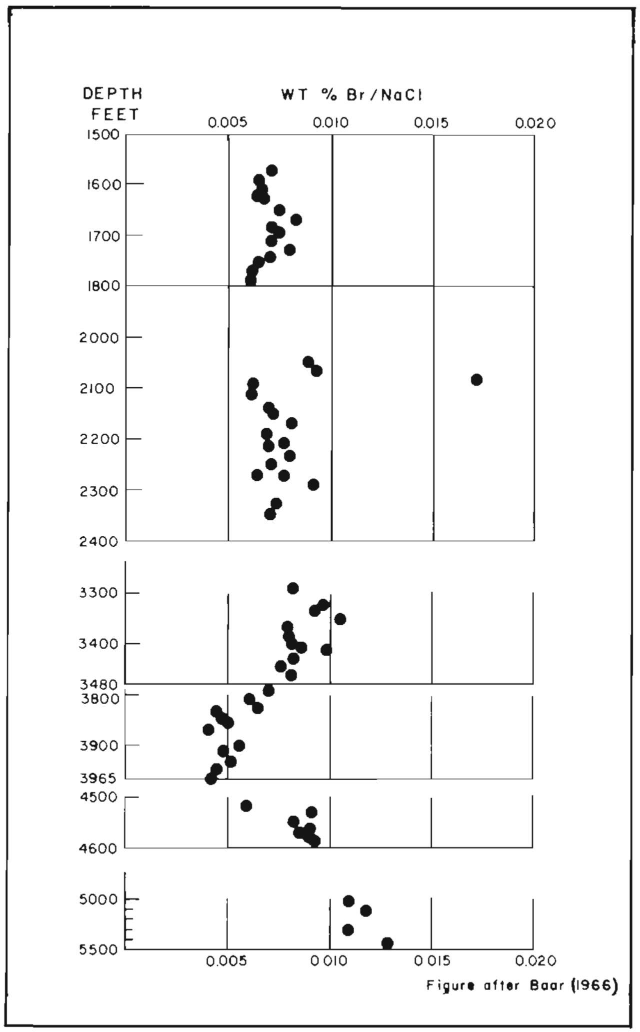


Figure 4-24. Bromine content of halite in Sunoco No. 1A, Nappan deposit.

Syncline (Bell, 1944) which plunges easterly from River Philip toward Tatamagouche (Fig. 1-10). The axial area is occupied by Pictou Group strata. The major stratigraphic units in the Oxford area (Fig. 4-25), include from oldest to youngest according to Norman and Bell (1938): Windsor Group comprising gypsum, red shale, limestone and grey shale; Claremont Formation comprising red conglomerate and grit, some sandstone and shale; Boss Point Formation comprising grey to red interbedded sandstone and shale; Cumberland Group (lower division) comprising red conglomerate and grit, sandstone and shale; Cumberland Group (upper division) comprising grey sandstone and shale, red shale and sandstone, coal; and Pictou Group comprising red sandstone, shale and conglomerate, some grey sandstone and shale.

Norman and Bell (1938) indicated that the Cumberland Group strata rest unconformably upon the Boss Point Formation. A similar situation is apparent on the northern flank of the Malagash-Clairmont Anticline where gently dipping Cumberland Group and Pictou Group strata appear to overlap the Windsor Group in the axial area. The contact between the Windsor and Pictou Groups is mapped on River Philip on the southern side of Oxford. Norman and Bell (1938) indicated that the Pictou Group strata in the area rest disconformably upon the Cumberland Group strata. The area mapped on the northern side of the structure may represent an onlap and overstep situation where Pictou Group strata onlap Cumberland Group strata and both may overstep the Windsor Group, Claremont and possibly Boss Point Formations. The possibility of Windsor Group rocks occurring in an intrusive and faulted relationship may not be ignored however, and indeed that is a highly probable situation. In general, the situation at Oxford is similar (in surface expression) to the Minudie Anticlinorium, but is not as broad. In this respect, it may more closely resemble the western end of the Minudie structure (see Nappan deposit).

The abundance of salt water springs and ponds testifies to the subsurface dissolution of

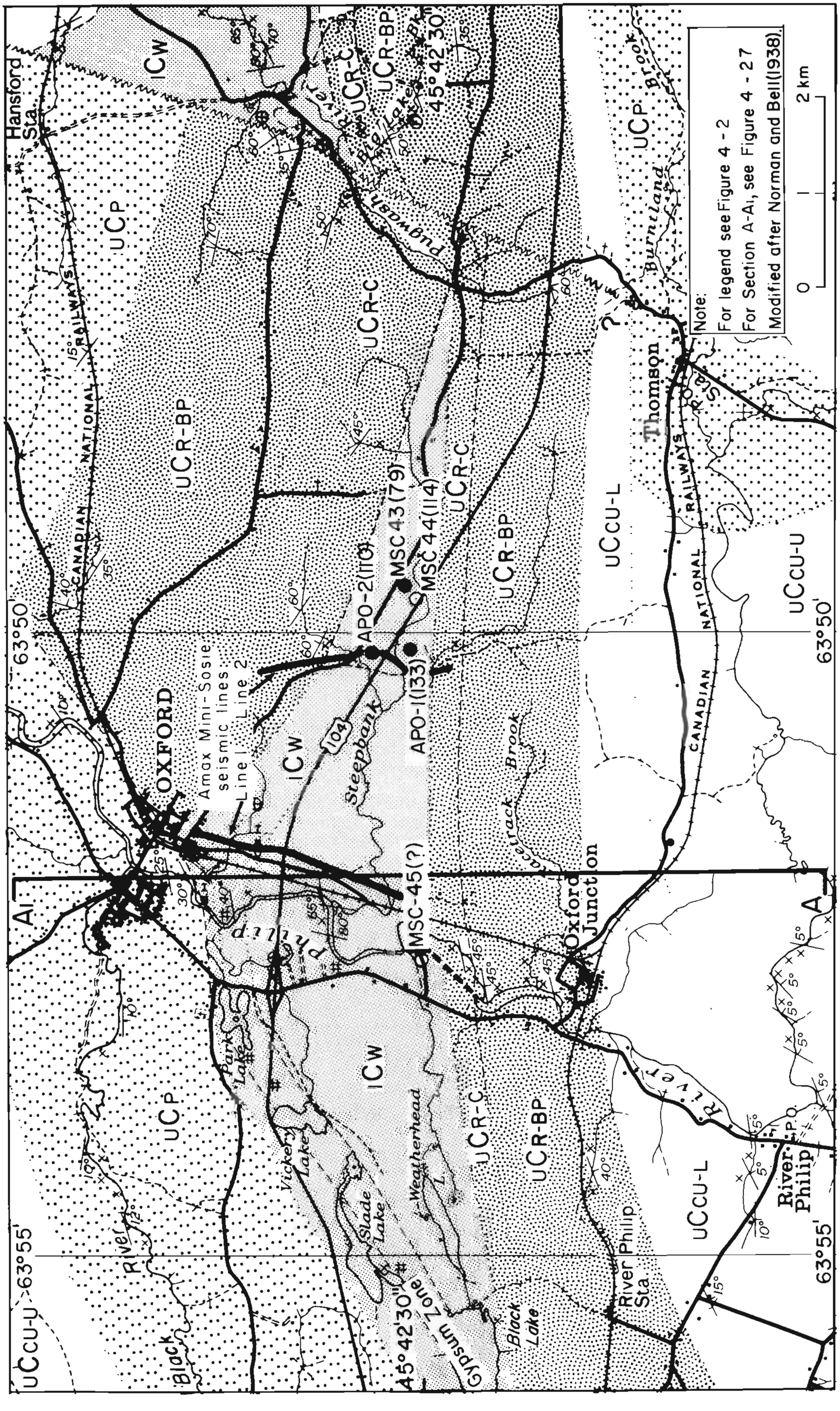


Figure 4-25. Geology in the vicintiy of the Oxford deposit.

salt. Shallow diamond drilling at Oxford in 1924 and 1926 failed to penetrate salt at depths to 91 m (300 ft.). Diamond drilling by the Malagash Salt Company in the eastern end of the Windsor Group in the core axial area in 1953 penetrated salt bearing shales at 79 to 125 m in MSC-43 (Fig. 4-26). The salt is reported to occur as reddish veins and crystals and is apparently secondary in origin. The parent salt mass of these salt veins appears to have been intersected in drilling by Amax Potash Ltd. in 1979 (MacDougall and Polley, 1980). Two holes were drilled less than 1 km west of MSC-43 (Fig. 4-25). The first, APO-1, (Fig. 4-26) intersected overburden and clay-mudstone to 132.6 m (435 ft.) and then salt with clay-mudstone to the total depth at 382.2 m (1254 ft.). Potash (grade unknown) with salt is reported at 209.1-226.8 m (686-744 ft.). APO-2 intersected overburden and clay-mudstone to 110.3 m (362 ft.), then clay-mudstone, salt and anhydrite to the total depth of 623 m (2044 ft.). Potash was not reported in this hole.

A schematic cross-section (A-A_1) through the Oxford occurrence is presented in Figures 4-27 and 4-25. This interpretation is based upon minimal inconclusive subsurface and surface data. The basic structural configuration is interpreted to be a diapiric anticline consisting of Windsor Group evaporites and mudstone. The northern border is believed to be a major fault that has been overstepped by Pictou Group rocks. The exact nature of the southern contact is uncertain but also may be a major fault or shear zone. The Windsor Group evaporites and siltstone-mudstone in the axial area are probably highly deformed.

GEOPHYSICS

Gravity surveys by the Nova Scotia Research Foundation have delineated a Bouguer gravity low anomaly (greater than 10 mGal) that coincides with the Windsor Group in the core of the structure (Fig. 4-28). The centre of the low is located east of the MSC-43 drillhole and the parent salt mass which may be responsible for this anomaly has been proven recently by further deep drilling. In addition to the gravity surveys, Amax Potash Ltd. conducted a shallow penetration reflection seismic survey across two lines near the location of the AOP-1 and -2 drillholes (Roth, 1979a, b). These surveys provide minimal information about the geology of the Windsor Group, but locally are useful in confirming the location of the contacts with younger rocks.

GEOCHEMISTRY

Potash minerals associated with the structure may occur in a similar highly deformed situation to that established in the Malagash Mine and in the Wallace Nos. 1 and 2 holes drilled in the Malagash area 40 km to the east.

Cole (1930a), reported the occurrence of three salt springs present in the Oxford area as follows:

> Oxford Springs (Nos. 9, 10, and 10A). In the park to the southwest of Oxford, Cumberland County, there are a number of saline springs, ponds and wells. At one place on the west side of the road about one mile to the south of the town of Oxford a concrete dam has been built which impounds the water back so that a lake covering several acres has been formed, the water in which is decidedly saline. In the interval to the east of the salt lake and between the highway and the railway there is a spring flowing at the rate of about two gallons per minute (No. 9). On the property of Laurin Thompson, 1/2 mile to the south of the salt lake, two wells have been drilled from which brine is flowing. These wells are about 100 feet apart and they flow into a saline pond of several acres in extent. The first well (No. 10) has a flow from a stand pipe of 1/2 gallon per minute, while the second well (No. 10A) has a flow of one gallon per minute.

The springs were sampled and the analyses reported by Cole (1930a) and are presented in Table 4-7. The waters have similar composition, but spring No. 9 has higher $CaSO_4$ indicating dissolution of significant gypsum in addition to the salt.

Table 4-7. Salt spring sample analyses, Oxford area, Cumberland County*

Sample No.	**9**	**10**	**10A**
FIELD NOTES AT TIME OF SAMPLING			
Temperature of atmosphere, °F	79	79	79
Temperature of brine, °F	46	50	18
Baume degrees	n.d	n.d	n.d.
Equivalent specific gravity	-	-	-
LABORATORY NOTES			
Specifc gravity at 60°F	1.009	1.016	1.0177
Total solids at 110°C	1.32	2.25	2.45
Reaction	None	None	None
ANALYSES OF SOLIDS			
Na .... per cent	27.96	32.97	33.01
K .... per cent	0.09	0.12	0.08
Ca .... per cent	7.41	3.74	3.40
Mg .... per cent	0.11	0.15	0.14
SO_4 .... per cent	16.97	8.44	8.10
Cl .... per cent	44.11	81.79	51.37
Br .... per cent	none	none	none
I .... per cent	none	none	none
Totals...	96.65	97.21	96.10
HYPOTHETICAL COMBINATION			
$CaSO_4$ ...... per cent	24.04	11.94	11.56
$CaCl_2$ ...... per cent	0.94	0.65	-
$MgSO_4$ ...... per cent	-	-	-
$MgCl_2$ ...... per cent	0.43	0.59	0.56
K_2SO_4 ...... per cent	-	-	-
KCl .... per cent	0.17	0.23	0.15
Na_2SO_4 ..... per cent	-	-	-
NaCl .... per cent	71.07	83.80	83.89
Totals...	96.65	97.21	96 16

*Cole (1930a)

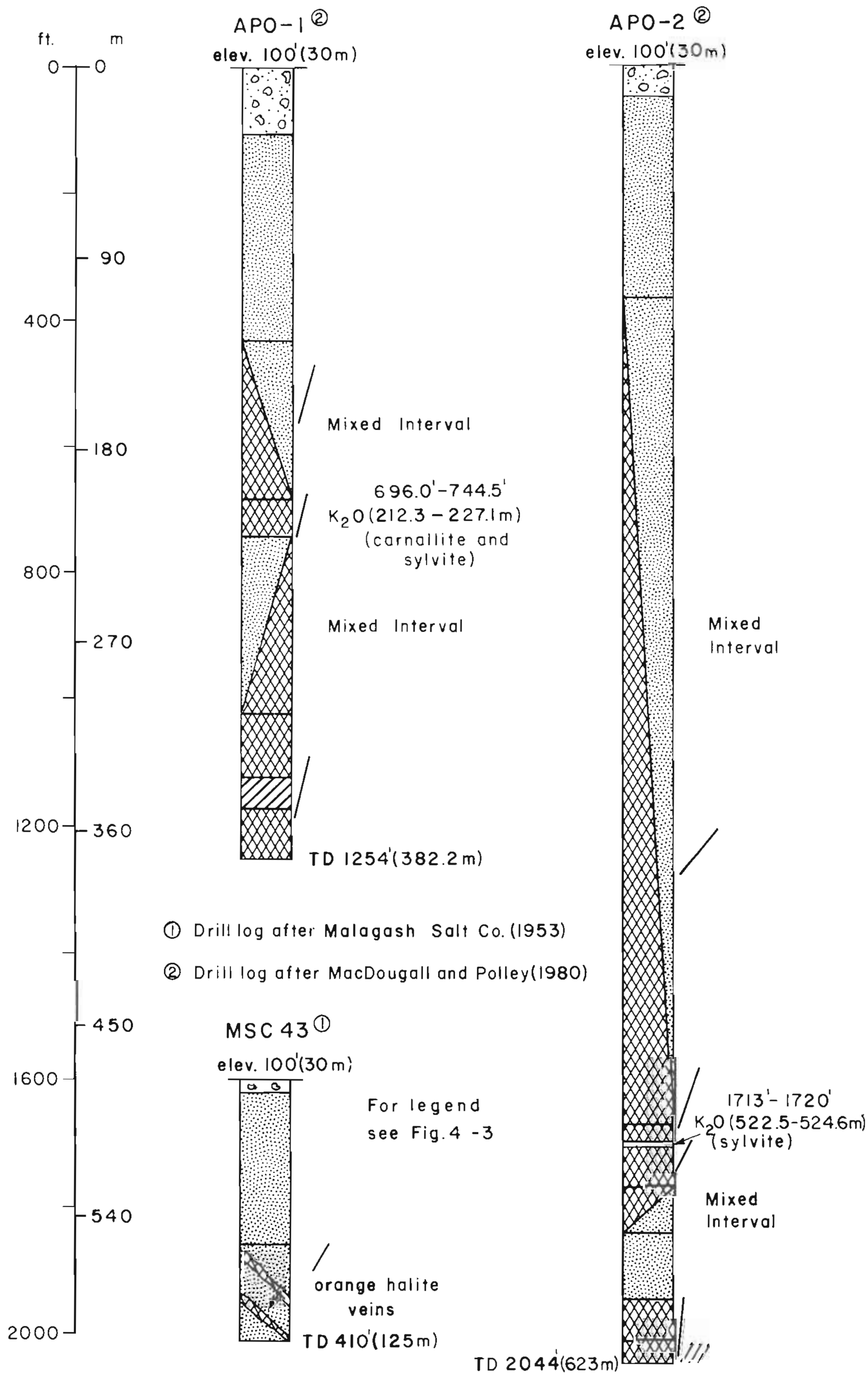


Figure 4-26. Drillhole profiles, Oxford deposit. (For locations see Fig. 4-25).

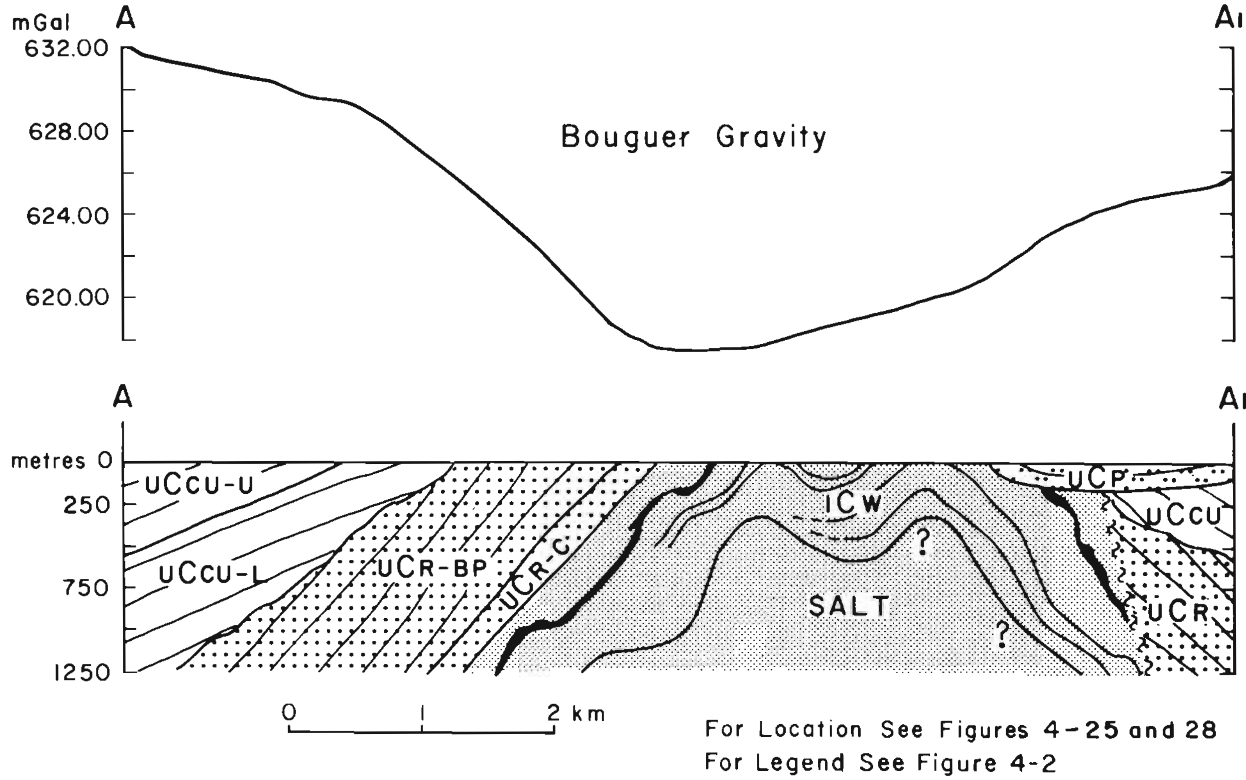


Figure 4-27. Geological and Bouguer gravity cross-section, Oxford deposit.

ECONOMIC CONSIDERATIONS

The Oxford deposit consists of orange halite veins and crystals in fractured red shales and salt interstratified with anhydrite and mudstone. A 17.7 m section of mixed potash and salt is reported in one drillhole APO-1 at a depth of 686 m. The area is readily accessible to railway shipping, but is approximately 20 km inland from potential tidewater shipping. Deep drilling has established the presence of a large salt mass and associated potash in the area. The deposit, as it is presently known, is not considered to be of commercial importance, but it does have potential for further potash exploration.

PUGWASH DEPOSIT

The Pugwash deposit is located south and west of Pugwash (NTS 11E/13E), northeastern Cumberland County (Figs. 1-10 and 4-29). Pugwash is readily accessible by paved highways, including Route 6 from Pictou to Amherst, Route 321 approximately 30 km east from Oxford, and Route 368 from Wentworth. A small tide water harbour shipping facility has been built in Pugwash which serves the Canadian Rock Salt Company Pugwash mine.

The Pugwash area is located in the gently rolling countryside of the Carboniferous Lowlands of northern Nova Scotia. Topography in this area rarely exceeds 50 m in elevation and the rivers draining the area have broad estuaries opening to the Northumberland Strait.

HISTORICAL BACKGROUND

The Pugwash area was investigated as part of a regional potash study by Hayes (1931). The area was assessed not to be immediately favourable for potash or salt exploration on the basis of the limited information available at the time. Salt springs indicative of salt and gypsum outcrops were not indicated to occur in the area.

Bell (1944) also considered the area to hold little promise for salt prospecting, because the salt zone was mainly submerged beneath the Pugwash River estuary.

In the 1950's, the Malagash Salt Mine was plagued by mining difficulties and ore grade problems that caused the Malagash Salt Company to explore for a new salt deposit in several areas including Pugwash. Salt was discovered in Pugwash in 1953 when a well drilled for water intersected salt at 137 m (150 ft.). In 1954 diamond drilling was undertaken in the area of the Pugwash inner harbour on the northeastern end of the Pugwash structure. Significant thicknesses of salt were intersected in approximately 7 holes. Based on the success of these diamond-drill holes, the Malagash Salt Company began sinking a mine shaft in early 1956. By 1959 the shaft was at 219.5 m (720 ft.) with a development level at 192 m (630 ft.). The mine was officially opened on November 4, 1959. Earlier in the year, the Malagash Salt Mine ceased production and was closed. Reserve estimates for the new salt mine were placed at 181.4 Mt (200 million tons).

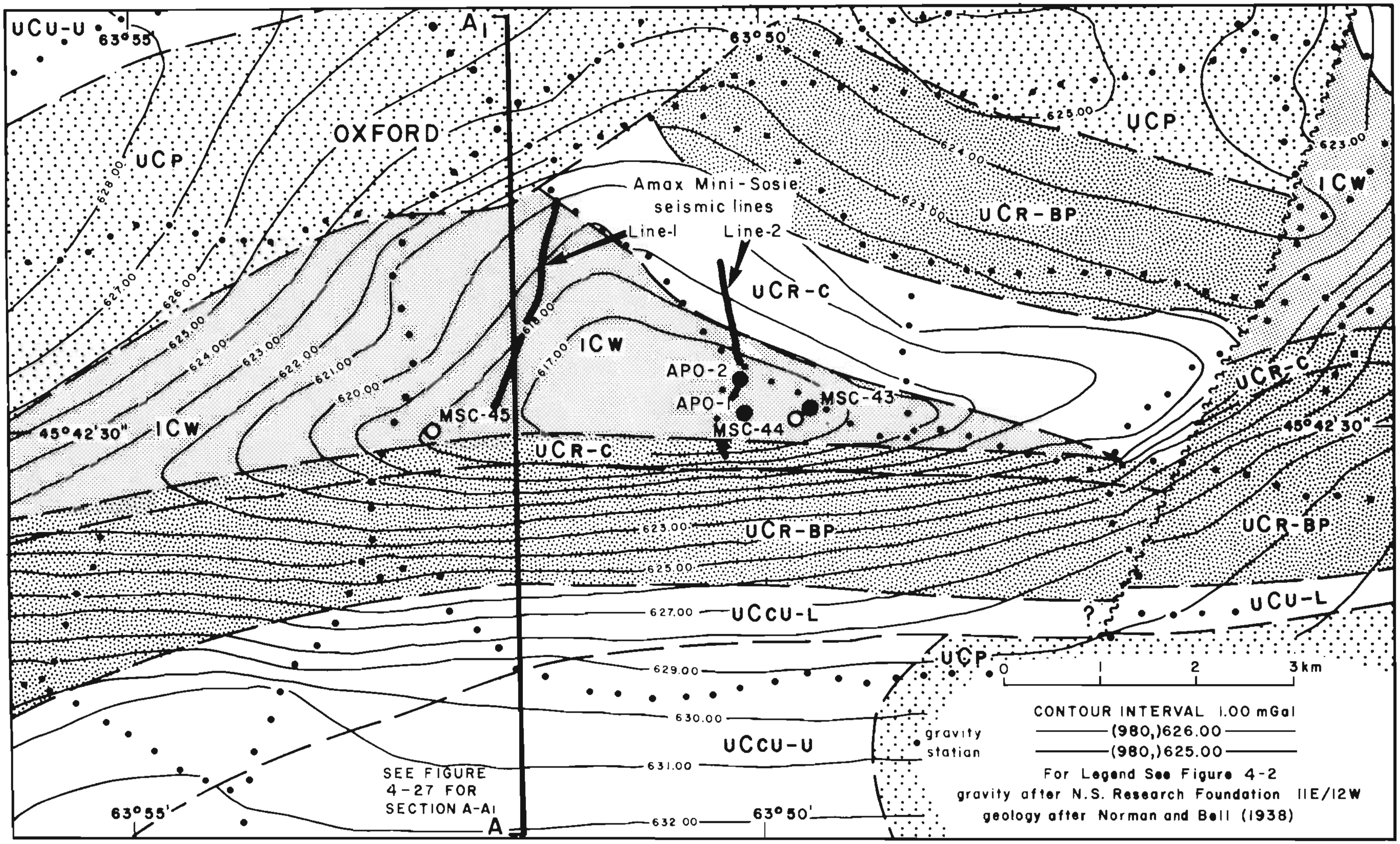


Figure 4-28. Bouguer gravity anomaly map, Oxford deposit.

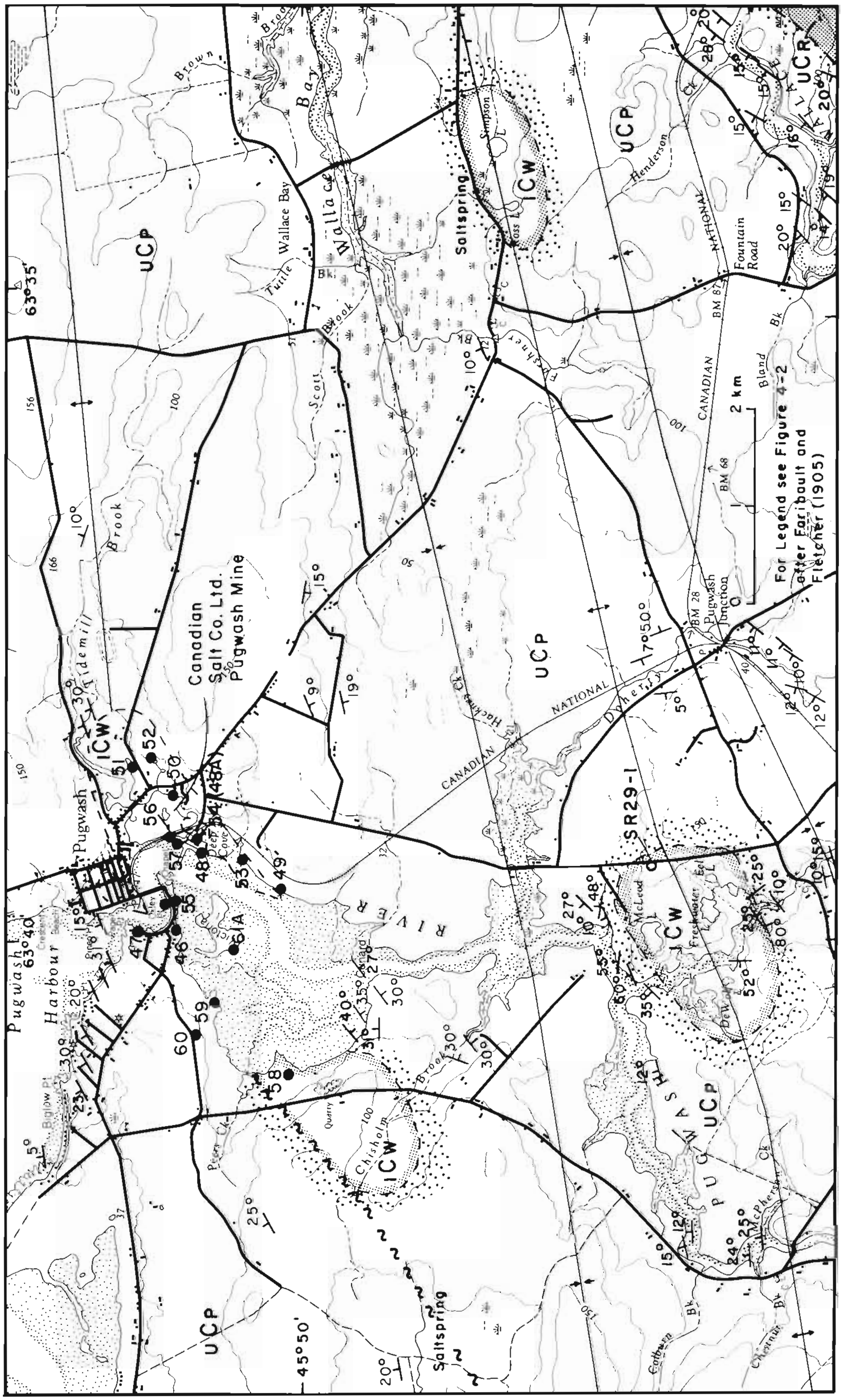


Figure 4-29. Geology in the vicinity of the Pugwash deposit, Canfield Creek and Simpson Lake, Cumberland County.

In 1961, the Malagash Salt Company reorganized to become the Canadian Rock Salt Company Ltd. and began drilling several new holes at Pugwash to further explore the salt mass. In June 1962 work commenced on a new production shaft 300 feet northeast of the original shaft. The present operation is producing salt at the 250 m (830 ft.) level.

In late 1963 Pacific Petroleums Ltd. spudded Pacific Fox Harbour C-96V (Figs. 4-12 and 4-13) 10.5 km east of the Pugwash Mine. As this was on the eastern extremity of the Minudie Anticline, salt was not intersected in this well until 2678 m (8785 ft.) and continued to 2856 m (9370 ft.). Salt and shale were intersected at 2966 m (9730 ft.) to the final depth at 2981 m (9780 ft.).

GEOLOGY

Faribault and Fletcher, published the first detailed geological map of the Pugwash area in 1905 (Fig. 4-29). This map portrays the Windsor Group (Carboniferous Limestone) as occurring in an elongated ellipsoidal, outcrop pattern whose long axis trends northeast-southwest. The Windsor Group, including limestone, shale, and gypsum in this area is surrounded and overlain by the Pictou Group comprising sandstone and shale. Bell (1944) reported that an unconformable overlap of Pictou Group strata over the Windsor Group red shales is exposed on the Pugwash River estuary "nearly a mile east 56 degrees south from the bridge over Peers Creek." Here basal grey conglomerate about one foot thick is overlain by light grey to purplish grey sandstone striking 066° and dipping 30° southeast. This section overlies unconformably, red shales of the Windsor Group striking 020° and dipping nearly vertically. Approximately 450 m to the northwest of this section, a limestone unit of the Windsor Group is found in a quarry at Dewar Hill. Bell (1944) assigned this to the B Subzone. He indicated this unit has a strike of 142°, dips 86° northeast and was overturned.

He also reported a measured section containing Windsor Group limestone and mudstone from the Dewar Hill quarry area located 4.5 km southwest of the Pugwash Mine.

Bell (1944) reported the shore section east of the quarry comprises vertically dipping or steeply eastward dipping brownish to brick-red and grey-green mudstone and shale with some gypsum stringers. This sequence apparently underlies conformably the overturned limestone section in the quarries and is probably directly underlain in the Pugwash River estuary by the evaporite succession. He estimated this shale section to be approximately 244 m (800 ft.) thick, which corresponds reasonably with a similar stratigraphic unit in the Nappan area.

The northeastern and central part of the Windsor outcrop area is characterized by gypsum outcrop and karst topography. Faribault and Fletcher (1905) mapped a possible fault on the northwestern side of the structure at the contact between the Windsor Group and the Pictou Group (Fig. 4-29). This fault trends northeast-southwest and may extend southwesterly to the Roslin area and form the western border of the Roslin structure. Three diamond-drill holes in this area penetrated Pictou Group sandstone, shale and conglomerate and never reached the Windsor Group.

Mine Stratigraphy and Structure

The Windsor Group evaporite rocks occupy the core area of the structure, which has an elliptical topographic outline that may be part of a regional anticlinal trend, or a local domal structure. The Pugwash Mine is situated on the northeastern end of the Windsor Group outcrop area.

The geology of the Pugwash Salt Mine was described by Evans (1967, 1972, and 1974). This work involved detailed studies on the internal structure, mode of deposition, and the stratigraphy of the evaporite rocks forming the Pugwash salt structure.

The stratigraphic column described by Evans (1972) presented in Figures 4-30 and 4-31 can only be considered to be a rough estimate of the Fig. 4-30 (47 Lines)

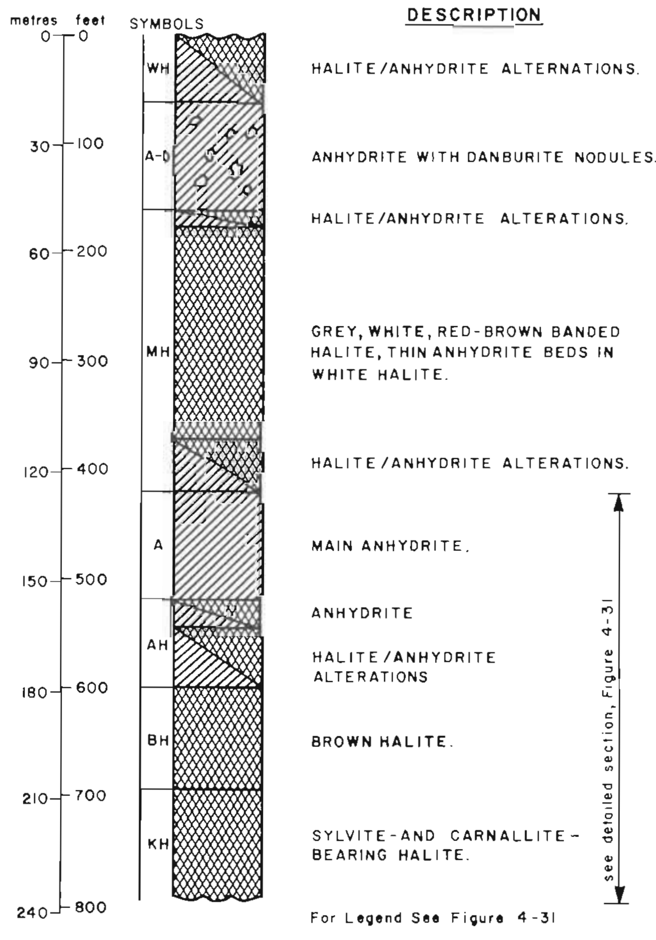


Figure 4-30. Simplified stratigraphy of the sequence exposed in the Pugwash Mine.

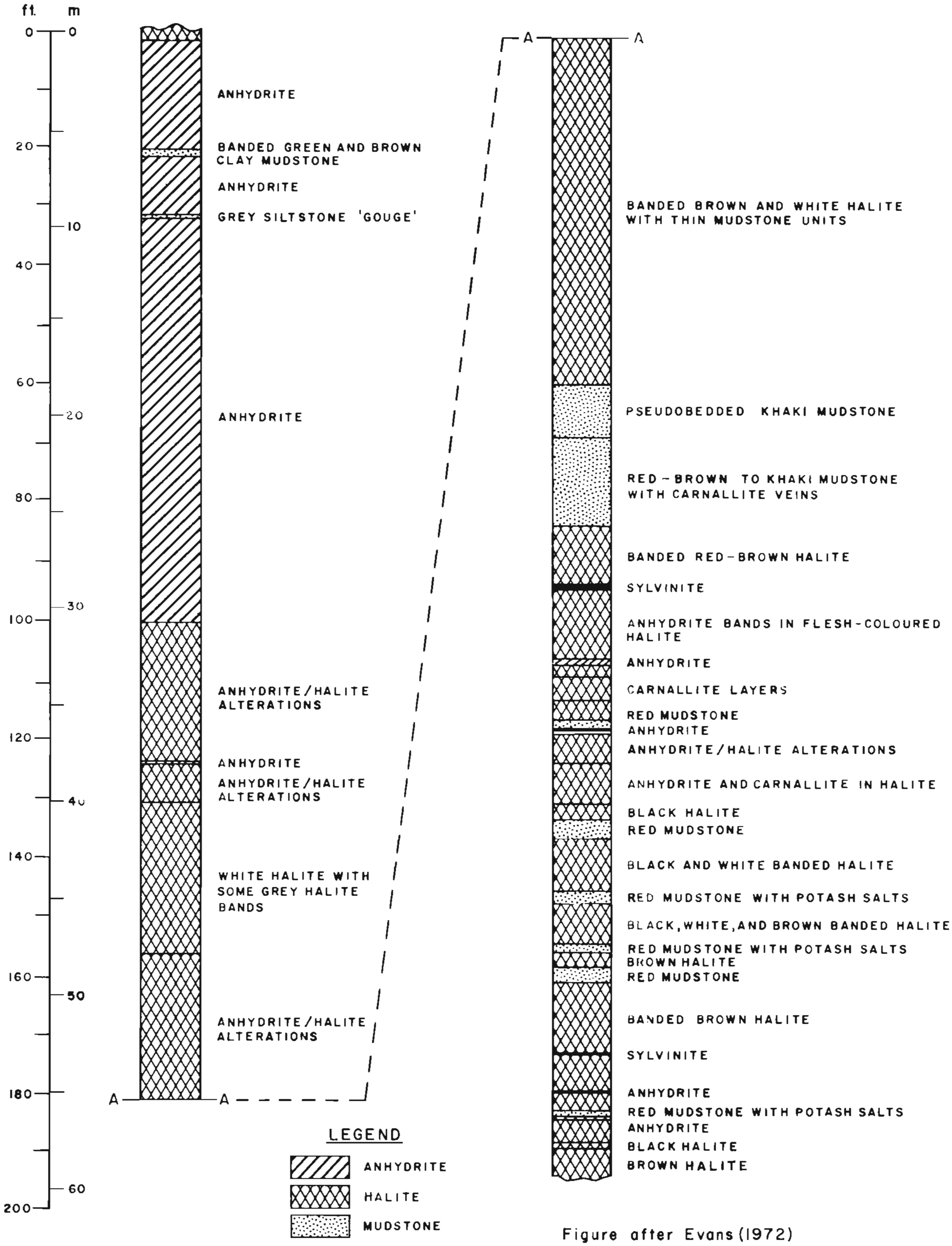


Figure 4-31. Stratigraphic column of the lower part of the section exposed in the Pugwash Mine.

original beds due to the effecta of tectonism. Neither the stratigraphic top nor the base of the Windsor evaporite succession is exposed in the mine. Due to extensive deformation and flowage many salt units have estimated thickness only, while the more competent anhydrite units are measured with some degree of accuracy. In most instances, Evans (1972) concluded that only salt beds in the fold nose could be considered as fairly close to the true thickness. The folding and refolding in some areas are often so severe that minor layer stratigraphy of the thinner layers was not determinable. This situation was well illustrated in the southeastern part of the mine area as shown on Figures 4-32 and 4-33. Evans (1972) also indicated that the fracturing of the thick anhydrite beds (main and danburite nodule) during the deformation and intrusion has, in some areas, produced a mixing of the stratigraphic units. The true sequence therefore was not readily determinable.

The evaporite sequence in the Pugwash structure is dominated by anhydrite and halite which occur both as thick beds and as interbedded intervals that are transitional into the thick beds (see frontispiece). The lower part of the stratigraphic column in the mine is characterized by the scarcity of anhydrite, the predominance of brown to black halite and the appearance of red mudstone with potassium salts. Sylvinite, a mixture of halite and sylvite, is also indicated at two horizons at this level. Evans (1972) attributed the halite colouration to finely disseminated red and brown clay.

The contact between the mine stratigraphic section described by Evans (1972) and the section of the Windsor Group described by Bell (1944) in the Dewar Hill area to the southwest is probably a fault.

The complex structural configuration of the evaporites in the Pugwash mine as mapped by Evans (1967, 1972) (Figs. 4-32 and 4-33) is the best detailed documentation of the stratigraphy of any salt intrusive in Nova Scotia. This complicated structure was not apparent or appreciated in the initial surface diamond-drill exploration (Figs. 4-29 and 4-34). Evans (1972) concluded that the fold configuration and severity of deformation were similar to the structural configuration of diapirs, but suggested the Pugwash structure is intermediate between piercement diapirs and deformed anticlines.

Three distinct fold trends are described in the Pugwash structure by Evans (1972). One trend is parallel with the peripheral Pennsylvanian cover fold axis trend. A second trend is approximately perpendicular to the first. Both trends are attributed to the influence of the Pennsylvanian structure on the growing diapir. Interfering fold patterns resulting from a blending of compressive forces are reported to occur in the centre of the structure. A third trend, oriented slightly southeast, is found in folds near the northwestern border of the structure. He reported that a plot of the measured fold axes from the Pugwash Mine shows a radial arrangement which is characteristic of dome type diapiric intrusions. Most of the folds in the halite units of the Pugwash structure, are similar and quasi-similar folds with steeply dipping axial planes and parallel to subparallel isoclinal limbs. Thin anhydrite interbeds have parallel geometry. Evans (1972) reported that refolding of these tight folds has produced complex fold forms with closures, crescent-shaped closures and "hooked" fold forms common. These interfering fold forms are attributed to a single continuing deformation rather than separate periods of deformation although the latter is possible. In the folding, the halite responded to the stress in a plastic manner and flowed extensively. The thick anhydrite beds are believed to have, in the early stages, bent under stress until their competence resulted in failure and rupture. These thick beds were broken, dislocated and apparently carried passively as rafts by the flowing salt in the later stages of the structures development. Attenuation associated with the halite flowage was often so severe that it apparently eliminated parts of the sequence.

The unconformable contact between Windsor and Pictou Groups strata described to the southeast of the Dewar Hill quarry is not exposed on the northern side of the structure. Faribault and Fletcher (1905), as previously mentioned, indicated a possible fault along this contact. Several factors must be considered in assessing this contact to determine whether it is an angular unconformity or a faulted intrusive contact. Cross-sections drawn by Evans (1972) in the vicinity of the Pugwash Mine (Fig. 4-33) indicate a relatively sharp contact between the steeply dipping Windsor evaporite succession, occurring stratigraphically below the limestone and shale section at Dewar Hill, and the more gently dipping Pictou Group sandstones. Based on this field evidence, simple angular unconformity with Pictou strata overlapping the Windsor Group evaporites does not seem to be an attractive alternative. The contact between Windsor Group evaporites and the Pictou Group (Fig. 4-33) is very steeply dipping over a vertical interval of 150 m. This dip would be highly unusual between water laid sediments deposited over and against water soluble strata. It is more probable therefore, that a combination of overlap and later faulting are responsible for the present configuration. The growth and development of the Pugwash structure, like other Cumberland area salt structures, appears to have caused sedimentary disconformities, angular unconformities, and overstep relationships in its vicinity. It is probable that the onlapping of Late Carboniferous (Pictou Group) sediments was complete and occurred prior to the breaching of the structure and the subsequent exposure of the soluble strata in the core area. This Pictou Group capping was probably intruded by the mobile evaporite in the core. Eventually, crestal block faulting and erosional processes removed the cover, exposing the evaporite core. Subsequent solution and collapse produced a variably thick residual mud, and insoluble gypsum limestone breccia to cap the evaporite core (Fig. 4-33).

Pugwash Mine

Initial development in the Pugwash Mine used a regular grid, room and pillar method based on an

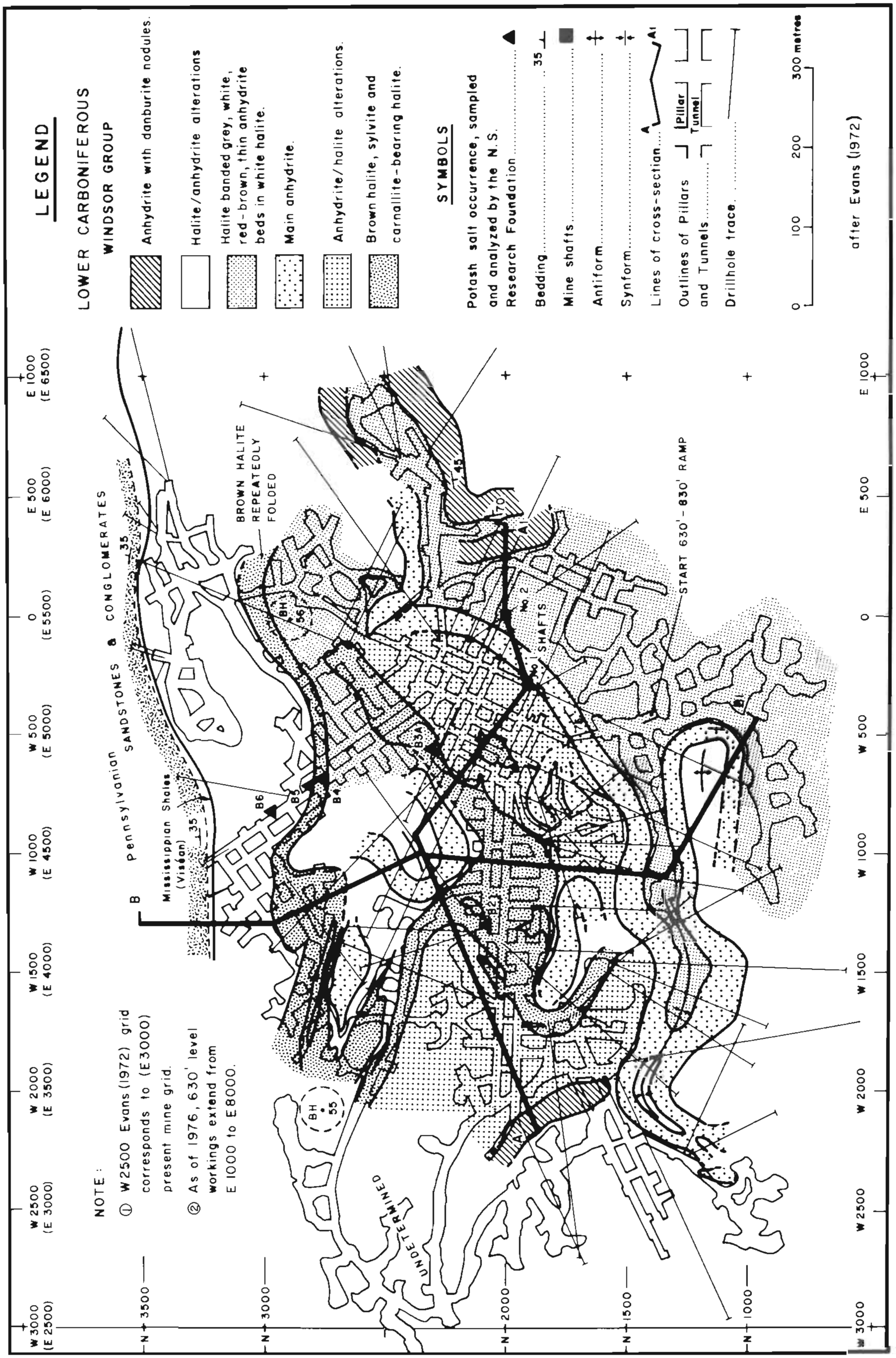


Figure 4-32. Simplified geological map and mine plan, 630 foot level, Pugwash Mine, Cumberland County.

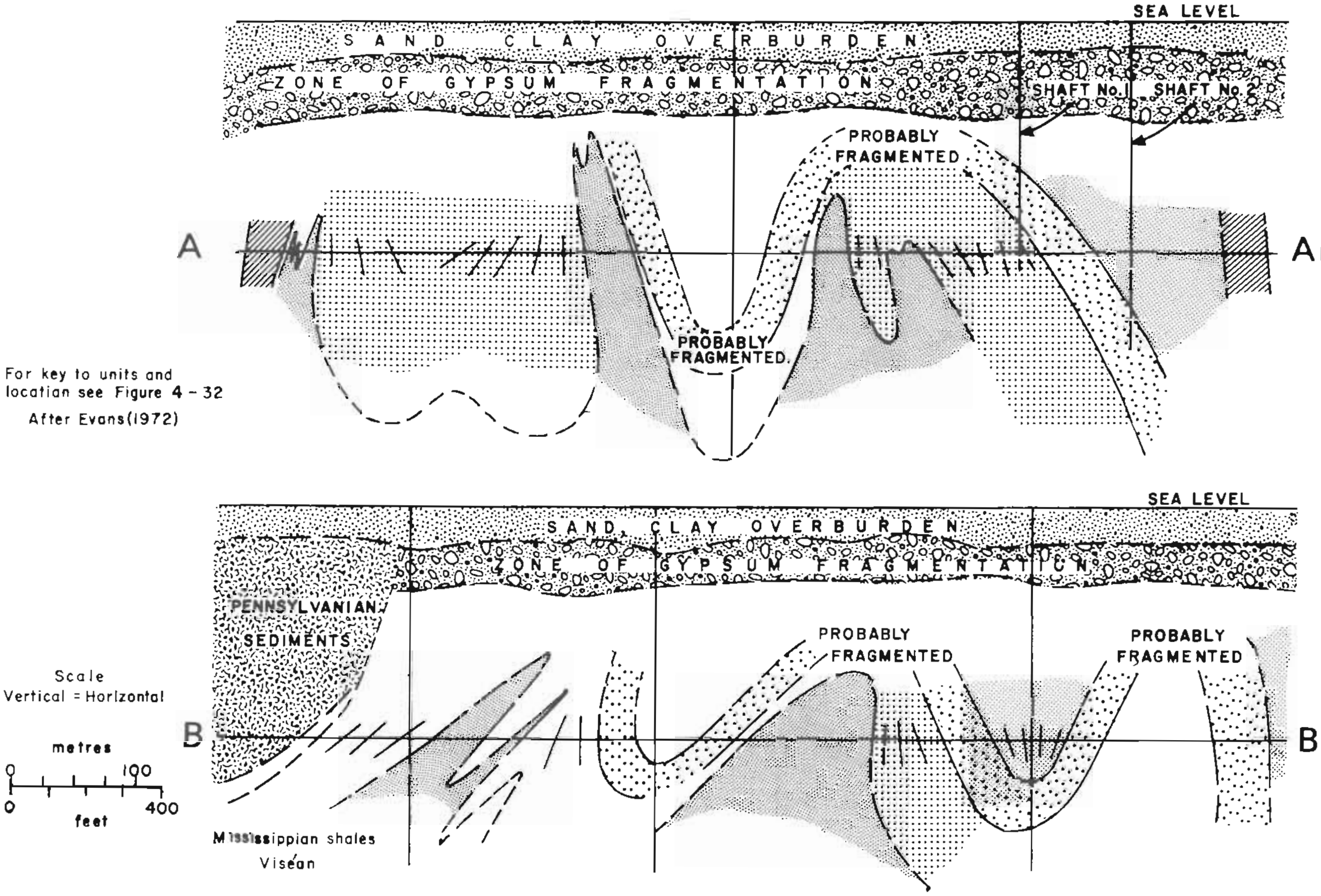


Figure 4-33. Geological cross-sections A-A_1, and B-B_1, Pugwash Mine.

interpretation of the drillhole data (Fig. 4-34) that said the salt mass was relatively consistent in grade and structurally simple (Fig. 4-35). This was soon discovered not to be the situation, and a modified (nongrid) room and pillar system was undertaken to avoid areas of waste (anhydrite) rock (Figs. 4-35 and 4-36).

In the modified room and pillar method mining is undertaken between the anhydrite waste bands. Drifts 9.1 m (30 ft.) high by 15.2 m (50 ft.) wide are driven parallel to the waste beds and are separated by pillars 22.9 m (75 ft.) wide. Crosscuts are driven at intervals to connect adjacent drifts.

During the initial development of the 830 foot level, all salt was hauled by truck up a ramp to the 630 foot level for crushing. Hoisting from the 830 foot level through the No. 2 shaft began in November 1975, and now all production and hoisting are handled in this manner. The No. 1 shaft is used for servicing during the production hoisting in the No. 2 shaft.

The mining procedure at the producing face involves drilling approximately ninety 4 m (13 ft.) long, 4.4 cm (1 3/4 in.) diameter holes in the face. The face is undercut with an electric hydraulic undercutter to a depth of 4 m (13 ft.) and the blast holes are loaded with a total of approximately 364 kg (800 pounds) of ammonium nitrate and fuel oil blasting mixture. The face is blasted, and the area scaled to remove loose pieces. The broken salt is loaded and hauled with rubber mounted equipment to a crusher on the 830 foot level. The crushed salt is transported by conveyor to the No. 2 shaft for haulage to the surface in eight ton capacity skips at a rated capacity of 363 t (400 tons) per operating hour.

The rock salt processing involves crushing and screening to remove the anhydrite impurity in two independent parallel circuits. Each circuit is capable of handling over 272 t (300 tons) per hour. In addition, the fines from the mill are transported to an evaporation plant for dissolution to make a feed stock for production of pure fine salt.

The rock salt is loaded and shipped both packaged and bulk via truck, rail and boat to destinations in Eastern Canada. The fine salt is shipped in packages, bulk and as blocks.

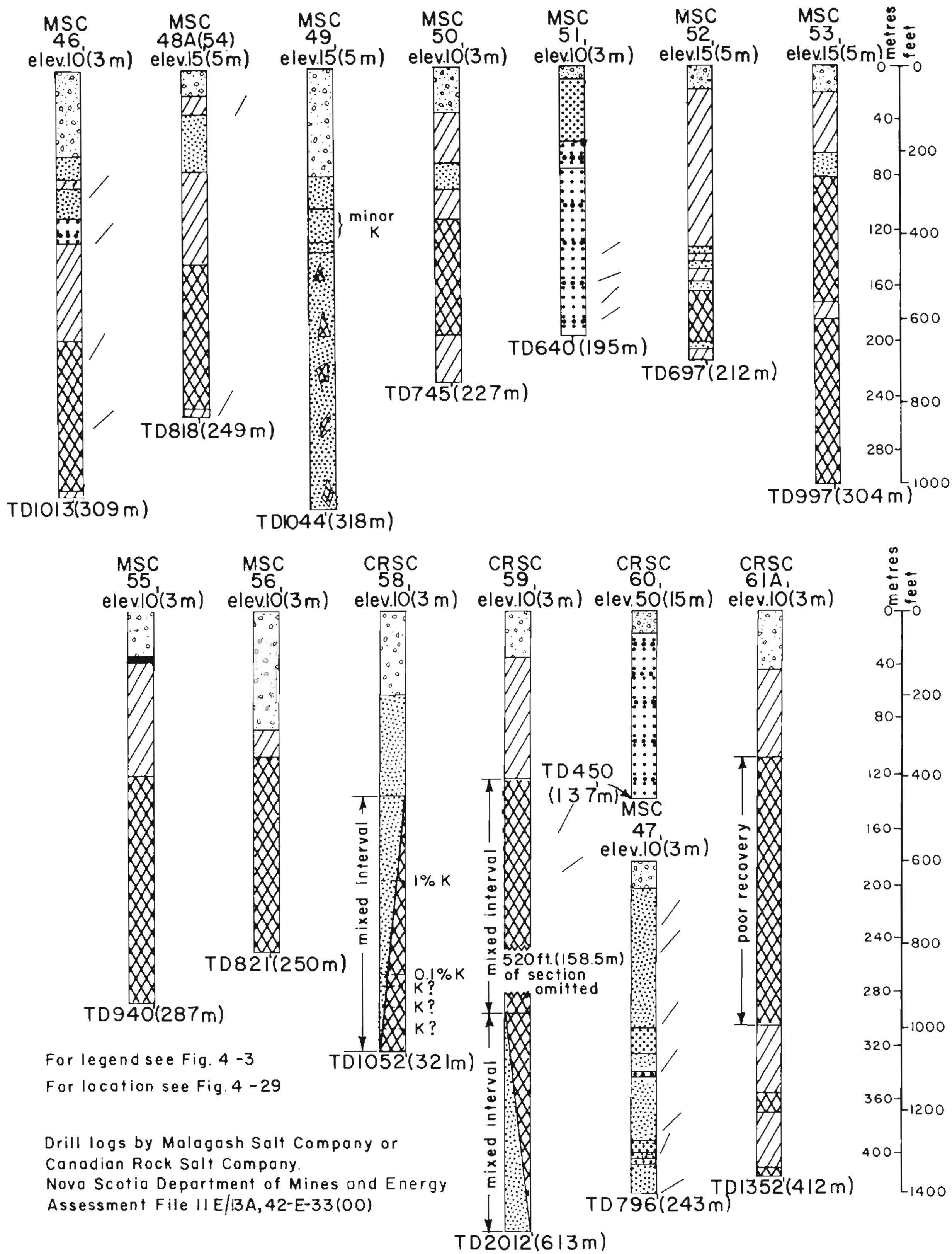


Figure 4-34. Drillhole profiles, Pugwash deposit, Cumberland County.

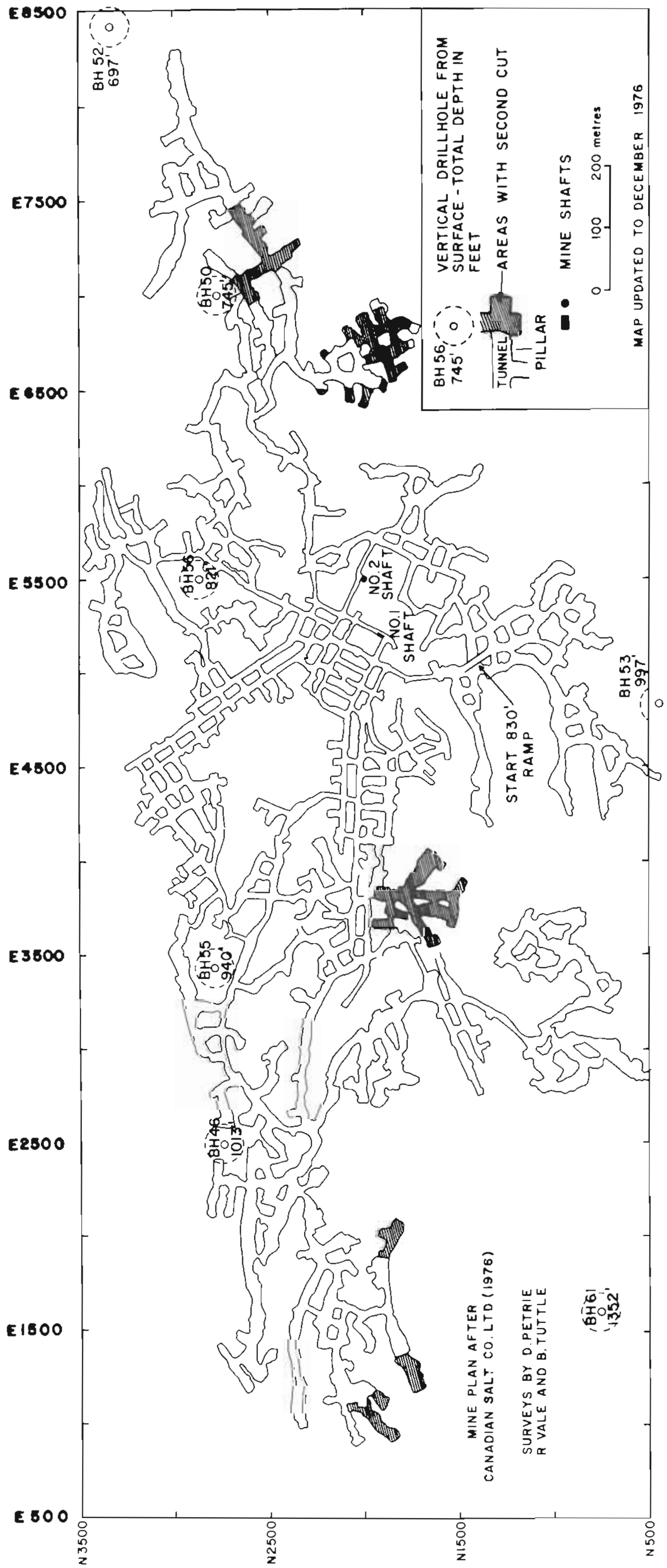


Figure 4-35. Updated mine plan, 630 foot level, Pugwash Mine.

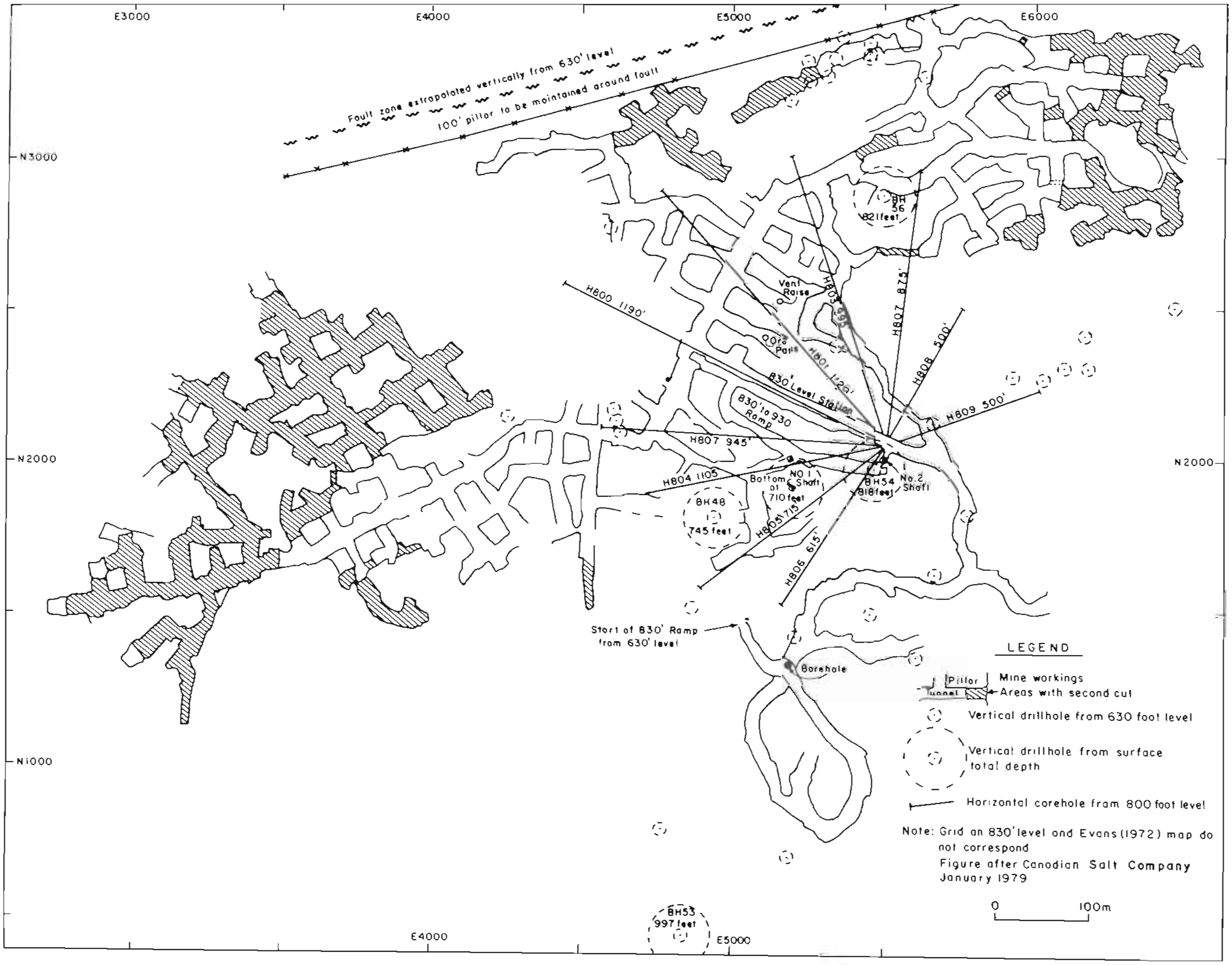


Figure 4-36. Mine plan, 830 foot level, Pugwash Mine.

GEOPHYSICS

The area in the vicinity of the Pugwash deposit is included on Nova Scotia Research Foundation Bouguer anomaly map 11E/13E (1964) at a scale of two inches equals one mile (Fig. 4-37). A distinct elongate 6 mGal negative Bouguer anomaly coincides generally with the Windsor Group outcrop area.

In 1963 the Nova Scotia Research Foundation ran a down hole gamma ray geophysical log on CRSC-59 drilled by the Canadian Rock Salt Company on the northwestern border of the structure (Figs. 4-29 and 4-38). These surveys helped to locate beds containing potash salts. Figure 4-38 indicates the positive correlation between potash salt intervals and increased gamma ray activity.

GEOCHEMISTRY

The bromine geochemistry of Pugwash deposit was investigated by Baar (1966). He reported large secondary halite crystals occurring in many places throughout the Pugwash Mine could be attributed to solutions mobilized during deformation. This mobilization and recrystallization altered the original bromine content and can place considerable restraints on the application of the bromine geochemical method used in potash exploration. Baar (1966) decided a large scale investigation might reveal the extent of alteration. He selected the Pugwash Mine for detailed sampling because of its unique stratigraphic data control, both perpendicular and parallel to bedding.

He described three potash bearing horizons (carnallite-breccia zones) lying above the uppermost salt unit of Evans (1972) as shown in the stratigraphic column in Figure 4-31. His analyses of bromine in vertical (perpendicular to bedding) and horizontal (parallel to bedding) profiles led to the following conclusions:

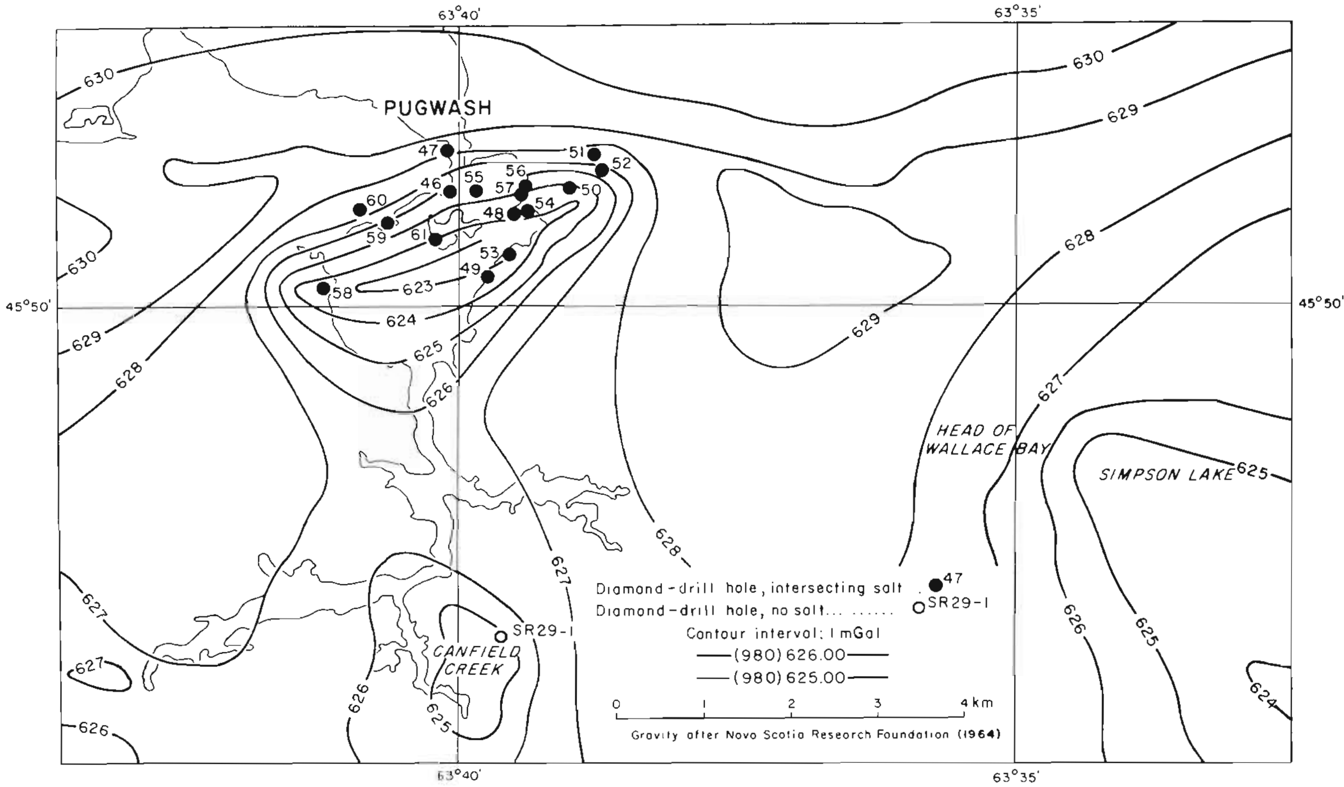


Figure 4-37. Bouguer gravity anomaly map, Pugwash deposit.

(1) The bromine contents in horizontal profiles of the rock salt beds at Pugwash were not remarkably altered in cases where thicker beds consist of halite with little anhydrite and no thick clay intercalations (Fig. 4-39). Because this rock composition would possess little or no permeability under plastic deformation the measured bromine content is believed to represent the original values.

(2) Bromine contents however were altered in the vicinity of clay partings which were brecciated during deformation. The brecciated clay apparently possessed significant permeability which provided migration routes for the solutions that modified the bromine contents of enclosing halite rocks when disequilibrium existed.

(3) He further concluded that the flat nature of the vertical (stratigraphic) bromine profiles (Fig. 4-40) did not display a trend toward increasing bromine content as might be expected when potash salts were precipitated. This data together with the occurrence of potassium salts in permeable carnallite breccias indicated a secondary origin for the potash from migrating solutions derived from deeper primary sources. Primary potassium salt precipitation apparently did not occur during the deposition of the salt observed in the Pugwash Mine. The abnormally high bromine values recorded were attributable to contamination from adjacent permeable strata containing secondary potash.

Up to 5 weight per cent K_2O were found between 358 and 434 m (1175 and 1425 ft.) in drillhole CRSC-59 located 1.6 km west of mine shaft 1 (Fig. 4-38). Unfortunately, the drill fluid used was not saturated with respect to potash and much of the highly soluble potassium salts were dissolved. Bromine contents below 366 m (1200 ft.) in the drillhole are indicated to be distinctly higher than those in the upper part of the sequence. Primary precipitate values of bromine are indicated just below 366 m and suggest that the potash in this interval could possibly be primary.

In conclusion, Baar (1966) stated that the bromine contents of halite in the Pugwash area indicate the potassium minerals (mainly carnallite) in the upper part of the structure are secondary resulting from precipitation from potassium rich fluids derived from primary mineralization at deeper levels. Because the migrating fluids with a high bromine content were not in equilibrium with halite rock adjacent to the permeable solution channels, alteration haloes were created. Primary potash mineral precipitation (based upon high bromine content) is considered to have been possible only in the lower part of the sequence. Since the secondary potash mineral is mostly carnallite and not sylvite, in the early stages of deformation the source beds consisted mainly of carnallite which on dissolution (more soluble than sylvite) left the sylvite behind. Sylvite should therefore be the dominant mineral in the lower part of the

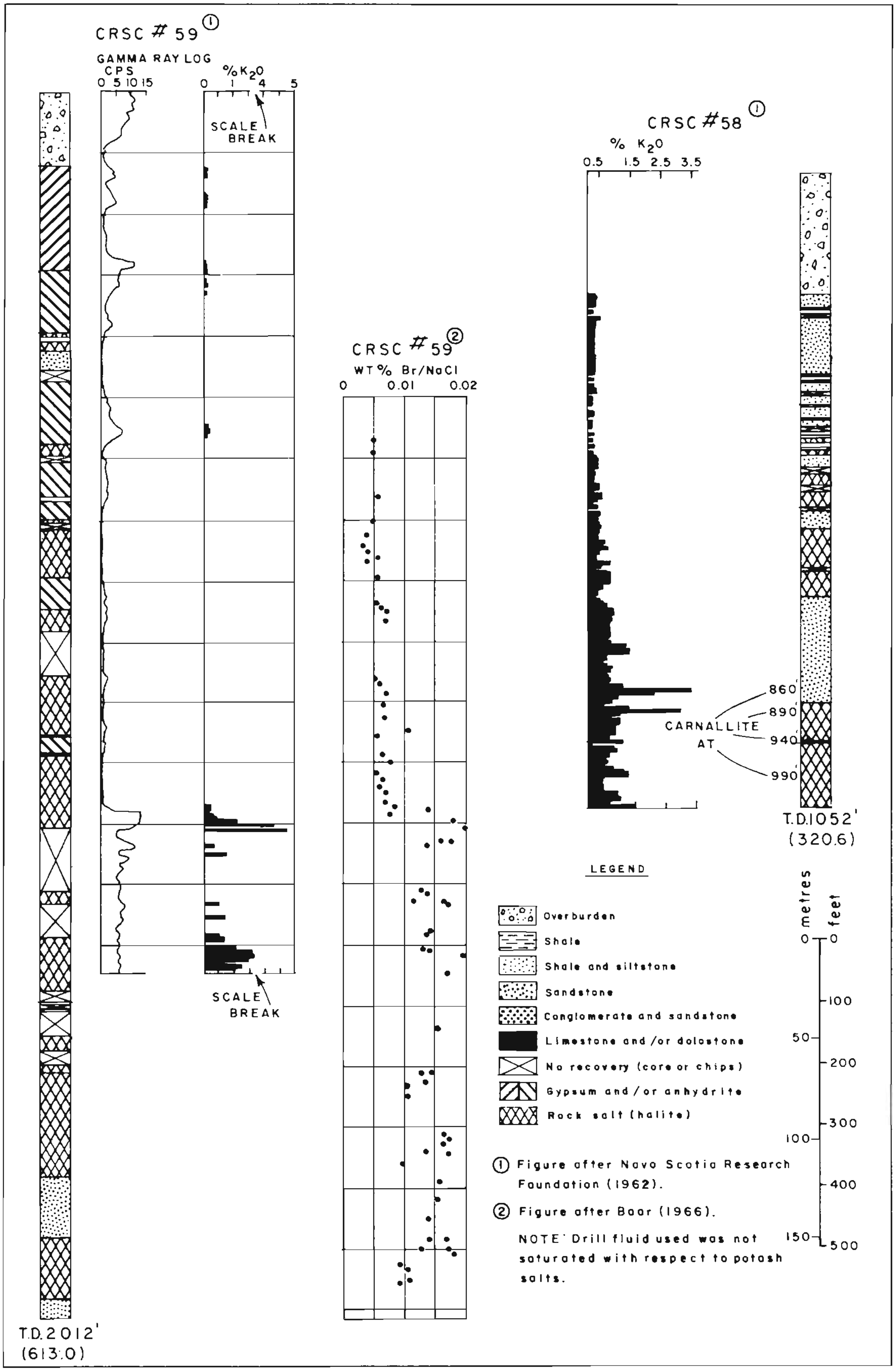


Figure 4-38. Geological, geochemical and geophysical profiles; CRSC #58 and #59, Pugwash deposit. (For locations see Fig. 4-29).

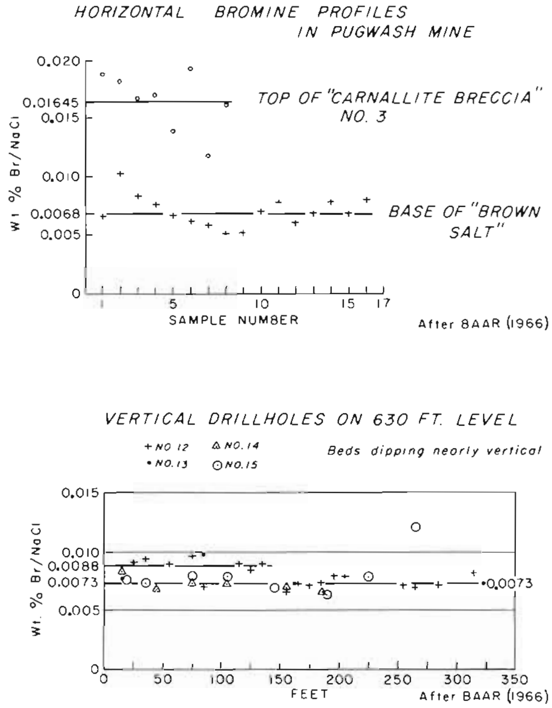


Figure 4-39. Horizontal bromine profiles of stratigraphic units in drill core and mine workings, Pugwash Mine.

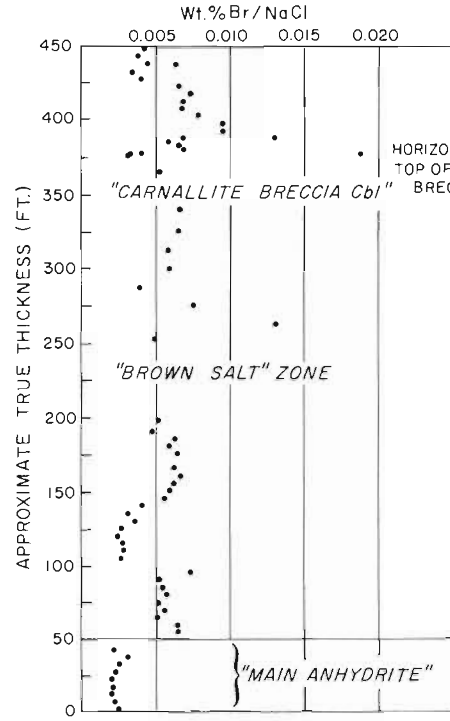


Figure 4-40. Stratigraphic bromine profile of salt units exposed in the Pugwash Mine.

section. It is interesting to note that Evans (1970c) reported sylvite after carnallite in mineralized Wallace No. 1 core from the Malagash deposit and concluded that the sylvite was a secondary product of leaching of primary carnallite.

Nova Scotia Research Foundation (1962) produced a report containing a geology map by Meilke and analyses of potash mineralized zones in the Pugwash Mine (Table 4-8, Appendix 2). Three types of occurrences of carnallite and sylvite were recognized: 1) matrix cement with halite in brecciated clay or mudstone areas, 2) tiny blebs in salt proximal to breccias, and 3) veins or small stringers with orange halite in clay or mudstone. In addition to the potash zones (carnallite breccias) in the Pugwash Mine, potash salts are reported in two diamond-drill holes, CRSC-58 and -59, on the western and northwestern borders of the structure. The analytical results are presented in Figure 4-38 and Table 4-9 (Appendix 2).

Aumento (1964) made a preliminary, but detailed study of the authigenic minerals associated with the Pugwash evaporites. Particular emphasis was placed upon selected samples from the potash salt bearing horizons which were studied with petrographic microscope and X-ray diffraction spectographic techniques on soluble and insoluble fractions and separates. Major rock forming minerals identified include halite, anhydrite, carnallite; intermediate abundances of sylvite, barite, calcite, gypsum, hydro-hematite, magnesite, polyhalite, pyrite and quartz; and trace quantities of acmite-aegerite, boracite, celestite, chlorite, glauberite, goethite, illite?, marcasite?, muscovite, prehnite?, riebekite, rinneite and talc. Details regarding sample sections, preparation and petrology are described by Aumento (1964).

In late 1963, Pacific Petroleums Limited spudded Pacific Fox Habour C-96-V in search of petroleum approximately 11 km east of the Pugwash Mine site (Figs. 1-10, 4-5 and 4-12). Windsor strata were reported to have been intersected at 1673 m (5490 ft.) and salt was first reached at 2678 m (8785 ft.). Approximately 178 m (585 ft.) total thickness of salt was intersected. Table 4-10 records Baar's (1966) reported analyses of cuttings from the salt interval in C-96-V. The bromine content of the salt is high but never reaches the potash threshold of 0.0200.

ECONOMIC CONSIDERATIONS

The Pugwash deposit consists of halite with associated thick and thin beds of anhydrite and thin potassium mineral (carnallite and sylvite) bearing grey shale breccias and local thin sylvinite bands. The salt occurs as intensely deformed beds in a Windsor Group diapiric evaporite intrusion with a general configuration of an ellipsoidal dome containing nearly vertically dipping isoclinal folds. Salt was first intersected at depths between 100 and 130 m and underlies a large portion of the ellipsoidal Windsor outcrop area (3 km x 0.8 km).

Table 4-10. Drill cutting sample analyses, C-96-V, Pugwash area*

Depth Feet	Depth Metres	%K	%Br	%NaCl	%Br/100%NaCl
8860	2700.5	0.046	0.0101	99.1	0.0102
8890	2709.7	0.082	0.0106	98.6	0.0108
8915	2717.3	0.125	0.0140	94.9	0.0147
8945	2726.4	0.142	0.0132	92.5	0.0142
8975	2735.6	0.062	0.0132	97.5	0.0135
9065	2763.0	0.068	0.0132	99.9	0.0132
9085	2769.1	0.149	0.0132	97.5	0.0135
9110	2776.7	0.097	0.0107	99.9	0.0107
9135	2784.3	0.082	0.0101	99.9	0.0101
9210	2807.2	0.132	0.0126	99.1	0.0127

*Baar (1966)

In the initial development stages of the Pugwash Mine in 1959, reserve estimates were placed at 181.4 Mt (200 million short tons), although no average grade or recovery ratio were indicated. The production of salt from the Pugwash Mine was slightly less than 1.09 Mt (1.2 million short tons) in 1979. Geological resources based upon 50% halite content in a block 3000 m long, 800 m wide and 300 m thick to a maximum depth of 500 m indicates approximately 725.6 Mt (800 million short tons) of unknown grade.

CANFIELD CREEK

In 1966 Scurry-Rainbow Oil Ltd. undertook a sulphur exploration program in salt structures in Nova Scotia. The Canfield Creek area located 6.5 km south of Pugwash (Fig. 1-10) (NTS 11E/13 East) was selected for diamond drilling (Figs. 4-29, -40, -41 and -42). It was believed to be underlain by a salt structure that was indicated as a negative Bouguer gravity anomaly (5 mGal) coincident with Windsor Group outcrop. A single drillhole, SR29-1, was drilled to a total depth of 420 m (1380 ft.) and penetrated an interstratified section of brick-red sandstone, siltstone, and shale with minor grey shale. The hole was not cored, and bedding dips are not known. Mapping by Faribault and Fletcher (1905; Fig. 4-29) indicated moderately to gently dipping younger (post-Windsor Group) rocks dipping northwest and southeast away from an oblong (2.2 x 1.2 km) core of vertical to steeply dipping Windsor Group red shale, gypsum, and a limestone with a fauna similar to Lime-kiln Brook section bed number 2 (Bell, 1944). Windsor Group gypsum is located several hundred metres south of the drillhole. Bell (1944) indicated the Windsor Group was faulted on three sides against Pictou Group strata (Fig. 4-42). The structure resembles the outcrop pattern of the Pugwash structure (on a smaller scale), but an accurate comparison is not possible with the present data.

A seismic reflection profile through part of the Canfield Creek diapir is interpreted by Bidgood and Blanchard (1967) to be similar to the Malagash-Wallace structure.

HEAD OF WALLACE BAY (SIMPSON LAKE)

Gravity surveys by the Nova Scotia Research Foundation have outlined a small 4 mGal negative Bouguer gravity anomaly at Head of Wallace Bay near Simpson Lake (Figs. 4-29 and 4-37) approximately 9 km southeast of Pugwash (NTS 11E/13 East) and 8 km west of Wallace (Fig. 4-29). Faribault and Fletcher (1905) indicated an elongated area 1.6 km by 0.8 km mapped as Windsor Group containing sinkholes (gypsum?) and a salt spring. This outcrop area coincides with the gravity anomaly. Although the area has not been drilled, the presence of a small salt structure is suspected.

MALAGASH ANTICLINE BETWEEN WALLACE RIVER AND OXFORD

The portion of the Malagash Anticline between Oxford and the Wallace River (Figs. 1-4, 1-10; NTS 11E/12, 11E/13 East and 11E/14 West) was investigated as part of a regional potash assessment by Hayes (1931). This portion of the structure has not yet been fully explored by deep drilling although Bouguer gravity anomalies coincident with the Windsor Group in the core of the anticlinal structure suggest salt intrusion occurred along its length.

Hayes (1931) reported that the bedding dips of the Windsor Group in this part of the Malagash Anticline are about 35° south. The dips become steeper easterly toward the Wallace River where Faribault and Fletcher (1905) indicated dips of 60-70° south. Hayes, (1931) suggested that the thrust faulting (presumably toward the north) brought the Windsor Group to the surface in an asymmetric anticline. He described the southern contact of the Windsor Group as a conformable onlap of "Millstone Conglomerate" which is probably equivalent to Middleborough and/or Claremont and possibly in part Boss Point Formations of Norman and Bell (1938).

The Windsor Group strata in the axial area have an outcrop width of 0.8 to 1.5 km. Bell (1944) reported that the presence of gypsum in the area is indicated by numerous sinks. Bell (1944) also reported that the Malagash Salt Company drilled a hole at Hartford (Fig. 4-43) to a depth of 46 m (151 ft.). The drillhole reportedly intersected calcareous grey shales containing Lower Windsor fossils. Bedding dips

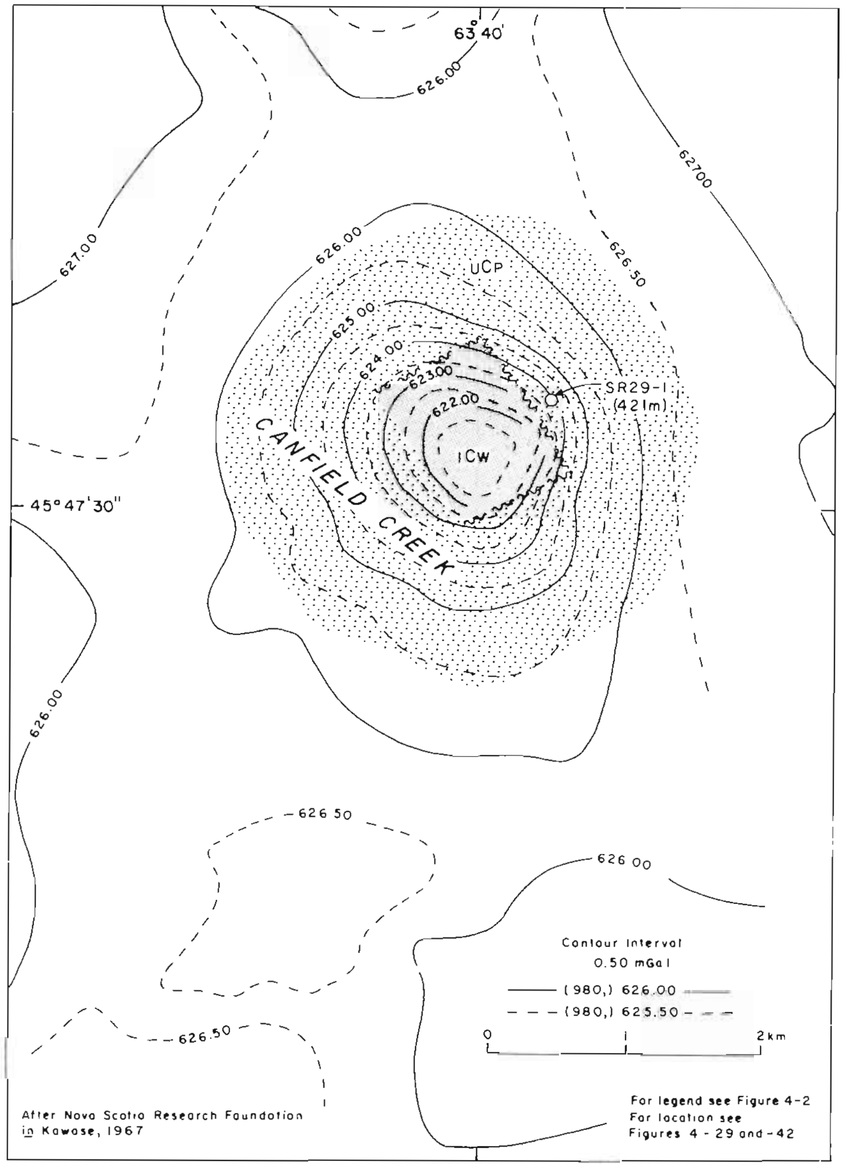


Figure 4-41. Bouguer gravity anomaly map, Canfield Creek, Cumberland County.

are indicated to be about 50° and are similar to those recorded for strata on the southern limb of the Anticline. Faribault and Fletcher (1905) indicated the occurrence of a mineral spring approximately 15 km west-northwest of Hartford. Cole (1930a) reported a salt spring (Conn Brook Spring, No. 7) near Conn Brook, 0.4 km southwest of Hartford (Table 4-11). Pohl (in Hayes, 1931) reported that in 1915 a water well drilled approximately 1.6 km east of Hartford Post Office, produced salt cuttings at a depth of approximately 30 m (100 ft.). In 1921 a water well drilled 0.4 km east of Hartford Post Office produced salt and brine at a depth of 29.6 m (97 ft.).

Cole (1930a) reported the occurrence of four springs in the Hansford area: the East Hansford Spring (No. 15), the Mayne Spring (No. 14), the Conns Brook Spring (No. 7), and the Birchwood Spring (No. 12) (Table 4-11). These springs have a composition dominated by NaCl, but No. 7 and No. 15 have a moderate component of $CaSO_4$ indicating the dissolutuon of gypsum.

Norman and Bell (1938) on Map 410A indicated the east-northeast to west-southwest trend of the Malagash Anticline is offset by a north-northeast trending (transverse) sinistral fault near Hansford, 8 km east of Oxford.

The basic structural situation, together with the presence of salt springs, suggest that salt is probably present in the Hartford-Hansford area, but its presence and depth remains to be proven. Gravity surveys in the area (Fig. 4-1) between Oxford and Wallace River indicate a long

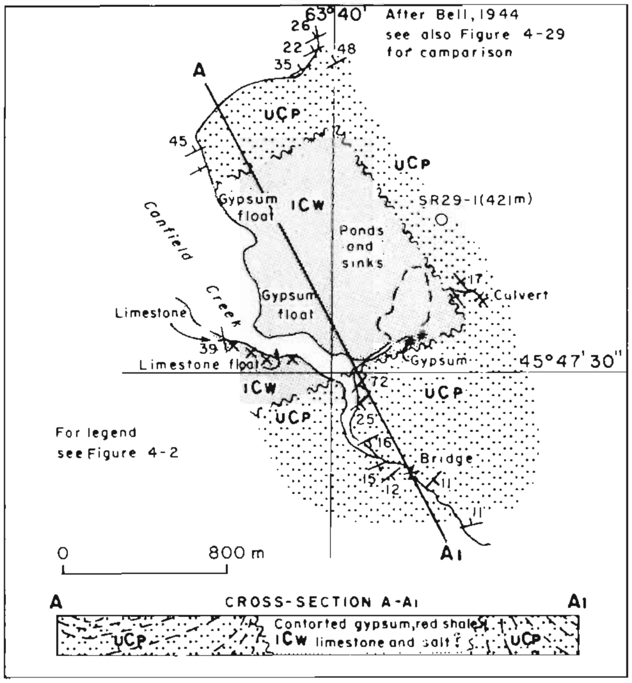


Figure 4-42. Geology in the vicinity of Canfield Creek, Cumberland County.

narrow negative Bouguer gravity anomaly coinciding with the axis of the Malagash Anticline. The anomaly magnitude is much less than that of the Malagash-Wallace, Pugwash, Oxford or Roslin anomalies and is interpreted to be caused by deeper and/or smaller salt masses occurring in a similar structural configuration.

SPRINGHILL AREA, BLACK RIVER DIAPIR

The western terminus of the Malagash Anticline occurs near Springhill (Fig. 1-10) where it is faulted against Late Carboniferous strata. To the west of Oxford, the Malagash Anticline changes its trend and forms a hook as it swings northwest, just east of Springhill and then northeast, north of Springhill. Here the Windsor Group is apparently terminated in an east-northeast trending fault. The geology of the Springhill area (Fig. 4-44) was described by Shaw (1951) and Copeland (1959) and more recently by Calder (1980). Shaw (1951) reported that the Windsor Group occurs in restricted areas as gypsum, fossiliferous concretionary limestone and calcareous black shale whose thickness, due to complex structure, is not measurable. In a cross-section, to accompany Shaw's (1951) Preliminary Map 51-11, the Windsor Group at Black River was indicated to occur as a moderate angle thrust or reverse fault in the core of an anticline (Figs. 4-44 and 4-45). Brine springs indicative of subsurface salt dissolution are also

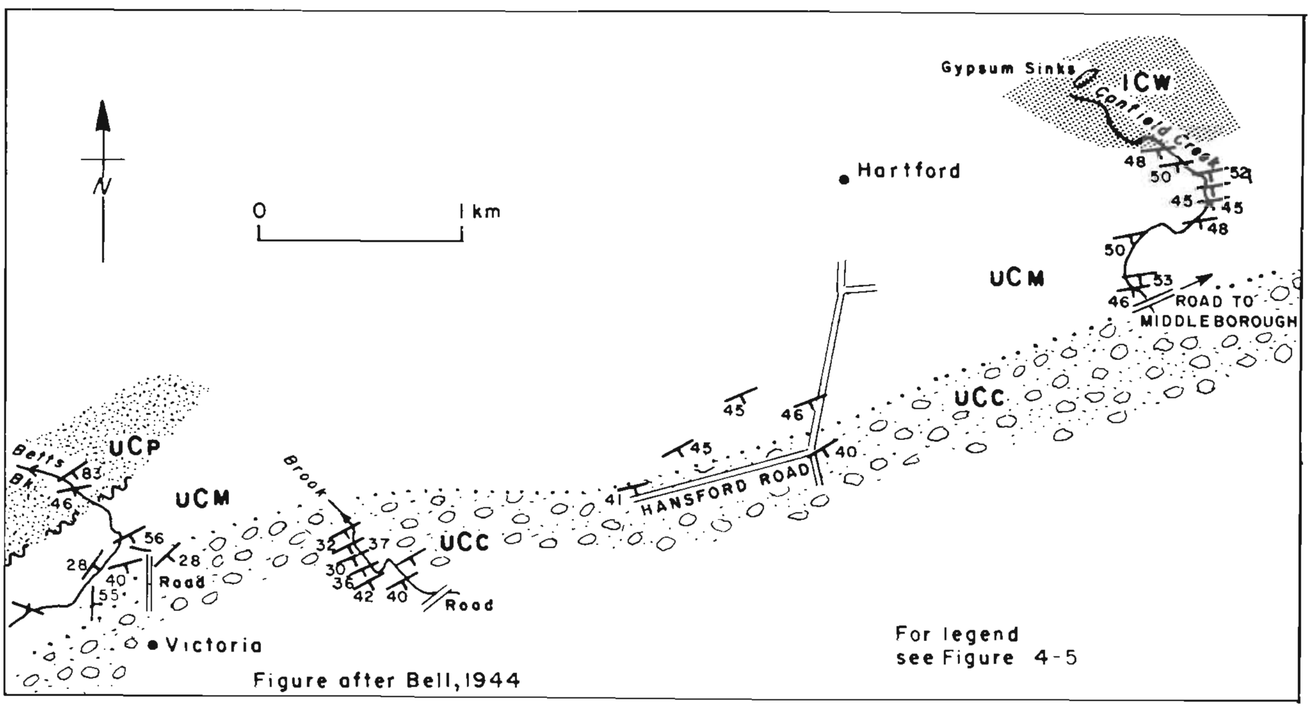


Figure 4-43. Geology in the vicinity of Hartford, Cumberland County.

Table 4-11. Chemical analyses of salt springs in the Hartford-Hansford area, Cumberland County*.

Sample No.	**7**	**12**	**14**	**15**
FIELD NOTES AT TIME OF SAMPLING				
Temperature of atmosphere, °F	75	77	76	76
Temperature of brine, °F	62	50	65	47
Baume degrees	1.5	n.d	n.d	n.d
Equivalent specific gravity .	1.010	-	-	-
LABORATORY NOTES				
Specific gravity at 60°F	1.012	1.0133	1.0005	1.0139
Total solids at 110°C	1.63	1.89	0.71	1.84
Reaction	None	None	None	None
ANALYSES OF SOLIDS				
Na ....Per cent	27.69	35.00	36.50	33.32
K ....Per cent	0.32	0.01	0.22	0.18
Ca ....Per cent	0.16	2.20	0.65	3.82
Mg ....Per cent	0.33	0.21	0.13	0.16
SO_4 ....Per cent	15.94	2.00	0.21	9.23
Cl ....Per cent	45.89	57.11	58.14	51.99
Br ....Per cent	n.d.	none	none	none
I ....Per cent	n.d.	none	none	none
Total	96.33	96.53	95.85	98.70
HYPOTHETICAL COMBINATION				
$CaSO_4$ ....Per cent	20.94	2.83	0.30	13.06
$CaCl_2$ ....Per cent	3.21	3.80	1.55	-
$MgSO_4$ ....Per cent	-	-	-	-
$MgCl_2$ ....Per cent	1.29	0.61	0.51	0.62
K_2SO_4 ....Per cent	-	-	-	-
KCl ....Per cent	0.61	0.02	0.41	0.34
Na_2SO_4 ....Per cent	-	-	-	-
NaCl ....Per cent	70.27	89.28	93.08	84.68
Total	96.32	96.54	95.85	98.70

*L. H. Cole (Table 1, p. 8, 1930a).

reported in the area by Shaw (1951) and Cole (1930a).

In 1941 the Nova Scotia Department of Mines drilled NSDM 931 for special investigation at Black River, near Springhill. The hole was drilled to a depth of 153 m (501 ft.) and penetrated alternating thick beds of red shale and gypsum. Salt was not intersected although salt is indicated in the vicinity by the presence of a salt spring (Salt Springs Spring) 0.4 km to the southeast. The analyses of water from this spring (Table 4-12), reported by Cole (1930a), indicate the major dissolved constituent is NaCl with low $CaSO_4$.

Gravity surveys in the area indicate a narrow negative Bouguer gravity anomaly (6 mGal) coincident with the Windsor Group outcrop area and apparently contiguous with the Oxford anomaly (Fig. 4-1). The presence and extent of salt in the area have not been proven by drilling. Copeland (1959) described the Windsor Group rocks as occurring in a diapiric structure which he called the Black River Diapir.

ROSLIN OCCURRENCE

The Roslin occurrence is located near Roslin (11E/13W), Cumberland County, northern Nova

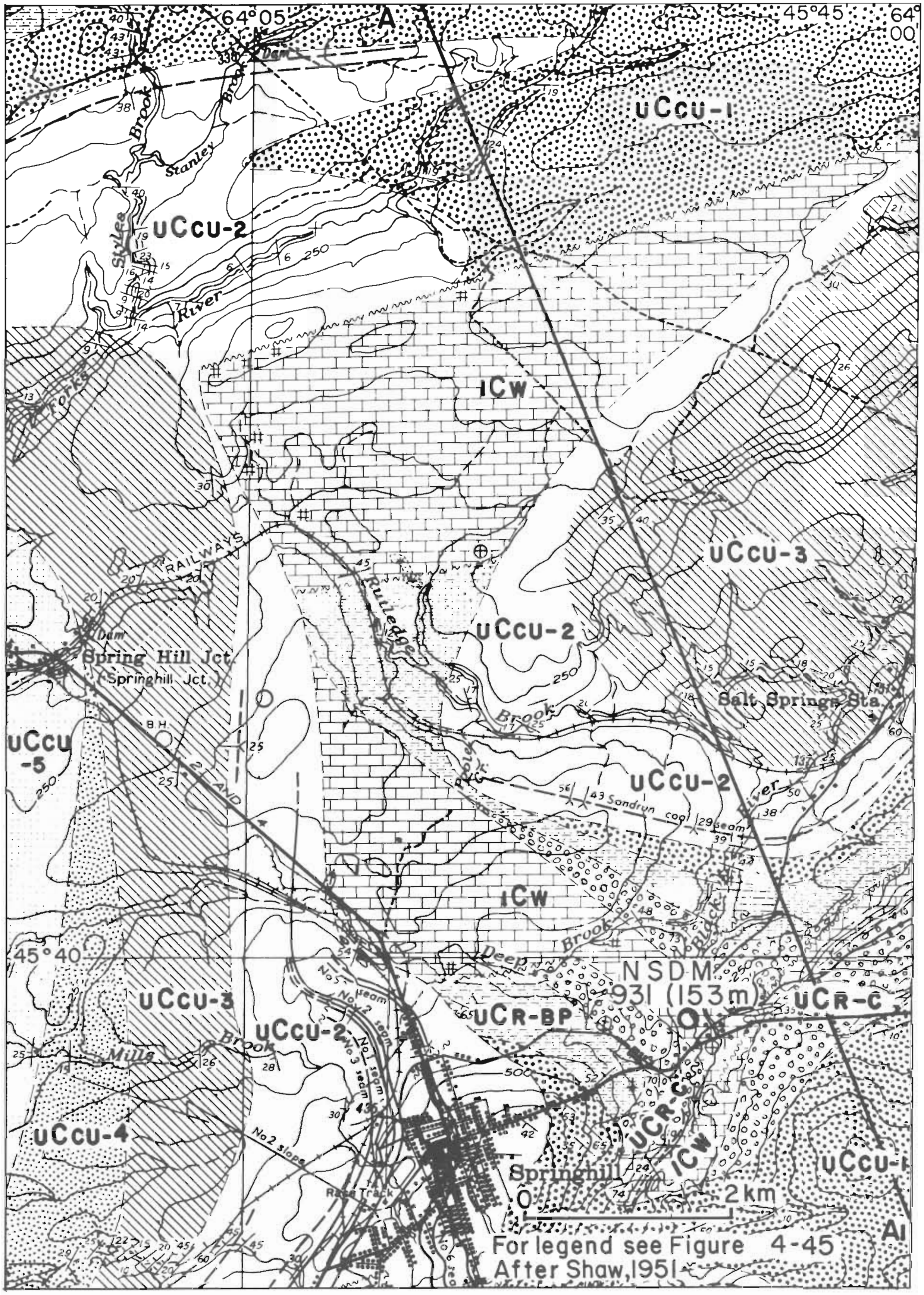


Figure 4-44. Geology in the vicinity of Black River near Springhill, Cumberland County.

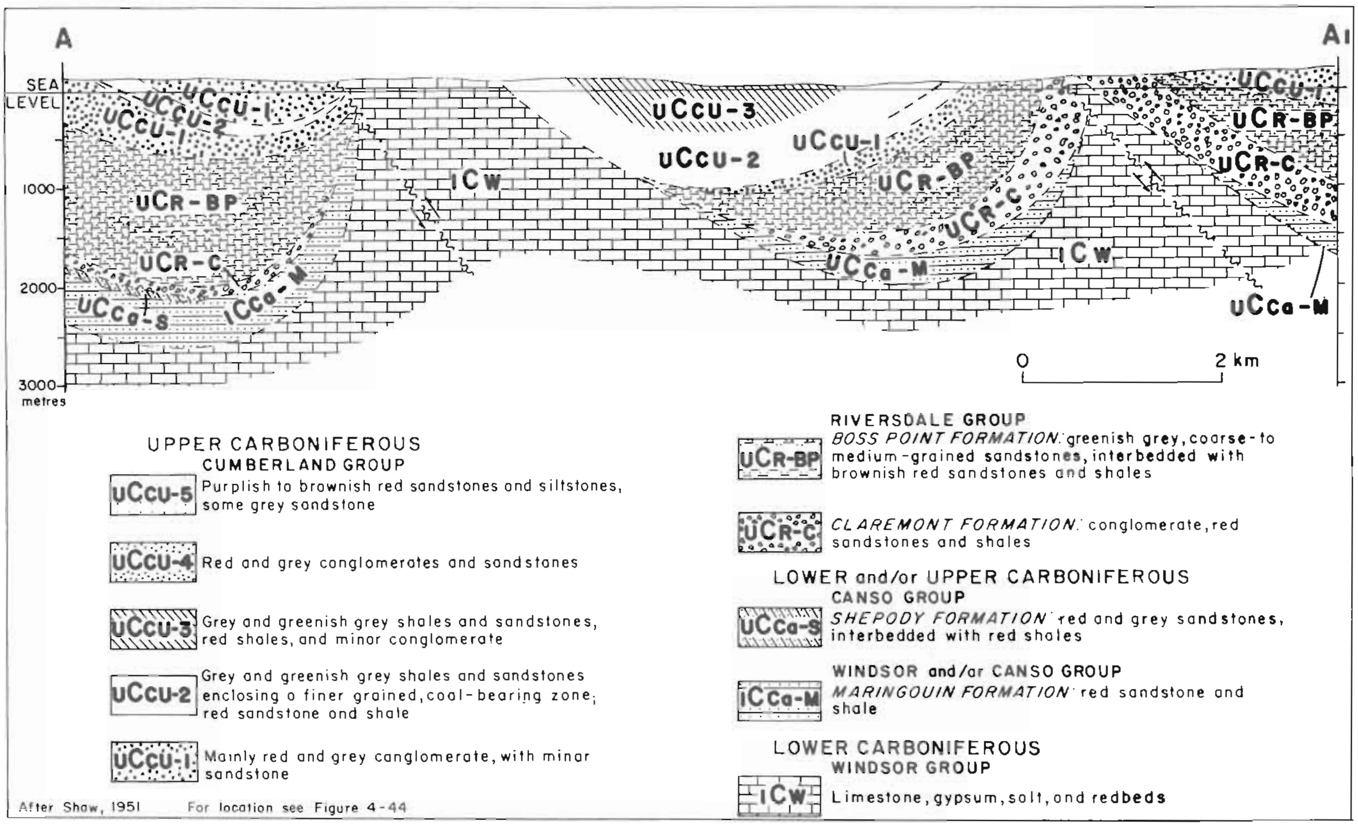


Figure 4-45. Geological cross-section and legend to accompany Black River area geological map, Figure 4-44, Cumberland County.

Scotia (Figs. 1-10 and 4-46). Roslin is situated 7 km northeast of Oxford and 13 km southwest of Pugwash.

The area is readily accessible by paved and unpaved roads. Roslin is located on Highway 21 that runs between Oxford and Port Philip on the Northumberland Strait and is connected to the Trans-Canada Highway 104 that runs through Oxford between Truro and New Brunswick. The mainline of the Canadian National Railway passes through Oxford. Tide water shipping facilities are situated at Pugwash.

The terrain in the vicinity of the Roslin occurrence is typical of the Carboniferous Lowlands in northern Nova Scotia. The area has gently rolling hills with elevations rarely exceeding 75 m. Rivers draining the area have broad estuaries on the Northumberland Strait shore.

HISTORICAL BACKGROUND

The Roslin area was investigated for its potash potential by Pohl as part of a regional study by Hayes (1931). Pohl (in Hayes, 1931) reported a salt spring in the vicinity. Cole (1930a) reported a salt spring near the Roslin Post Office. It is not certain if these reported springs are the same one.

In 1965-1966 the Nova Scotia Department of Mines and Nova Scotia Research Foundation undertook geophysical and geological surveys as part of a potash exploration project in Cumberland County. The program was funded by the Atlantic Development Board and on the basis of these surveys, diamond drilling was initiated on some of the structures including the Roslin structure. One hole, Roslin No. 1 (NSDM 4307) was drilled to a total depth 306 m (1005 ft.). Salt impregnated brecciated red and green mudstone and siltstone were encountered between 114 m and 306 m. No further drilling has been undertaken to penetrate the evaporite section indicated by the Bouguer gravity anomaly.

GEOLOGY

The geology in the Roslin area was first mapped by Faribault and Fletcher (1905). Many occurrences of gypsum and several outcrops of limestone are indicated as occurring in the rectangular outcrop area of "Carboniferous Limestone" or Windsor Group. These evaporites were remapped by Bell (1945) as part of the Windsor Group. The north-northwesterly trending rectangular outcrop of Windsor Group rocks are in fault contact with the Cumberland Group on the west, east and south (Fig. 4-46a). The Cumberland Group comprises grey and red sandstone, grit and conglomerate, and red shale.

Table 4-12. Chemical analyses of Salt Springs, Springhill, Cumberland County*

Salt Springs Spring (No. 11) near Black River

FIELD NOTES AT TIME OF SAMPLING	
Temperature of atmosphere, °F	78
Temperature of brine, °F	54
Baume degrees	n.d
Equivalent specific gravity ...	-
LABORATORY NOTES	
Specific gravity at 60°F	1.0522
Total solids at 110°C	7.40
Reaction	None
ANALYSES OF SOLIDS	
Na ....Per cent	37.22
K ....Per cent	0.15
Ca ....Per cent	1.08
Mg ....Per cent	0.06
SO_4 ....Per cent	1.55
Cl ....Per cent	58.35
Br ....Per cent	none
I ....Per cent	none
Totals	98.41
HYPOTHETICAL COMBINATION	
$CaSO_4$ ....Per cent	2.20
$CaCl_2$ ....Per cent	1.22
$MgSO_4$ ....Per cent	-
$MgCl_2$ ....Per cent	0.24
K_2SO_4 ....Per cent	-
KCl ....Per cent	0.29
Na_2SO_4 ....Per cent	-
NaCl ....Per cent	94.48
Total	98.43

*Cole (1930a)

The southwesterly trending fault apparently continues into the Hartford-Hansford area several kilometres to the south. The northern contact is not indicated as a fault, but is apparently an angular unconformity with overlying Pictou Group rocks comprising red sandstone, shale, grit and conglomerate with some grey sandstone and shale. The Pictou Group strata at this location are very steeply dipping and locally overturned near the contact. This suggests the contact is more than a simple angular unconformity. Bell (1944) published a small sketch map of this same area (Fig. 4-46b). He later modified the interpreted structure somewhat on the 1945 map (842-A). The 1944 map (Fig. 4-46b) indicated an east-west trending fault on the northern contact with Pictou Group rocks and marked the eastern contact by a north-south trending fault giving the Windsor Group outcrop area a triangular fault bound outline with the Pictou Group strata.

Rocks of the Windsor Group in the Roslin structure comprise gypsum, limestone, and red shale. A salt spring reported by Cole (1930a) near the Roslin Post Office and diamond-drilling both indicated that salt is also present at depth. Bell (1944) reported that gypsum carrying abundant selenite outcrops on the shore of River Philip near Roslin. Here a strike of 142° and a dip of 38° east is indicated, and he suggested that a string of sinkholes along Plaster Creek may also indicate its presence. He further reported locally fossiliferous limestone and calcareous shale at several localities. Two outcrops of thinly bedded limestone and calcareous shale are located on Plaster Brook. Fossils identified by Bell (1944) from the outcrop 488 m (1600 ft.) southeast of where the Creek crosses the highway are reported to be the same as the Lime-kiln Brook fauna of bed (2). These beds strike 128°, are apparently overturned with dips of 55° to the southwest, and overlie the gypsum horizon. Bell (1944) reported 9.8 m (32 ft.) of calcareous shale and siltstone overlying red shale, at a location 475 m (1500 ft.) southeast of the above locality. Here the beds are vertical, with tops facing to the west and are assigned to the B Subzone. The stratigraphic relationship to the other limestone beds is uncertain.

Diamond drilling (NSDM 4307) undertaken in 1966 as part of the 1966 Potash Project by the Nova Scotia Department of Mines penetrated a mudstone-siltstone breccia with salt as infillings and veins from 114 m (increasing in abundance) to the bottom of the hole at 306 m (Fig. 4-47). Although the main evaporite zone was not intersected in this hole, it is probably present at greater depth.

The overall surficial expression of the Roslin structure is similar to that described in the Canfield Creek area. Outcrops are scattered and scarce, and the strata exposed are disturbed, steeply dipping and often overturned.

GEOPHYSICS

The area in the vicinity of Roslin is included on a Nova Scotia Research Foundation Bouguer anomaly map, at a scale of 4 inches equals 1 mile (Fig. 4-48).

Gravity modelling by Bidgood (1970) on the Roslin Bouguer gravity anomaly indicated a "good fit" using a density contrast of 0.22g/cc for a body 2700 m across extending from 25 m below the ground surface to a depth of 2700 m. A total intensity magnetometer high (Fig. 4-49) coincident with the Bouguer gravity anomaly minimum was thought to be caused by the occurrence of a rather rare mineral rinneite ($FeCl_2.3KCl.NaCl$). This mineral is believed to result from reaction of evaporite bittern with clay minerals (Nova Scotia Research Foundation, 1967a).

A reflection seismograph survey was carried out by Beaver Geophysical Services Limited along Highway 21 which runs diagonally across the Roslin structure (Fig. 4-50). A large up-thrust fault block was inferred with faulting shown in the regions of shot points 203 and 208 (Beaver Geophysical Services Limited, 1965).

GEOCHEMISTRY

Cole (1930a) reported the following analyses of water taken from salt spring No. 8 that bubbles up in the centre of a pond on Plaster Creek near

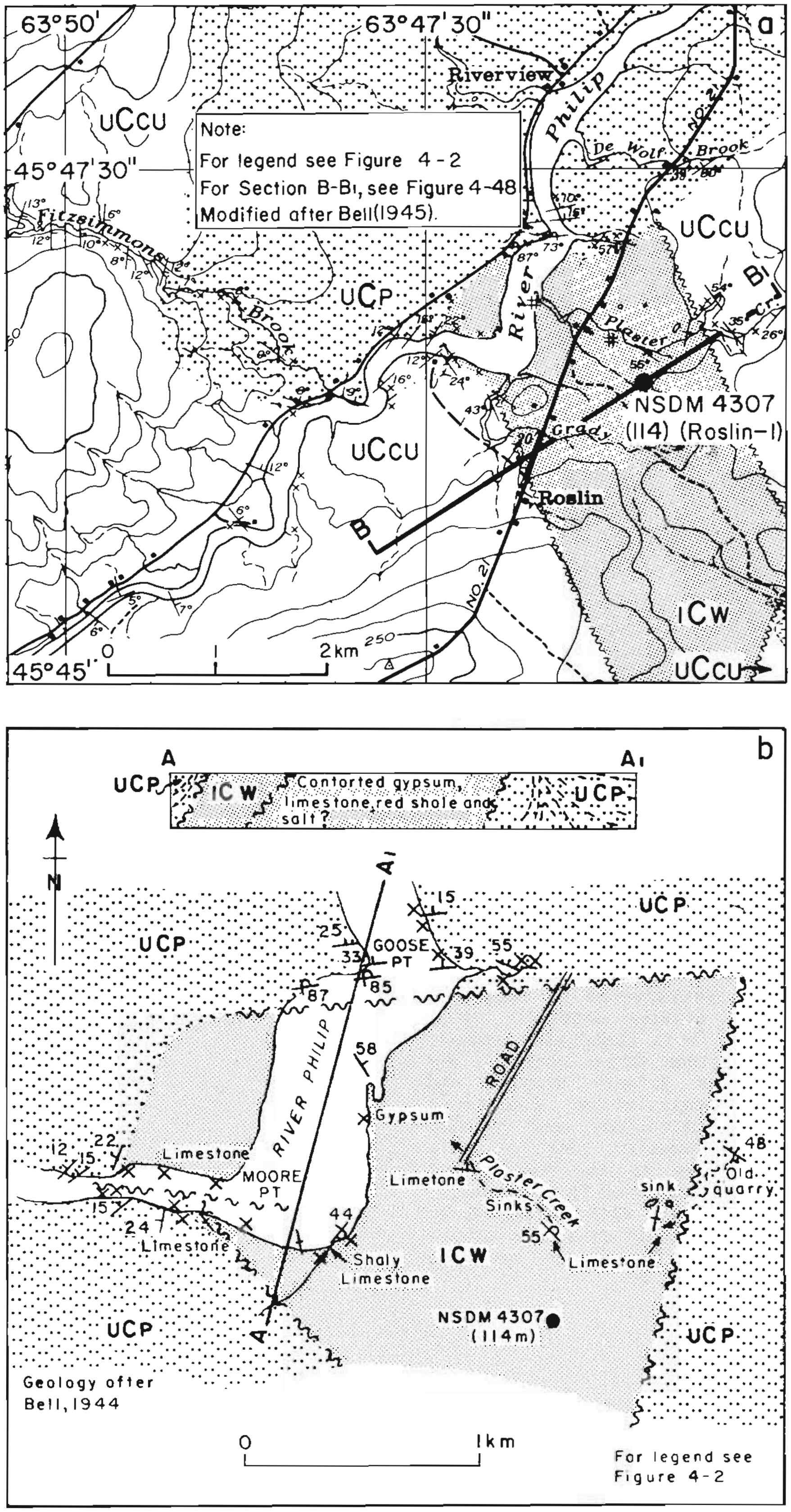


Figure 4-46. Geology in the vicinity of the Roslin occurrence, Cumberland County.

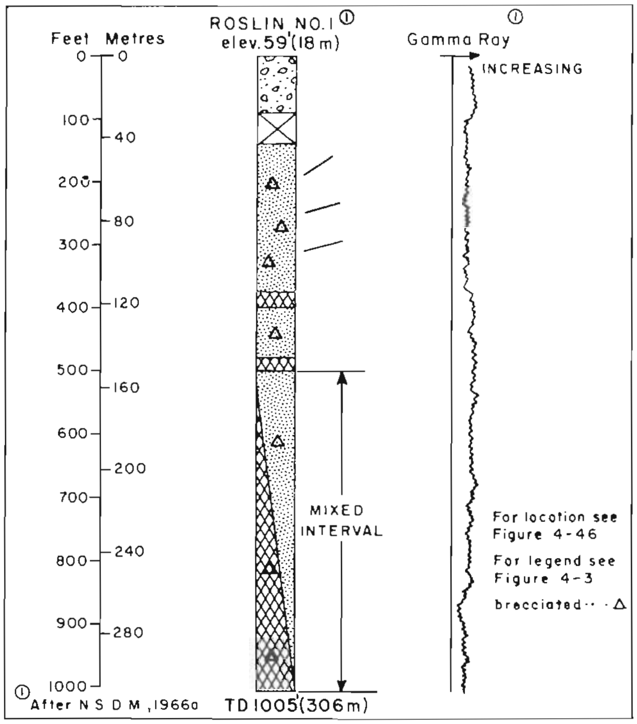


Figure 4-47. Drillhole profile, Roslin No. 1 (NSDM 4307), Roslin occurrence, Cumberland County.

Roslin Post Office (Table 4-13). This composition is typical of moderate $CaSO_4$ rich springs indicative of significant dissolution of gypsum in addition to salt.

ECONOMIC CONSIDERATIONS

The Roslin occurrence consists of impure halite veins in brecciated mudstone and siltstone. The main evaporite section was not penetrated by diamond-drilling, but its presence is suggested by a negative Bouguer gravity anomaly. This structure is apparently fault bound with younger Pictou Group and Cumberland Group rocks. The Windsor Group comprises steeply dipping and locally overturned fossiliferous limestone, calcareous shale, red siltstone, and gypsum. These rocks are similar faunally, lithologically and structurally to those in the Nappan and Pugwash areas. This is considered to be a small, complex diapir with the salt mass occurring at depth. Based upon the available data this occurrence is not considered to be of economic interest.

Table 4-13. Chemical analyses of Roslin Spring, Cumberland County, Nova Scotia.*

Roslin Spring (No. 8)

FIELD NOTES AT TIME OF SAMPLING	
Temperature of atmosphere, °F	78
Temperature of brine, °F	47
Baume degrees	1.0
Equivalent specific gravity ...	1.007

LABORATORY NOTES	
Specific gravity at 60°F	1.008
Total solids at 110°C	1.13
Reaction	None

ANALYSES OF SOLIDS		
Na	Per cent	25.66
K	Per cent	0.31
Ca	Per cent	7.95
Mg	Per cent	0.21
SO_4	Per cent	18.65
Cl	Per cent	42.30
Br	Per cent	n.d.
I	Per cent	n.d.
Totals		95.08

HYPOTHETICAL COMBINATION		
$CaSO_4$	Per cent	26.42
$CaCl_2$	Per cent	0.49
$MgSO_4$	Per cent	-
$MgCl_2$	Per cent	0.82
K_2SO_4	Per cent	-
KCl	Per cent	0.59
Na_2SO_4	Per cent	-
NaCl	Per cent	66.77
Total		95.09

*L. H. Cole (Table 1, p. 8, 1930a)

Chemical analyses of Roslin No. 1 are presented in Appendix 2.

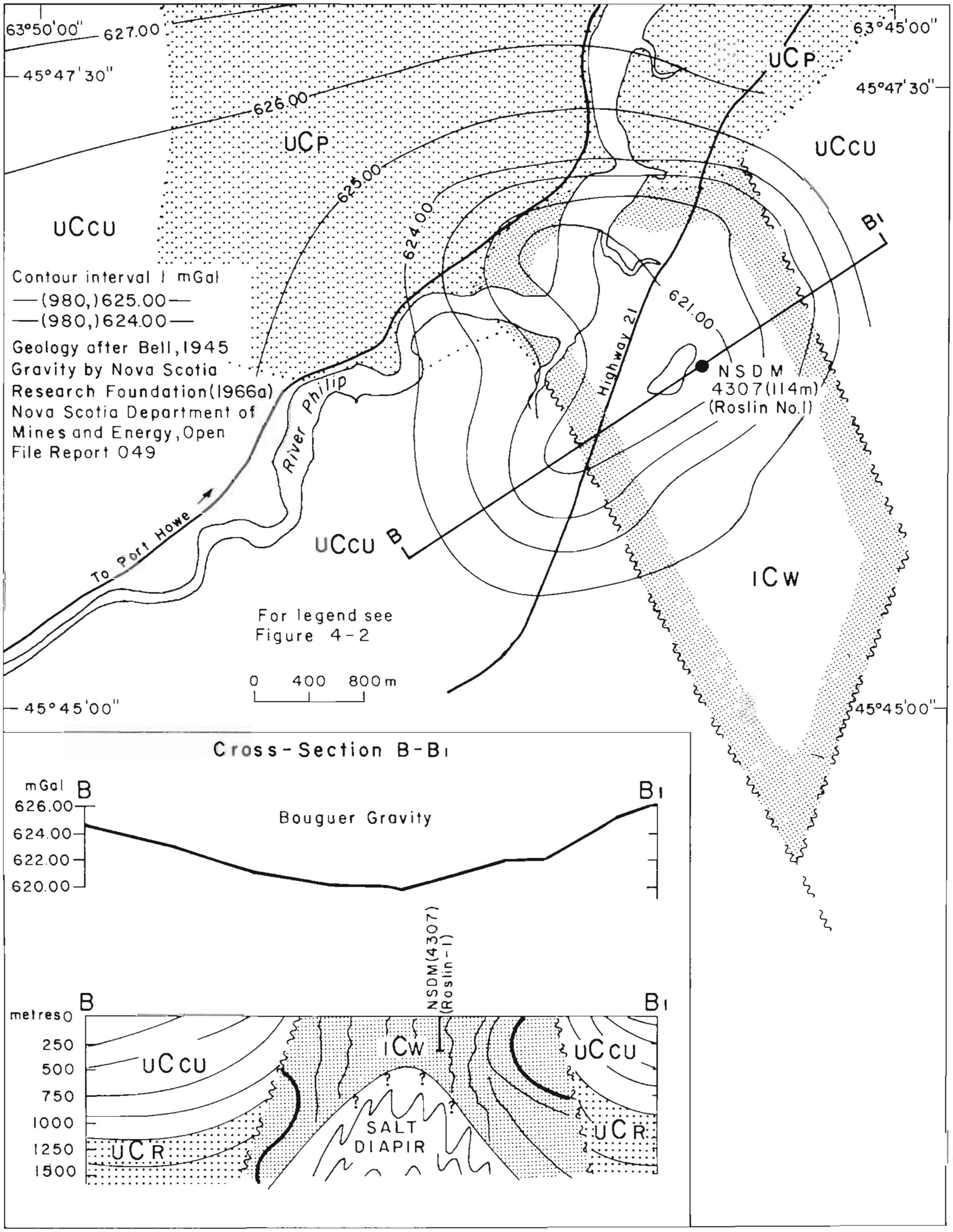


Figure 4-48. Geological and Bouguer gravity anomaly map with accompanying cross-section, Roslin occurrence, Cumberland County.

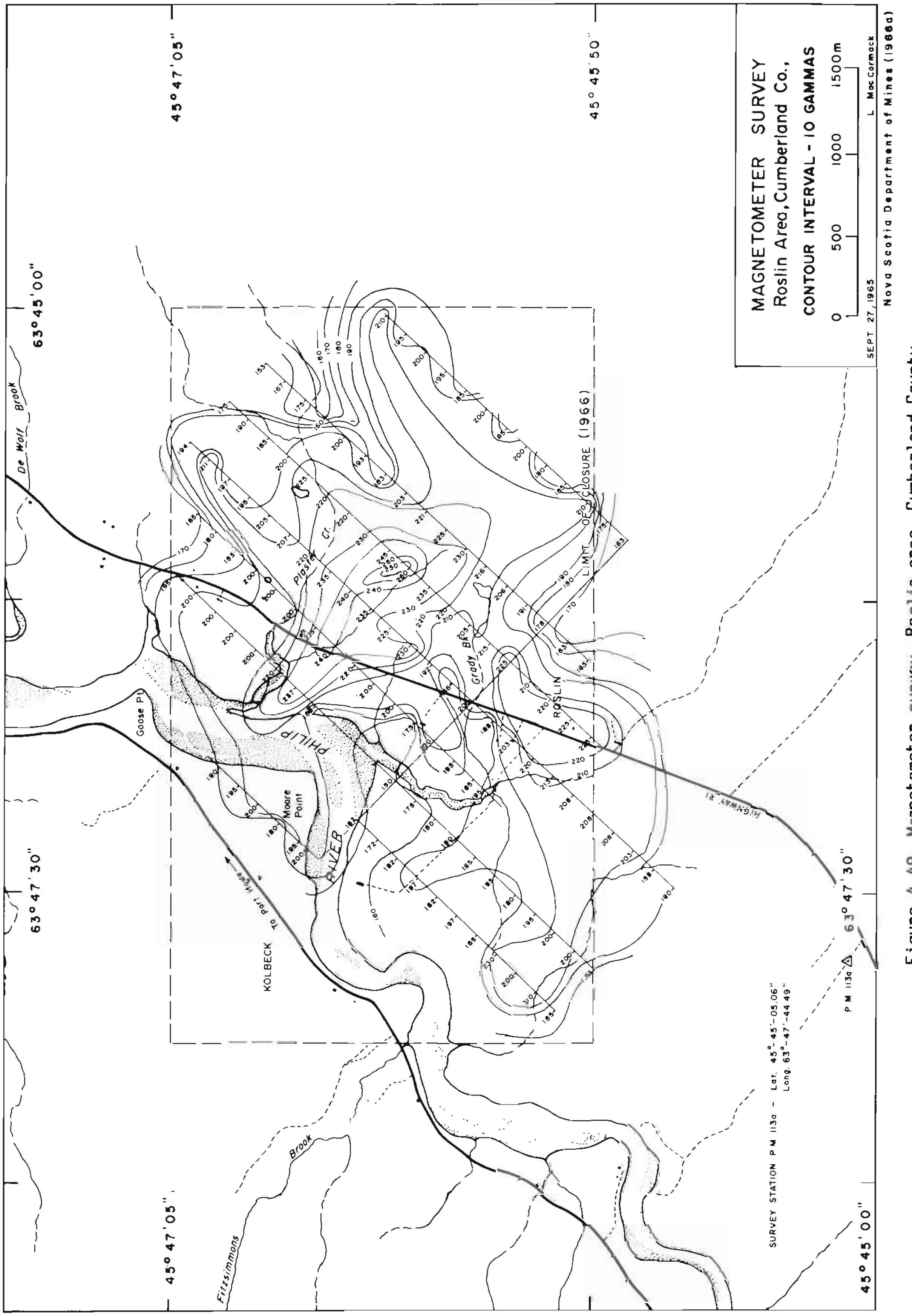


Figure 4-49. Magnetometer survey, Roslin area, Cumberland County.

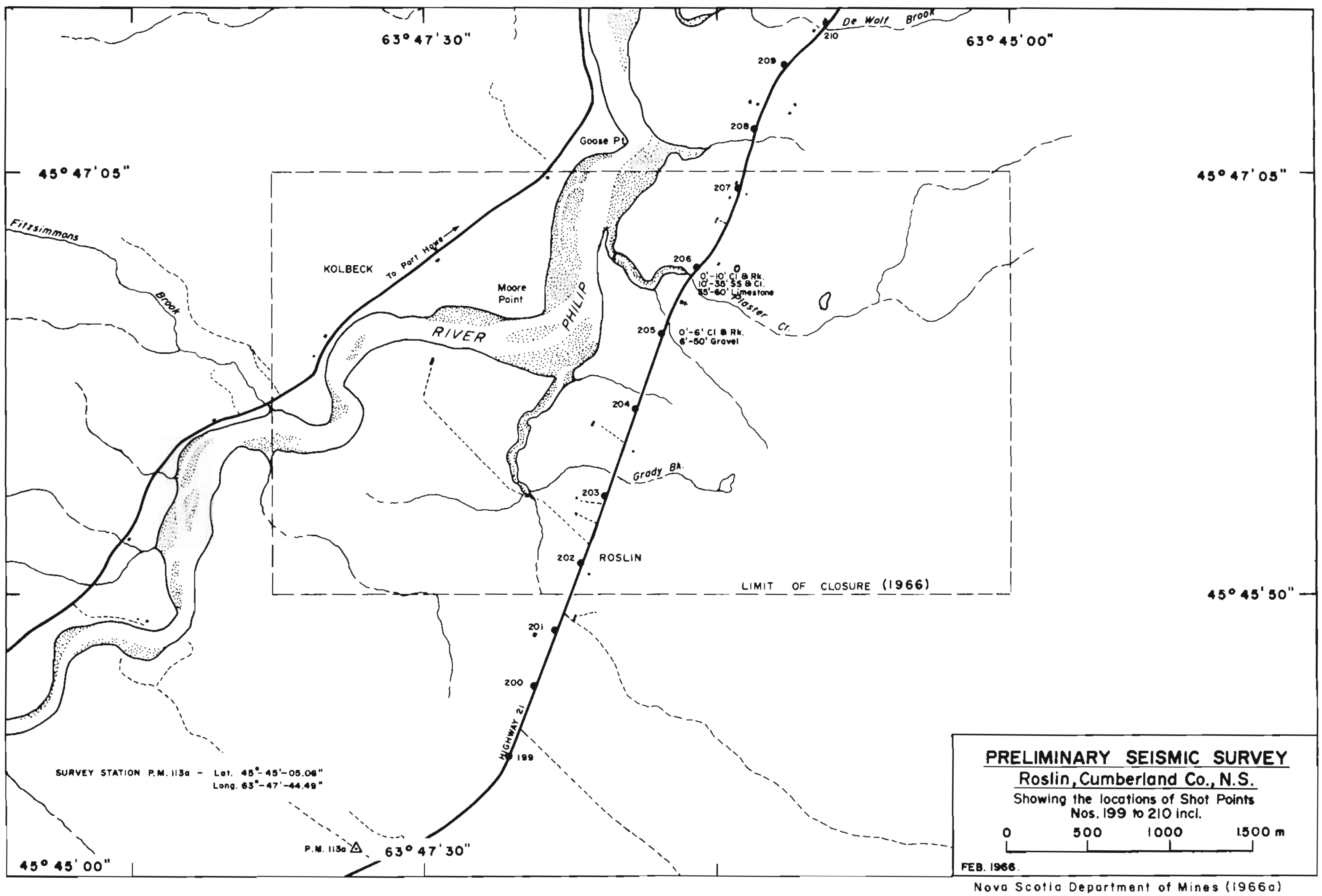


Figure 4-50. Preliminary seismic survey shot points location map, Roslin occurrence, Cumberland County.