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THE GEOLOGY OF THE JUBILEE ZINC-LEAD DEPOSIT, VICTORIA COUNTY, CAPE BRETON ISLAND, NOVA SCOTIA

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GEOLOGY OF THE JUBILEE ZINC-LEAD DEPOSIT, VICTORIA COUNTY, CAPE BRETON ISLAND, NOVA SCOTIA

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The Jubilee zinc-lead deposit (lat. 45° 49′ N, long. 60° 57′30" W) occurs near Little Narrows on Cape Breton Island. Over an intermittent exploration history of 50 years, 2 adits, 115 drillholes (total length drilled from 1974 to 1979 of 12,131.9 metres) have outlined at least 500,000 tonnes in excess of 6% Zinc and lead mineralization that occur in limestone, particularly where it is brecciated. The limestone breccia is better developed and thicker in a narrow zone parallel to the Jubilee Fault.

Twenty-six cores were examined in detail in this study and the main lithologies include in ascending order green and red conglomerates, limestone, limestone breccia, interbedded limestone and evaporite, and capped by a thick evaporite. The enhanced carbonate section is adequately accounted for by deposition on the downthrown side of growth faults which were active during deposition of the Windsor, and possibly upper Horton groups.

It is proposed that fluids venting at points along the growth faults provided nutrient loci to localize thicker accumulation of biogenic carbonate. As carbonate deposition continued, positions along the growth faults were continued sites of preferred carbonate production and synchronous and/or later brecciation through both mechanical granulation and dissolution by venting fluids. Liquid hydrocarbon migration occurred at least in part after brecciation to fill porosity (and possibly as methane early in the history which provided nutrients for the carbonate forming biota). Mineralizing fluids deposited sphalerite and galena followed by barite and calcite into hydrocarbon-filled porosity. After initial carbonate sedimentation and subsequent growth fault activation, the deposit is a site of not only focussed flow from below along the growth fault itself, but discharge of fluids from the Horton aquifer along the faces of the growth fault.

The growth fault setting over thick Horton clastic sub-Windsor basement opens much more of the Horton/Windsor surface for potential mineralization. If the same structural and sedimentological setting that is responsible for the localization of sedimentary exhalative vent fluids can assist in providing localization of benthic carbonate-producing vent biology, the identification of this sedimentological environment is fundamental in successful exploration for deposits of this type.

INTRODUCTION

General Statement

The Jubilee zinc-lead deposit (lat. 45° 49' N, long. 60° 57'30" W) occurs near Little Narrows, on the Iona Peninsula, Cape Breton Island (Enclosure 1, in pocket).

The maps accompanying this report (Enclosures 1-3, 6-10) are on various scales, including: regional geology map (1:20,000); index map to drillholes (1:10,000); detailed index map to drillholes and geology in area of original showings, detailed geological map, isopach maps and structure map (1:5,000). Detailed logs of drillholes are drawn according to metric scales shown with the logs (Enclosures 4 and 5). The schematic sections drawn of the logs show the major lithologic, thickness and facies variations as observed in the drill core. The footages indicated along the sections indicate the footage tags (in feet) encountered in the drill core during logging. No adjustment has been made on the log sections for expanded core or apparent enhanced section encountered when bedding is at high angles to the drill core.

This study commenced November 1987 and continued until May 1988. The investigation was prompted by a need for a summary of the geologic features of this deposit, taking into account the economic information and post-1977 drill data to allow the Jubilee deposit to become part of the suite of mineral deposits in the Windsor Group whose features must be considered when assessing the Windsor as an exploration target. It was hoped that detailed geological information could be obtained and summarized that would be useful in the search for new orebodies in the Windsor Group.

For this report all measurements are used as reported. Conversions are provided to metric where necessary to compare units in the context of the immediate discussion only. We deem this necessary at this stage to reduce error of conversion in the documentation process.

Acknowledgements

The authors would like to particularly thank Dr. Don F. Sangster of the Geological Survey of Canada (Ottawa), the project's Scientific Authority. His interest and comments throughout the compilation were most welcome and encouraging.

In a project such as this where earlier data are essential one must depend upon a variety of colleagues. In this case we would particularly like to recognise the essential cooperation of Mr Fred J. Johnson, Vice President of Canamax Resources Inc. (Toronto). The release of Canamax's detailed reports and maps has proven most useful. To this end Mr Greg P. Isenor, now of Seabright Resources Inc. (Sackville, NS), a former Amax (Canamax) geologist, has been most cooperative and helpful.

We also received assistance in locating un-archived reports from Tony Barrett of Aurion Minerals Inc. (Halifax), Don Hattie of Geosleuth Ltd. (Sackville, NB), Bob Boehner of the Nova Scotia Department of Mines and Energy (Halifax), and Pat G. McMahon of the same department. Valerie Brisco and Barb DeLory of the Nova Scotia Department of Mines and Energy library and the staff of the claims registry assisted in sorting out the early history of the Jubilee properties. Terry Davis and Gerald Wilson of the Little Narrows Gypsum Company located a missing core.

Colleagues Marcos Zentilli and Casey Ravenhurst (Dalhousie University, Halifax), Sam Akande (University of Ilorin, Nigeria), and Al Sangster (GSC, Ottawa) also contributed to conversations on the mineralization in the Carboniferous of Nova Scotia

Francis Kelly assisted in the draughting and Gerry Hickman and Darlene Van de Rijt contributed to the word processing.

Jim Langille of the Nova Scotia Department of Mines and Energy Core Storage Facility in Stellarton provided informed and enthusiastic cooperation during the core logging phase of this project.

Jack Colwell of the Geology Department of Acadia University provided access and Nancy Van Wagoner provided photomicrographic facilities for the study of the extensive thin section collection of E.B. Stewart.

BACKGROUND AND PREVIOUS WORK

History of the Deposit

While there is a sometimes-repeated assumption that the French at Louisbourg used the Jubilee deposit as a source of lead for cannon balls (Greg Isenor, Seabright Resources Inc., personal communication, April 28, 1988) no documentation could be found to confirm this suggestion. The Fortress of Louisbourg is unaware of any evidence to support the suggestion:

> A 1965 historical report produced for the Fortress of Louisbourg identified a number of mines and quarries which the French operated on Cape Breton Island between 1713 and 1758. Among the materials extracted were freestone, flatstone, rubblestone, slate, gypsum, limestone and coal. Rumours concerning French gold and silver mines would surface after the final defeat of 1758, but such stories remain unsubstantiated.
>
> As for your query whether the French ever extracted lead or lead-zinc for cannon balls, evidence of such deposits or activities is non-existent. Personally, I doubt whether the myth or rumour, to which you refer, has any foundation, though I would be interested to learn the source... (Letter of May 26, 1988 from Eric Krause, Historical Records Supervisor, Fortress of Louisbourg, file 8400-100).

Indeed Hugh Fletcher of the Geological and Natural History Survey of Canada first mapped in the area beginning circa 1876 through to circa 1884. His map shows the same basic roads traversing the Jubilee deposit area (Fletcher, 1884a) as does today's topographic map. Fletcher shows numerous areas of gypsum on his map and clearly walked all the streams and roads; he shows some structure but does not show any specific outcrop areas of limestone or of the Horton conglomerate in the interior area around the now-known lead-zinc showings. Fletcher's map of 1884 shows no lead-zinc showings and, the only mineral occurrence of note is 'boulders of iron ore' shown north of the mouth of Mackinnon Harbour (north of Ottawa Brook) well south of the Jubilee area (Enclosure 1). Fletcher's reports of progress of 1876-77 and of 1882-84 report only gypsum mineralization in the area (p. 442; Fletcher, 1878; pp. 49H-50H; Fletcher, 1884b) and oysters "on the low gravelly flats about Portage Creek [and] St. Patrick's Channel" (p. 83H)!

In 1928 the Nova Scotia Department of Public Works and Mines published a 43-page pamphlet on, "Lead and Zinc in Nova Scotia". Again there is no mention whatsoever of an occurrence at the Jubilee - Little Narrows area (Messervey, 1928). The table of "Occurrences of Lead and Zinc in N.S." lists for the counties of Cape Breton Island no deposits in Victoria County, four deposits in Cape Breton County, six in Inverness County, and one in Richmond County. We have found no evidence of the Jubilee zinc-lead deposit being known prior to 1928.

An Amax Resources Inc. memo on "Mineral Rights - History of Activity" suggests that a Murdock McLeod, "reported high grade galena mineralization at Jubilee in a limestone of the Windsor group" in the "1920's" (Clemiss (?), 1978). Again we cannot substantiate this date. A December 2, 1935 memo of an October 28, 1935 visit to the property by a Nova Scotia Department of Public Works and Mines person (Anonymous, 1935) suggests that Murdock A. McLeod's first involvement was simply "several years ago at Jubilee, Victoria County". McLeod did no work on the lease he took out "covering the district" and he, "later forfeited [it] to Miss Christena Ackers for non-performance of work (Anonymous, 1935). She too lost the property for the same reason in 1934 and Murdock A. McLeod "obtained a License to Search on the property on July 22, 1935" (Anonymous, 1935). The October 28, 1935 report simply notes that the 1935 program consisted of test pits and trenching to test the depth of overburden and to trace the ore body, and notes that, "Work will be carried out next summer on the vein by means of tunnels, two of which have already been started in previous years." (Anonymous, 1935). No further report of this work is found in the Nova Scotia Department of Mines and Energy Assessment files.

The 1935 Annual Report of the Nova Scotia Department of Public Works and Mines does not report the visit to the Jubilee Lead Prospect but does report (p. 125) that, "The Victoria Gypsum Company commenced operations at Little Narrows, Victoria County during the past summer" (Anonymous, 1936). The Annual Report of the next year contains a more detailed report (pp. 166-169) and has a 5-page photo section between pp. 168 and 169 (Anonymous, 1937). It is clear that exploration and development work to prepare for the summer 1935 opening had gone on over several years previous to 1935. It is probably safe to deduce that it was during this significant period of geological work that Murdock A. McLeod or others discovered the original mineral showing southwest of Green Pond (Enclosure 2).

The two adits which were started prior to 1935 were further examined by J.P. Labaw of Norwood, New Jersey in early 1937 and described in a report on the "Gilmac Mine" apparently owned by a Gilbert D. Hedden of Chester, Nova Scotia. Labaw reported quite rich values of lead and zinc from five samples taken in the 150-foot long northernmost tunnel and from an open surface cut above the tunnel (Labaw, 1937). Labaw noted: "Wages are low compared with U.S." and "... All this points to low costs, and good profits. For that reason I would recommend drilling with a diamond drill to prove the extent, and grade in depth of the deposit." He recommended at least three holes.

The owners got a second opinion locally from Professor G.F. Murphy of the Nova Scotia Technical College. He positioned the first hole on his first visit, surveyed it in on his second visit and positioned a second hole. He met the man who drove the 150-foot long tunnel who reported that the tunnel, "had no rock whatever on [its] east wall for the total (?) length of the tunnel and that the tunnel ended in loose ground", implying that this tunnel ran almost along the bedrock surface (?) (Murphy, 1937).

Murphy eventually positioned four holes. He was not impressed with the results and recommended to Mr. Gilbert D. Hedden, on August 9, 1937 after the fourth hole was done, "to discontinue the drilling. I am convinced that the occurrence of ore at the tunnel site is an isolated patch". Mr. Hedden apparently did so and no record of work is found for almost a decade until 1946.

A group of "Cape Breton business and professional men calling itself the Maple Leaf Mining and Development Company Limited" did some trenching in 1946. A consulting geologist, Donald J. MacNeil, visited the site of the 1946 activities and wrote a brief report on October 25, 1946. He recommended up to three proposed drill holes in this report (MacNeil, 1946). In May of 1947 he approached Professor G.F. Murphy at the Nova Scotia Technical College to ascertain the positions of the earlier holes (MacNeil, 1947a); it is believed he located this information since there are some secondary entries on his October 27, 1947 map showing what are believed to be the four 1937 Gilmac Mines holes (MacNeil, 1947c).

Four holes were drilled by the Maple Leaf Mining and Development Company Limited in 1947. MacNeil reported on these in late 1947 (MacNeil, 1947 b;c). He identified the lead-zinc mineralization as being associated with a seven-foot thick Windsor Limestone bed along a fault zone which he initially believed to be, of "no displacement". He later concluded that the fault was a reverse fault dipping to the south with a displacement of "about 35 feet". He assumed the strike of the fault to be, "about 60° east of south magnetic".

MacNeil (1947b) recommended a geophysical program to delineate the fault and a diamond drilling program along the fault to define the mineralized zone. The Cape Breton investors did not proceed with the proposed program.

The trenching field work of the Maple Leaf Mining and Development Company Ltd. was reported in the Nova Scotia Department of Mines Annual Reports of 1946 (p. 65) and 1947 (p. 55) (Anonymous, 1947a, 1948). The 1946 report also contained (p. 59) and index topographic map of the trenching sites and results east and south of Green Pond at a scale of approximately 1:4266. This map also shows one of the tunnel entrances south of the west end of Green Pond (Anonymous, 1947b).

The 1948 Annual Report of the Nova Scotia Department of Mines reports (p. 59) that, "A programme of diamond drilling was carried out by the Department on the property of Maple Leaf Mining and Development Company Limited, in the Jubilee area, near Little Narrows, Victoria County." (Anonymous, 1949a). This note implies that the Department of Mines ran an additional set of diamond drillholes in 1948 after the four supervised by Donald J. MacNeil were completed in 1947 (MacNeil, 1947a; b; c).

None of the other subsequent programs or reports on this property seem to have noted these eight holes by the Nova Scotia Department of Mines or else have confused them with the four 1947 Maple Leaf Mining and Development Company Ltd. holes. The Amax reports do not note the holes (eg. Clemiss(?), 1978). Even the Nova Scotia Department of Mines and Energy Mineral Occurrence Data Card prepared by Bisson (1977) and updated by White-Smith (1982) notes only p. 59 of the 1948 Annual Report on Mines. In fact Nova Scotia Department of Mines and Energy drilled eight short holes (up to 155 feet in length) between October 2 and December 10, 1948 on claim O of Tract 87 at Jubilee; Nova Scotia Department of Mines and Energy Record Nos. 1457 to 1464 inclusive record the results (Anonymous, 1949b, pp. 103-105). The published logs note mineralization in at least two of the eight holes. This project has not re-examined these cores, if they survive; we too did not realize that they were run until very late in the project.

It appears that no one has ever made a careful and accurate compiled composite of the original two adits, the four Gilbert Hedden drillholes, the four Maple Leaf Mining and Development Company Ltd. drillholes, the eight Nova Scotia Department of Mines and Energy drillholes, the two McIntyre Porcupine Mines drillholes and the relevant trenching and sampling on an accurate map of the topography and geographic features such as Green Pond and the various brooks. Certainly, this has never been combined with the later drillholes in the area of the original showings. This project has not done the job either mainly because it was not realized until very late in the project that such a compilation was even possible from the available data. It is a job that can and should be done.

The apparent domal structure defined by the somewhat circular outcrop area of the Horton conglomerate and the fact that oil seeps had been identified in the Horton elsewhere in Cape Breton combined to encourage the Little Narrows Petroleum

Company to drill three holes in the Jubilee area in 1946-1948. Both were spudded in the limestone close to the Horton/Windsor contact and all passed quickly into the Horton conglomerate. The first hole at the Little Narrows No. 1 site in the south of the area to the northeast of Cains Mountain (Enclosure 2), was terminated early at 327 feet; another hole was rum at this site just three feet south of the first attempt and this hole was drilled to 1614 feet; it was a dry hole with only one petroleum show reported at 297 feet (and at 272 feet in the first attempt). There was no zinc-lead mineralization specifically reported in the wells (Anonymous, 1948; p. 77). A second hole was spudded as Little Narrows No. 2 in 1947, 83 feet east of the schoolhouse just southeast of the then-known lead-zinc deposit; MacNeil (1947c) described it as a "geological test hole" on his map. It too was a dry hole with a 2004 foot total depth; oil shows or staining were reported at 250, 421-422, and 511-512 feet, but no zinc-lead mineralization was specifically reported (Anonymous, 1949a; p. 100).

These two locations (No. 1 and No. 2) are shown on Enclosures 2 and 3 and slightly revised absolute geographic co-ordinates have been scaled from the 1:5,000 index map (Enclosure 3); these holes were never surveyed in as far as we know:

Little Narrows No. 1 (2 holes)

$45_{0}58'26.0"\pm0.5"$	North latitude
$60_{0}56'48.0"\pm0.75"$	West longitude
327 feet (99.7 metres)	Total depth, first hole
1614 feet (492.0 metres)	Total depth, second hole
not known	Elevation of rotary table
P-68 (NSDME Record No. 1235)	

P-69 (NSDME Record No. 1236)

Little Narrows No. 2 (one hole)

$45_{o}58'58.3''\pm0.5''$	North latitude
$60_{o}56'43.5''\pm0.75''$	West longitude
2004 feet (492.0 metres)	Total depth, first hole
not known	Elevation of rotary table
P-70 (NSDME Record No. 1452)	

The surface casing of the Little Narrows No. 2 well was still known to protrude from the ground in 1979 (Greg Isenor, Seabright Resources Inc, personal communication, April 15, 1988). No core or cuttings are known to have survived from these three holes.

The logs of these three petroleum holes are recorded in the Department of Mines' Annual Reports of 1947 (Anonymous, 1948) as N.S.D.M.E. Drilling Record Nos. 1235 and 1236 on page 77 and in the Annual Report of 1948 (Anonymous, 1949a) as N.S.D.M.E. Drilling Record No. 1452 on p 100. MacNeil (1948) reports on the Little Narrows Petroleum Company's activities. Sigma resources Inc. (1981) most recently held these petroleum licenses. McMahon et al. (1986) have compiled all petroleum holes in the Province of Nova Scotia into one volume; the Little Narrows Petroleum Company holes appear as Well Identifiers P-68, P-69 and P-70 on pages 86-88. McMahon et al. also listed the 1975-1978 Texasgulf-Amax drillholes, which had oil staining in this same report (pp. 135-172 inclusive).

While Donald J. MacNeil's original client for the zinc-lead deposit did not take up his suggestion to do geophysical surveys, he did get a chance to do resistivity surveys in 1950 for the

Victoria Gypsum Company Limited. These lines were centered to the north of the zinc-lead deposit (MacNeil, 1950). This was the first geophysics in the area.

In 1954, L.J. Weeks wrote his Geological Survey of Canada Memoir on the geology of Southeast Cape Breton Island. He visited the Jubilee prospect and reported on it briefly (p. 105). He suggested further surface work to locate a "major structure to give an entry to mineralizing solutions". Weeks reported chalcopyrite for the first time at Jubilee and reported that, "A gossan of limonite and malachite covers most of the massive sulphide nodules". He cited the shear zone as striking 160_o.

Apparently, in 1953, McPhar Geophysics Limited did geochemical work on the property (Watson, 1954); we know this mainly from the report submitted by Derek Johnston in 1972. He states:

> In 1953 McPhar Geophysics conducted a geochemical survey over the areas of Claims N, O and P on a 100 X 200 foot grid, and over Claims B, C, D, E, F, G, K, L and M on a 100 X 400 foot grid. Two anomalies resulted: a) one in Claim P with a maximum value of 5,000 ppm lead and 10,000 ppm zinc downslope from a scrap dump and from an old adit; b) another with values of 10,000 ppm lead and 30,000 ppm zinc, was located near a, "galena mineralized limestone" outcrop on the boundary of Claim F and C, with lesser anomalies extending eastward into Claim B. There is no evidence (no report was filed) of the analytical method employed by McPhar. (Johnston, 1972, pp. 1-2).

The McPhar map is all that the Nova Scotia Department of Mines and Energy has on file for this project (Watson, 1954). In another company's assessment report in later years the McPhar work was cited as being for the Mineral Exploration Corporation

Ltd. (Minex Ltd.). Derek Johnston of the Nova Scotia Department of Mines and Energy has recalled that they were active in the Province at that time (personal communication, May 30, 1988).

In 1963, McIntyre Porcupine Mines Limited took an interest in the property. They hired Scope Mining and Exploration Consultants Limited to cut a 300 foot grid over the original showing on Claims N, O and P on the north half of Tract 87 and to run a gravity program. The gravity was reported on in July, 1963 (Fountain, 1963) and maps of the geology and geochemical programs are found in the Nova Scotia Department of Mines and Energy files dated November, 1963 (Anonymous, 1963a; b). The geochemical program was run on a 100 foot grid and produced a more restricted Zn-Pb anomaly and one of lower amplitude than the 1953 McPhar anomaly. The gravity produced no significant anomalies.

Johnston (1972, p. 2) reports for the McIntyre Porcupine work that, "Two diamond drillholes were put down (logs, sections and plan not filed); one near the westernmost adit and another 400 ft along strike to the east. No work was conducted upon the southern half of Tract 87". the "McIntyre Grid" was shown on various of the later Texasgulf-Amax joint venture maps and we have incorporated it on the 1:5,000 detailed index map to drillholes (Enclosure 3).

It was in 1963 that Lionel A. York first staked the Jubilee showing in Tract 87. He has held an interest in the tract ever since. It was converted to Development License No. 0036 in the name of Texasgulf Canada Ltd. on July 22, 1976 and was subsequently transferred to Mr. Lionel A. York on February 4, 1987.

Little work was done on the Jubilee prospect from 1963 to 1972 when Derek Johnston (1972) reported on a geological and geochemical program done for Getty Mining Northeast Ltd. who had optioned the land from Lionel A. York. Getty had work done on the southern part of Tract 87. A grid of lines at 400-foot intervals was cut and a geological, geochemical, and IP program was run. Johnston reported three lead-zinc anomalies were defined, coinciding with the earlier McPhar work though varying in maximum amplitude. The IP work defined two conducting zones, one definite and one probable, both of which coincided with soil anomalies (Gledhill, 1963).

Two holes were drilled (J-1 and J-2) in late 1972. Getty Mining Northeast Ltd. did further work in 1973. We show the "Getty Grid" and these two holes on our detailed index maps of Enclosures 2 and 3. The 1972 drilling and 1973 Getty work were reported on by J.G. Bryant (1974). In the meantime, Amax Potash Ltd. was becoming interested in the area and commissioned a geological report by G. Lauzier (1973).

In September and October, 1973 Amax of Canada Limited acquired some 48 square miles of lands around the holdings of Getty Mining Northeast Ltd. This was highgraded down to some 13 square miles by the first anniversary date in 1974. Getty Mining Northeast Ltd. and Amax carried out three joint venture holes along their common boundary in the south of the area in June

1974. These three holes IR-1-74, IR-2-74, and IR-3-74 are reported in drill logs found in Assessment File 11F/15C, 27-Q-09(09); AMAX Exploration Inc. was the operator for the drilling program (1974). One will find the property referred to as "Iona Rear" rather than "Jubilee" in a number of the earlier Amax-Texasgulf reports, hence the Amax-Getty joint venture holes are prefixed by IR for Iona Rear. The prefix TG is for Texasgulf and the common prefix ATG seen on drill logs and maps stands for the Amax/Texasgulf joint venture.

On August 2, 1974 Ecstall Mining Limited (shortly to become Texasgulf Canada Ltd.) optioned the Lionel A. York property (Tract 87). They proceeded to plan and carry out a systematic diamond drilling program. In 1975, seventeen drillholes were run using a Nova Scotia Department of Mines drilling rig (Graham, 1975; 1976; MacDougall and Grimm, 1976). On July 31, 1975 Amax staked lands formerly held by Getty Mining Northeast Ltd. to totally surround the Lionel A. York 16-claim block optioned to Texasgulf Canada Ltd. Amax of Canada Ltd. ran some five miles of IP surveys outside of Tract 87 in 1975 (Roth and LeBel, 1975).

On March 19, 1976 Amax Exploration Inc and Texasgulf Canada Ltd. entered into a joint venture 50/50 agreement which pooled 121 claims held by Amax and the 16-claim Lionel A. York property held under option by Texasgulf Canada Ltd. the joint venture was at times referred as the "Texam Joint Venture". On July 22, 1976 Tract 87 was converted to Development License No. 0036 held by Texasgulf Canada Ltd. (Enclosure 1).

Further diamond drillholes were drilled by the joint venture with Amax Exploration Inc. as the operator in each of 1976, 1977, 1978, and 1979. These results and various Assessment Reports (eg. Clemiss, 1978; Isenor, 1977; 1978; 1979; Graham, 1975; 1976; 1977) are discussed in the main report. The last drillholes put down by the joint venture were early in 1979. On August 17, 1979 eighty claims were consolidated into Development License No. 0066 was transferred on March 10, 1983 to 121991 Canada Limited and on the same date was transferred from 121991 Canada Ltd. to Canamax Resources Inc., a Canadian subsidiary company created by Amax. Canamax still holds Development License 0066 (Enclosure 1); Development License 0036 was transferred from Texasgulf Canada Ltd. back to Lionel A. York on February 4, 1987 and is still held by him (Enclosure 1).

In 1977, a second IP/resistivity survey was run by the joint venture (Roth and LeBel, 1977). A downhole IP experiment was performed and logs prepared in 1977 (Gaucher, 1977). Some additional geochemistry was run by the Amax-Texasgulf joint venture (Clemiss, 1978f); our 1:5,000 index map shows the Amax grid in the northwest (Enclosure 3). In 1978, G.W. Felderhof mentioned barite (and "thick black bitumen") in a hand sample of galena, sphalerite, and minor limestone (pp. 452-453; sample F15-5005 in Appendix III). Stewart (1978) prepared an M.Sc. thesis at Acadia University on the Jubilee deposit. Stewart's extensive thin section collection from 1975 and 1976 drilling is still available for study at the Department of Geology at Acadia

University, Wolfville, Nova Scotia and was studied in this study (Figures 5 through 14). Earlier Holleman had prepared a B.Sc. (1974) and an M.Sc. (1976) thesis on the evaporites of the area.

R.A. Fergus Graham was the site geologist for the 1975 Texasgulf drilling. Greg P. Isenor was the site geologist during the 1976-1979 drilling. Further drilling was recommended in a 1979 report by Graham, but the suggestion was not taken up by the partners in the joint venture. The Jubilee zinc-lead deposit has been inactive since the drilling in 1979.

To date, excluding the early holes, 3 holes of 1386 feet were drilled by the Amax-Getty joint venture in 1974, 17 holes of 2117 feet were drilled by Texasgulf Canada Ltd. on Tract 87 in 1975 and the joint venture of Amax and Texasgulf (Texam) drilled 72 holes of 36,299.8 feet and accumulated and reported some $356,521 of exploration expenditure credits from 1976 to the end of 1979.

Exploration at the Jubilee Zn-Pb Deposit

Operator	Activity
Murdock A. McLeod (et al. ?)	2 adits; circa 1933-34
Gilbert D. Hedden, Gilmac Mine	4 holes; 1937
Maple Leaf Mining and Development Co.	4 holes; 1947
Nova Scotia Department of Mines	8 holes; 1948
Little Narrows Petroleum Co.	3 holes; 1946-48
McIntyre Porcupine Mines Ltd.	2 holes; 1963
Getty Mining Northeast Ltd.	2 holes; 1972
Amax/Getty joint venture	3 holes; 1974
Texasgulf Canada Ltd.	17 holes; 1975
Texam Joint Venture	72 holes; 1976-79
Total	2 adits; 115 drillholes
Total length drilled from 1974 to 1979:	39,802.8 feet
	12,131.9 metres

The Victoria Gypsum Company which changed its name to the Little Narrows Gypsum Company Limited at midnight on December 13, 1954 commenced operations in 1935. The firm then converted their holdings to a 20-year lease in 1982. Lease No. 82-1 was granted to Little Narrows Gypsum Company Limited for gypsum and anhydrite on July 8, 1982 for the following claims on reference map 11F/15C:

Tract	Claims
104	LMNO
105	CDEF GHJ
106	ABCD EFGH KLM
107	AHJ

The gypsum company has carried out extensive drilling and has operated continuously for 53 years. However, apparently none of their drilling has been deep drilling through the evaporite deposits into the underlying limestone and conglomerate.

Stratigraphy

The Jubilee zinc-lead deposit (Latitude 45° 49′ N; Longitude 60° 57′30" W) is located near the village of Little Narrows, on the Iona Peninsula, Cape Breton Island (Enclosure 1, in pocket). In this area Mississippian (Visean) rocks unconformably overlie Devonian intrusive rocks (Bell,1929). These Mississippian rocks consist of the lower Horton Group, comprised mainly of 'continental' sandstones, siltstones, and conglomerates; and the upper Windsor Group, consisting of predominantly marine evaporites and carbonates (Isenor et al., 1980).

A survey of the literature shows that the upper contact of the Horton with the Windsor is not clearly understood in the study area. Stewart (1978) stated that the Horton Group is conformably overlain by the Windsor Group (Table 1), whereas more recently Isenor, et al. (1980) indicate that this is a disconformable relationship. Elsewhere in the Maritimes this contact has been interpreted as being conformable (Weeks,1948; Kelley,1967; Belt,1968), disconformable (Cameron,1948; Bell,1960; Benson,1974; Geldsetzer,1977), and regionally unconformable (Smith and Collins, 1979) (Figure 1).

Similarly, there is uncertainty regarding the lithologic distinctions between the Horton and Windsor groups. In Cape Breton Island, the Windsor Group differs from the type section (Windsor, Nova Scotia, Dawson, 1873, redefined by Bell, 1944, see Williams et al., 1985) in that there is a lower conglomeratic unit, the Grantmire Formation, at its base (Stewart,1978, Table 1). This unit was originally mapped by Bell (1938) to designate the basal conglomerate member of the Windsor Group below lower Windsor limestone or sandstone in the Sydney coalfield. Later, Weeks (1954) redefined the Grantmire Formation as including all the Windsor conglomerates that form the base of the group, regardless of lower or upper Windsor age. Geldsetzer (1977) recognized two major carbonate facies within the Windsor Group - an eastern fossiliferous carbonate, and a western stromatolitic laminated limestone. He concluded that deposition of the Grantmire Formation was completed prior to deposition of the basal Windsor carbonates. Most recently, Smith and Collins (1979) consider that most units described as 'Grantmire

Formation' are, in fact, equivalent to the lowermost Horton Group and not basal Windsor units.

Smith and Collins (1979) have also documented another unconformity within selected sections of the Lower Windsor Group of Cape Breton Island and central Nova Scotia. This unconformity is underlain by either basal Windsor limestones (Macumber Formation) (Table 1, Figure 1) or Pembroke Formation karstic breccias. Massive evaporites then accumulated above the unconformity. The Lower Windsor units and associated unconformities are thought to be widespread, with regional consistency during the Late Mississippian. They found that copper mineralization was associated with the Horton-Windsor contact, with copper being mobilized during weathering of the Horton and fixed as sulphides by the presence of organic matter, either near the top of the palaeosol or in the overlying carbonates during the earliest phases of the Windsor transgression. Post-Mississippian thrust faulting caused repetition of Horton and Lower Windsor units. Rocks mapped as "Uist Formation" in Cape Breton are thrust-fault repetitions of Horton Group sediments (Smith and Collins, 1979) (Figure 1).

The most recent work is Hamblin's (1988) study of the sedimentology, tectonic control and resource potential of the Horton Group, Cape Breton Island. In this study more than 11,000 m of Horton strata were measured in outcrops focused in the Mabou/Lake Ainslie/Baddeck areas of western Cape Breton Island (lat. 45^{o} 45' to 46^{o} 30' N, long. 60^{o} 30' to 61^{o} 30' W) (Figure

2A). Hamblin (1988) found that the general stratigraphic scheme proposed by previous workers (Norman, 1935; Bell, 1958; Murray, 1960; Kelley, 1967) is recognized in most outcrop sections, with the stratigraphy of Cape Breton Island subdivided into four units (Table 1):

a) Fisset Brook Formation ("pre-Horton"): unconformably overlying Acadian basement with localized distribution over basement blocks; up to 500 metres thick, consisting of basic to felsic volcanic rocks with interbedded red sediment; gradational contact with overlying Craignish Formation.

b) Craignish Formation ("lower" Horton): locally conformably overlying Fisset Brook Formation, or more commonly unconformably overlying Acadian basement; up to 1500 metres thick, consisting of a fining-upward sequence of conglomerate and sandstone (Graham River Member) --> sandstone and siltstone (Skye River Member) --> siltstone and sandstone (Macleod Member); thickest toward the western basin centre, thinnest toward the eastern basin margin (Figure 2B).

c) Strathlorne Formation ("middle" Horton): sharp but conformable base with underlying Craignish Formation; up to 300 metres thick, comprising grey, laminated siltstone or mudstone, with thin sandstone and limestone interbeds; thickest toward the western basin centre, thinnest towards the east (Figure 2B); conformable and gradational contact with overlying Ainslie Formation.

d) Ainslie Formation ("upper" Horton): conformable and gradational lower contact with the underlying Strathlorne Formation; up to 700 metres thick, consisting of grey and red sandstone, siltstone and conglomerate, arranged in a fining-upward sequence of conglomerate, sandstone and siltstone (McIsaac Point Member) --> siltstone and sandstone (Glencoe Member); top is sharp and disconformable with the overlying Macumber Formation of the Windsor Group.

Toward the basin centre near Mabou River (Figure 2B) the Horton attains a composite thickness of 2700 metres, which thins to 1000 metres near the eastern margin of the basin near Baddeck River (Figs. 2A, 2B). The Craignish - Strathlorne - Ainslie subdivisions ("Horton megafacies") maintain their identity across the basin, although they are interpreted as being a result of diachronous deposition in fault-bounded basins (Hamblin, 1988).

Sedimentary Environments and Facies

A preliminary review of the available recent literature (Stewart, 1978; Isenor, et al., 1980; Amax, 1977a; b; c; Bryant, 1974; Clemiss, 1978; Gaucher, 1977; Isenor, 1976; Roth and LeBel, 1977) shows that the sedimentary facies in the Jubilee area can be summarized into a general sequence as follows:

a. conglomerate/siltstone/calcareous clay,

b. thickly laminated, grey to black micritic limestone, with oncolitic and/or pelletal textures,

c. laminated, algal stromatolitic micrite, and

d. thick evaporites.

These trends have been interpreted by others (Geldsetzer,1978; Stewart,1978) as representing (a) high to low energy, freshwater to brackish deposition followed by (b) deep, low energy, subtidal deposition to high energy events followed by (c) intertidal/supertidal deposition, ending with (d) deep, low energy, basinal deposition. More recent stratigraphic and sedimentologic work in Cape Breton and in Newfoundland on equivalent facies give different interpretations.

Hamblin (1988) in his detailed work on the clastic units of the Horton Group in Cape Breton Island, interpreted the "lower" Horton Craignish coarse clastics as alluvial fan, braidplain; the "middle" Horton Strathlorne fine clastics and limestones as lacustrine (?); and the "upper" Horton Ainslie of coarse to fine clastics as fluvial (?) (Figure 2B).

Schenk (1967) originally interpreted the Macumber Formation as a Mississippian analog to recent strand-line carbonates of the Persian Gulf. More recent work on the Macumber carbonates in Newfoundland (von Bitter, et al., 1988; Paul Schenk, Department of Geology, Dalhousie University, Halifax, NS, personal communication, 1988) indicate that much of the Macumber may be deep-water in origin. Hydrothermal vent communities occur in carbonate mounds of the Lower Codroy Group (Lower Carboniferous) on the Port au Port Peninsula, Newfoundland. The vent communities are preserved as calcareous fossilized tubes in association with laminated carbonates of probable microbial mat origin (von Bitter, et al., 1988). The laminated carbonates consist of laminated, peloidal shaly carbonates of the Macumber facies and are interpreted as bacterial in origin, with the peloidal and lamination textures resembling those of bacterial mats in modern vent sites. Much of the lamination texture is due to stylotization of the mat carbonates (Schenk, personal communication, 1988). The interpretation of the laminated Macumber facies as due to bacterial growth as opposed to algal in origin, eliminates the need for shallow-water (i.e. subtidal to intertidal) deposition within the photic zone for the laminated carbonates within the Macumber facies.

On a broad scale the Jubilee sequence correlates well with the lower half of Moore's (1967) section for the western Minas sub-basin and with the type section of the Macumber Formation (Weeks,1948). Superficially, the Jubilee sequence also strongly resembles selected sequences measured in detail by Smith and Collins (1979) (Figure 3). The Lower Windsor carbonate unit mapped at the Jubilee deposit, corresponds to the usual Macumber carbonate facies, consisting of carbonate laminite, which also occurs in the Walton borehole and in parts of the East Bay section (Figure 3, Smith and Collins (1979)). Differences occur in the Kaiser and Coxheath boreholes (Figure 3). In the Kaiser area, the lower Windsor is a biosparite with abundant algal-laminated oncolites; while at Coxheath the biosparite grades upward into a carbonate laminite.

The final unit of particular interest to the Jubilee area is the Pembroke Formation, a breccia comprised mainly clasts of Macumber lithologies, with a mixed matrix including calcareous sand, red mudstone, local anhydrite, with some coarse calcite filling. This breccia directly overlies the lower Macumber or locally may completely replace the Macumber Formation. Clifton (1967) and Smith and Collins (1979) interpret this breccia as a collapse breccia, formed by solution of evaporites in the interbedded upper part of the Macumber Formation during Triassic or post-Triassic time. Schenk (1969) proposed that the Pembroke was due to reworking of Macumber sediments by storm-action during the Mississippian. As pointed out by Smith and Collins (1979), if the Pembroke represents a solution collapse feature, then there should be a regional and extensive period of erosion prior to deposition of the overlying massive and thick evaporites. This implies that a major disconformity or hiatus would occur between the lower Macumber and the Pembroke breccia.

Smith and Collins (1979) propose a complicated, three-stage origin for the Pembroke breccia, with evaporite and karstic solution occurring firstly during the pre-evaporite hiatus; secondly associated with pre-Triassic erosion (as proposed by Clifton, 1967); and thirdly, beginning in the late Tertiary and continuing to the present. Clearly, the origin of the Pembroke breccia is not well understood.

Details of the Pembroke breccia are not well established in the Jubilee area. Brecciation occurs on all scales from a few centimetres to several metres (Stewart, 1978; Isenor et al., 1979; Amax, 1977a; b; c; Bryant, 1974; Clemiss, 1978; Gaucher, 1977; Isenor, 1976; and Roth and LeBel, 1977). Generally, units have not been described specifically as the Pembroke breccia, and the type of brecciation has not been well noted on the available logs. This unit is of particular interest because much of the mineralization occurs as void infilling of the breccia, or as massive replacement of breccia clasts. The development of the breccias with respect to sedimentary facies, pre-existing topographic features on the pre-Windsor landscape, and relationship to faulting in the area has yet to be documented.

PURPOSE AND METHODS

Purpose

The purpose of this study is five-fold:

1. To synthesize the existing data regarding the geology of the Jubilee deposit.
2. To describe and interpret the facies observed in drill-core, to outline their distribution and geometry in the Jubilee area, and to relate the distribution of facies to major structural features in the area.
3. To ascertain the timing, distribution and origin of the Pembroke Breccia with respect to development of other sedimentary facies, and possible unconformities and disconformities within the Windsor Group.
4. To outline the nature of the contact between the Windsor and the Horton Group in the study area, and the effect of this contact on facies distributions, subsequent faulting, and mineralization.
5. To determine the relationship of mineralization to sedimentary facies patterns and the timing of mineralization with respect to diagenetic and epigenetic history of the sediments.

Methods

In order to address sedimentological, geologic, and mineralization problems of the Jubilee deposit, the following tasks were done. A compilation was prepared of the known surface geology and structural geology of the study area, including major sedimentary facies, mineralized zones, locations of outcrops and drill holes (Enclosures 1-3, 6).

Detailed core-logging was done of the existing core at the Stellarton core-storage facility, with particular emphasis on the sedimentary facies below the evaporite beds, the extent and type of mineralization, and any possible structural complications in the core, including possible fault-repeated section and fault gouge. Each core logged was described on a bed-by-bed basis, for beds greater than 2 centimetres in thickness. Thin interbeds (<2 cm thickness) were described as an interbedded or interlaminated lithology within the dominant rock type. In the core description the following data were recorded: rock type, bed thickness, basal bed contacts, apparent grain size as seen by eye or hand lens, primary sedimentary structures, biogenic sedimentary structures, and the type of framework -- i.e. whether clast-supported or matrix-supported. The rocks are classified into facies, defined on the basis of lithology, sedimentary and biogenic structures, the presence or absence of grading, and the presence of a matrix- versus clast-supported framework (Enclosures 4,5).

Ore mineralogy, paragenesis, and texture was noted as core was logged. Evidence for the nature and extent of any wallrock alteration was also noted. Limited sampling from drill core was done for petrography, lab mineralogy, and future geochemical analyses. Doubly-polished thin sections of several sphalerite, barite, and ore calcite samples from one core were selected for reconnaissance investigation of fluid inclusion populations. A limited number of typical sphalerite, galena, pyrite, chalcopyrite, and barite grains were analyzed with the electron microprobe at Dalhousie University to determine compositional variation.

Detailed stratigraphic cross-sections were drawn of the deposit showing the positions of all lithological units, structural units, breccias, and mineralization. Facies associations were defined, and isopach maps of these associations were drawn for the study area (Enclosures 7-9). A structure map was constructed, showing elevations of the Windsor/Horton contact and using sea level as a datum (Enclosure 10).

Vertical facies trends, recurring lithofacies patterns, and syn-depositional and post-depositional structural features in core were analyzed by Markov-chain analysis. A Markov process is one in which the probability of occurrence of a process or state depends upon the immediately preceding occurrence. Markov-chain analysis has been widely applied to the analysis of lithofacies sequences (Ethier, 1975; Cant and Walker, 1976; May and Jones,1982; Johnson, 1984) and in the analysis of structural data (Naylor and Woodcock, 1977). The applicability of this approach and the effectiveness of the various statistical computations have been extensively discussed recently (Powers and Easterling, 1982; Carr, 1982; Harper, 1984a, 1984b). In the present study, a row-scaling technique (Gingerich-Read method) was used in combination with Harper's (1984a) method of binomial probabilities. In the row-scaling technique, the random probabilities are calculated from a specific facies or state to all the other facies or states. Each facies row is calculated independent of all the others. The Gingerich-Read row-scaling method is used in conjunction with Harper's (1984a) method of binomial probabilities for testing of significance of the residuals. In this analysis the MacIntosh personal computer software has been adapted from M. Ranger's (Department of Geology, University of Alberta, Edmonton, Alberta, personal communication, 1987) numerical study of trace fossil associations from the subsurface in Alberta.

In summary, a palaeogeographic model is developed which accounts for the observed lateral and preferred vertical facies trends, as seen from the results of the isopach maps and the results of the Markov-chain analysis. The proposed palaeogeographic model presents a genetic interpretation and classification of the Jubilee deposit. Such a summary of features and characteristics could serve as a basis for exploration for deposits with similar settings.

RESULTS

General Statement

Ninety-two holes, with a cumulative depth of 39,803 feet (12,132 metres), were drilled by the joint venture of Amax and Getty Mining Northeast, by Texasgulf, and by the Texam Joint Venture on the Jubilee property (Enclosure 2). Most of these holes (about 80%) were drilled north of the Jubilee dome, outlining mineralization along the Jubilee Fault (Enclosure 6). The remainder were in peripheral areas, and along the Road Fault (Enclosures 2, 3, and 6). Of the ninety-two holes core data is available on 89 holes (Table 2a). Of these eighty-nine holes, eighty are in storage in the Nova Scotia Department of Mines Core Storage Facility, Stellarton, Nova Scotia and one core from a hole all in evaporites (ATG-42-77) was given to the Little Narrows Gypsum Company for storage. Of the eighty-one holes in storage, detailed logs were made on a bed-by-bed basis of twenty-six cores (Enclosures 4 and 5).

During the early core-logging phases of this study, the following information was not available to us: the final sections of Isenor (1978; 1979); the geologic map with the outline of the area containing greater than 3.5% Zn+Pb over at least 8 feet (subsurface) of Graham (1979); the assay results for much of the study area; the final reports of Isenor (1978; 1979) and Graham (1979);nor an accurate and detailed map of the surveyed drillholes. This information only became available to us in the final two months of the study period. Consequently, our core-logging and sampling was guided by available assay data and what we were able to see "by eye" in core at the core-storage facility. Unfortunately, our reconnaissance survey missed most of the "ore body" zone as outlined by Graham in his 1979 report (see Enclosure 6). Future work will be required to examine certain key cores now known to be in the ore zone.

Comprehensive year-end reports of the drilling operations on the Jubilee (or Iona Rear) property near Little Narrows on Cape Breton Island have been written by G. Isenor, as summaries to Amax and Texasgulf (Isenor, 1977; 1978; 1979). Isenor (1978, 1979) presents a complete tabulation of all the drill data, sections, maps, and interpretations of the geology of the property. R.A.F. Graham (1979) further reviewed the geology , mineralization and economic potential of the Jubilee deposit. The following is a summary of the geology of the region as discussed by Isenor (1978, 1979), Graham (1979), and briefly outlined in Isenor et al. (1980).

Bedrock Geology of the Jubilee Area

The oldest rocks in the Jubilee area are Devonian granitic and dioritic intrusive rocks, with minor gabbroic and dioritic dykes (Table 1 and Enclosure 1). These resistant rocks underlie upland terrain to the northwest of the study area (Stewart 1978). Unconformably overlying the Devonian intrusives are the clastic successions of the Horton Group (Bell 1929) (Table 1).

In the Jubilee area the main geologic feature is the northwesterly elongated Jubilee dome. Conglomerate is exposed in the core of this dome (Enclosures 1, 2, 3, and 6), which is disconformably overlain by thin limestone. The thin limestone is succeeded by a thin transitional unit of interbedded limestone and evaporite, which is capped by a major thick anhydrite unit. The conglomerate belongs to the Lower Carboniferous Horton Group, with the overlying limestones and evaporites belonging to the Lower Carboniferous Windsor Group (Table 1).

Extending northwestwards from the dome is a normal fault - the Jubilee Fault. A number of other faults parallel the trend of the Jubilee Fault (Enclosures 1 and 6). One of these more prominent faults is 1400 feet northeast of the Jubilee Fault (Enclosure 6) and forms the northeastern boundary of the study area. This has been called the "Road Fault" in the Texam/Amax reports. Most of the drilling has concentrated along the Jubilee Fault. There has been reconnaissance drilling over a length of 4400 feet by twenty drill holes along the Road Fault (Enclosure 6). The Road Fault has a downthrow to the northeast which increased from 30 feet at the northwest end to 550 feet in the southeast. Although not discussed by Graham (1979) or Isenor (1978; 1979), the extension of the dome into the Jubilee Fault suggests that this dome may be a horst. This is further substantiated by isopach information of dominant limestone facies as delineated by the present study and discussed later in this report.

To the northwest of the study area the structural features are not as well documented. A synclinal axis may occur along the Little Narrows channel in the Bras d'Or Lakes. Another major fault occurs parallel to the Trans-Canada Highway, at a trend perpendicular to the Jubilee Fault (Enclosure 1). This fault places the Lower Windsor succession in fault contact with the Precambrian; hence, this fault has been called the "Precambrian Basement Fault." It is thought that the Jubilee Fault does not extend north of the synclinal axis in the Little Narrows Channel. No drilling has been done in this area to the northwest. Other smaller faults parallel the trend of the Precambrian Basement Fault in the study area, i.e. orthogonal to the trend of the Jubilee and Road Faults (Enclosure 6); however their displacement is much less pronounced than that along the Jubilee and Road Faults.

Zinc and lead mineralization occur in the limestone, particularly where it is brecciated (Enclosure 6). The limestone breccia is better developed and thicker in a narrow band parallel to the Jubilee Fault (Enclosure 6). Laterally this breccia passes into the interlaminated anhydrite-limestone unit. The origin of the breccia is not well understood. Originally it was interpreted as representing talus-cone deposits from a carbonate bank that was deposited along the line of an incipient fault -- later to become the Jubilee Fault. Later (in 1979) it was thought to be a secondary deposit formed by solution of anhydrite from the transitional zone, which resulted in a "reaccumulation" of undissolved limestone fragments (Graham, 1979; Isenor, 1979). This dissolution and karstification was most pronounced in sites where the transitional interlaminated anhydrite-limestone unit was juxtaposed by faulting (as along the Jubilee Fault) against more porous conglomerates, which could carry large volumes of connate water. The highly porous reaccumulation of limestone as breccia clasts then provided a good host for later precipitation of sulphides. Similar breccias were hypothesized to be expected along any faults of similar age and involving the juxtaposition of similar lithologies.

As pointed out by Graham (1979) this model satisfactorily accounts for the breccia and shows the importance of the northwest-trending faults in the study area. However, anomalous thick laminated limestones occur beneath the limestone breccia (as will be shown in the isopach maps and cross-sections later in this report). Average thickness of the laminated unit beneath the breccia in the vicinity of the Jubilee Fault is 12.3 feet, whereas to the north of the dome the average breccia thickness decreases to 8.7 feet. The breccia unit reaches a maximum thickness of 50 feet and is usually thicker than the transitional zone (10-20 feet in areas removed from faults) from which it was thought to be derived. These features cannot be explained solely on the basis of a secondary origin for the breccia. As mentioned by Graham (1979) (and arrived at independently in the present study before Graham's report was found) these factors suggest that the Jubilee Fault (and possibly others) may have been growth faults which affected primary sedimentation in the area.

Description and Interpretation of Lithofacies

The main lithologies in the cores at Jubilee include mainly green and red conglomerates (with minor sandstones and siltstone/shale interbeds), limestone, limestone breccia, interbedded limestone and evaporite, and evaporite (see Enclosures 4 and 5). Of the clastic part of the section (i.e. the Horton Group), the conglomerate comprises about 80% of all the beds measured in this study, with finer clastic units occurring mainly as interbeds. Twenty-one lithofacies are recognized, with the major features described below (Enclosures 4 and 5). The bed-thickness and frequency variations are given in Table 3.

Facies 1 - Matrix-Supported Conglomerate. Facies 1 has a disorganized appearance, random and chaotic pebble fabrics, and a high matrix content of mudstone. Clasts tend to be angular, polymictic in composition, and are dispersed (i.e. "floating") within the finer-grained mudstone. Beds are ungraded and average 0.4 m thick (Table 3). This facies is relatively uncommon, accounting for only 5% of the thickness of the cores in which it occurs (Table 3). These sedimentary features suggest very rapid rates of deposition from sediment-laden gravelly flows, which contained large amounts of suspended sediment. Such flows may have been muddy debris flows or possibly hyperconcentrated flood flows.

Facies 2 - Ungraded and Massive Conglomerate/Pebbly Sandstone. Beds within facies 2 are very poorly sorted, clast-supported, and matrix-filled conglomerate. The matrix is sand-size. Clasts tend to be subangular to rounded and polymictic in composition. Beds are ungraded and average 0.4 m thick (Table 3). This facies is common, averaging about 20% of the thickness of the cores in which it occurs (Table 3). The lack of stratification, poor sorting, and coarse grain-size suggest very rapid rates of deposition from gravelly flows. Such flows may have been high-energy flood flows.

Facies 3, 4, and 5 - Inverse and Normally Graded-Stratified Conglomerate. Beds within facies 3,4 and 5 are very poorly sorted, clast-supported, and matrix-filled conglomerate. The matrix is sand-size. Clasts tend to be subangular to rounded and polymictic in composition. Beds show various patterns of grading, including inverse grading (facies 3), inverse-to- normal grading (facies 4), and normal grading, in some cases with stratification at the top (facies 5). Beds average between 0.46 and 0.53 m thick (Table 3). These facies are relatively uncommon, accounting for only 4-9% of the thickness of the cores in which they occur (Table 3).

The variable grading patterns, general lack of good stratification, poor sorting, and coarse grain-size suggest that these facies were deposited by sediment-gravity flows. Such sediment-gravity flows may be sandy debris flows or hyperconcentrated flood flows initiated by high seasonal runoff on unstable, weathered slopes. These flows are intermediate between viscous muddy debris flows and more fluid flood flows. Similar "intermediate" flow deposits have been reported from sediment-laden volcaniclastic flows associated with the Mt. St. Helen's eruptions (Smith, 1985, 1986) and are also common in deep-water sediments (Nardin et al., 1979; Hein, 1984).

Facies 6 - Stratified Conglomerate/ Pebbly Sandstone. Beds within facies 6 are poorly sorted to moderately sorted, clast-supported, matrix-filled conglomerate and pebbly sandstone, with crude to well-developed stratification. The matrix is sand-size. Clasts tend to be subangular to rounded and polymictic in composition. Pebble fabrics are subparallel, horizontal to slightly imbricate patterns. Beds are ungraded and average 0.5 metres thick (Table 3). This facies is relatively uncommon, averaging about 9% of the thickness of the cores in which it occurs (Table 3). In the coarser grain sizes the stratification is planar, discontinuous, and discernable through subtle changes in grain size and pebble fabrics. Discontinuous sandy interbeds also occur. As the grain sizes become finer in the conglomerate and pebbly sandstone beds, the stratification becomes better defined as clear alternations of granule/pebble sizes.

The origin of the crudely stratified conglomerate is difficult to clearly ascertain because the origin of stratification is poorly understood in gravels. Crude stratification has been reported from braid bars and from diffuse gravel sheets in proximal fluvial settings (Eynon and Walker, 1974; Hein and Walker, 1977; Smith, 1985; Southard et al., 1984). Distinct gravelly stratification suggests sedimentation under high discharge levels in fluvial settings as low relief coarse-grained bedforms, diagonal bars, or diffuse gravel sheets (Gustavson, 1974; Hein and Walker, 1977).

Facies 7 - Cross-bedded Conglomerate/Pebbly Sandstone. Cross-bedded conglomerate and pebbly sandstone of facies 7 is generally clast-supported and matrix-filled. The matrix is sand-size. Cross-bedding appears to be trough cross-bedding, defined by concave-up crossbeds which have tangentially based lower set contacts. Set thicknesses average 0.2 m thick, with multiple sets occurring in stacked units up to 1.5 m thick (Table 3). Beds within facies 7 are moderately sorted to well sorted. Clasts tend to be subangular to rounded and polymictic in composition. This facies is rare, accounting for 2% of the thickness of the cores in which they occur (Table 3).

Crossbedding in the facies 7 conglomerate indicates that the gravel was originally transported as bedload. The trough crossbedded conglomerate and pebbly sandstone is interpreted as being deposited from fields of large-scale, three-dimensional ripples or dunes (Harms, et al., 1982), which were active under high flow conditions.

Facies 8, 9, and 10 - Sandstone and Facies 11 and 12- Siltstone/Mudstone. Within the clastic sections examined in core, the finer sandstone, siltstone, and mudstone facies occur mainly as thin interbeds within predominantly conglomerate/pebbly sandstone successions. These lithologies are rare, comprising 1-4% of the thickness of cores in which they occur (Table 3). A variety of sandstone facies occur, including structureless (facies 8); stratified, with well-developed horizontal stratification (facies 9), and cross-bedded, with ripple and larger-scale trough cross-bedding (facies 10). Sandstone beds average about 0.23 metres in thickness and account for only 2-4% of the thickness of core in which these facies occur (Table 3). Siltstone/mudstone facies are burrowed (facies 11) or structureless (facies 12). Bed thicknesses average 0.12 metres for facies 11 and 0.09 metres for facies 12. These facies are rare, accounting for only 1-2% of the thickness of core in which their occurrence was noted (Table 3). Due to the rare occurrences of these finer clastic units and thin interbeds within mainly conglomerate associations, it is difficult to interpret their origins without considering the enclosing facies. Generally, the sedimentary features of these facies suggest that they were deposited under lower energy conditions, perhaps as suspension fall-out or low flow events. These may be overbank deposits. The rare coaly interbeds that occur in the succession also support this interpretation.

Facies 13, 14, 15, and 16 - Structureless, Laminated, Stromatolitic, and Pisolitic/Laminated Limestone. The base of the Windsor limestone facies association is usually laminated (facies 14); rarely a dark structureless micrite occurs at the base (facies 13). In three cores, stromatolitic limestones (facies 15) are interbedded with the laminated limestone (facies 14 (Table 3), but these occurrences are quite rare, accounting for only 4% of the thickness of core in which they occur. Stromatolites are small domal (biscuit) structures, between 10-25 centimetres thick, occurring in stacked units reaching a maximum of 0.6 metres thick. More commonly the stromatolitic limestones average 0.4 metres thick. The laminated limestone has a gradational upper contact with the pisolitic/laminated limestone (facies 16).

Units of laminated limestone average 1.2 metres thick (Table 3). This facies is common, accounting for 13% of the thickness of the cores in which it occurs (Table 3). The laminated limestone is characterized by macro- and micro-scale lamination. Lamination is defined by parallel, horizontal to subhorizontal alternating bands of light limestone separated by dark, organic-rich residue. Internally both the light and dark beds tend to be poorly sorted to very poorly sorted. Within the dark organic bands are dispersed microscopic-scale limestone intraclasts. The tops and bases of the dark bands tend to be irregular, less commonly showing stylolites. In the lower parts of the laminated limestone units, laminae are ungraded; however further upsection laminations show various patterns of grading, including inverse grading, inverse-to- normal grading and normal grading. Rare low-angle cross-lamination and ripple lamination occurs within the lighter limestone laminae of the upper units. Rare shell debris occurs in the laminite facies. In the cores examined only one shell was noted, although Isenor (1979) and Stewart (1978) indicate a more common occurrence of shelly material within this facies. The laminated limestone grades into the overlying pisolitic/laminated limestone (facies 16).

Units of pisolitic/laminated limestone average 1.1 metres in thickness (Table 3). This facies is common, accounting for 12% of the thickness of the cores in which it occurs (Table 3). The pisolitic/laminated limestone is characterized by macro- and micro-scale lamination, with abundant pisolites within the laminae. Internally the laminae tend to be poorly sorted to very poorly sorted. Lamination is defined by parallel, horizontal to subhorizontal alternating bands of light pisolitic limestone separated by dark, organic-rich residue (Figures 5 and 6). Within the dark organic bands are dispersed microscopic-scale limestone intraclasts (Figure 6). Some of the intraclasts may be polycyclic, with some of the borders showing colour-banding due to iron staining, and others micritization (Figure 6). The tops and bases of the dark bands tend to be very irregular (Figure 5), some showing stylotization. Most of the laminations are ungraded; however, crude-inverse, inverse-to-normal, and crude-normal grading occur. Rare convolute lamination occurs higher upsection within the pisolitic laminite. Grain-support is more common than matrix-support in the pisolitic/laminated units (80% versus 20%, respectively) (Figure 5). Locally matrix-supported lamination may dominate (Figure 6).

The variable grading patterns, lack of good algal microfilaments, poor sorting, and occurrence of rare cross-bedding and convolute structures suggest that the laminated and pisolitic/laminated limestones (facies 14,16) are not algal in origin. Bioturbation features are generally lacking within the limestones as are abundant shelly material. The occurrence of grading, and the lack of shallow-water features, including good bidirectional cross-bedding, wave ripplemarks, flaser structures, etc. suggest that the environments were not within wave-base. The graded portions of the laminite and pisolitic laminite resemble the types of grading patterns in resedimented carbonates in deep subtidal (Whisonant, 1987) or deep (greater than 200 metres) basinal settings (McIlreath, 1977). The carbonates are resedimented by sediment-gravity flows, including turbidity currents and lutite plumes associated with storm events or strong offshore-moving currents.

The ungraded laminite and pisolitic/laminite may have originated as microbial mats, which upon compaction and diagenesis underwent shortening and stylotization to produce the alternating dark organic residue and lighter carbonate bands. Such mats have been reported from the Macumber facies in Newfoundland (von Bitter, et al., 1988), and are interpreted as representing possible deep-water vent communities. Recent submersible dives on the Oregon subduction zone show that dense faunal populations and authigenic carbonates occur in association with venting sites of methane and hydrocarbons at water depths of greater than 2,000 metres (Kulm, et al., 1986). Other dense biological communities occur in over 3,800 metres of water depth on the Laurentian Fan. Here the communities are sustained by chemosynthetic processes operating on exposed, organic-rich sediments (Mayer, et al., in preparation). Thus, there are no depth constraints on the occurrence of such vent communities, and the laminite and pisolitic/laminite may be deep water in origin.

The rare occurrence of the stromatolites within the laminite facies need not imply shallow-water conditions. In the present study, no algal filaments were noted in thin sections from the laminite facies. Lanier (1988) has shown that stromatolitic structures can be formed in reducing environments. Micro-stromatolites formed in the early carbonate-replacive black cherts from the Transvaal Supergroup in South Africa. Here, carbonate precipitation involves anaerobic respiration by microbial populations in restricted to reducing environments. The micro-structures in the Transvaal cherts are virtually identical to those structures seen in macro-scale stromatolites in the Macumber facies. Given appropriate environmental conditions, if larger colonies could be established (on the scale of centimetres) on the seafloor, then the occurrence of such stromatolitic features need not imply deposition under oxygen-rich, shallow water conditions.

Facies 17 - Convoluted Limestone. Beds of convoluted limestone average 0.7 metres thick and range from 0.25 to 3.3 metres in thickness (Table 3). This facies is less common, accounting for 8% of the thickness of the cores in which it occurs (Table 3). Generally, the convoluted limestone units occur higher upsection, generally near the top of the pisolitic/laminite (facies 16), near the contact with the breccia (facies 18), or as limestone interbeds within the breccia (facies 18). In more extreme cases of convolution and fragmentation, the limestone has been classified as having the "breccia" texture.

The convoluted limestone shows different degrees and scales of soft-sediment deformation. The enclosing beds are unaffected by the folding. In some cases only very thin intervals are contorted (millimetre-scale); other units occupy stratigraphic intervals greater than 3 metres in thickness. In all cases, the convoluted limestone is highly contorted but the shear strength of the sediment mass was not exceeded (Figure 7). The beds maintained their coherence and did not flow. These units are interpreted as slumps. Due to the limited view seen in core, it is difficult to ascertain the timing and extent of slumping. It is most likely syn-depositional in origin.

Similar sorts of folds and convolution have been reported from deep-water carbonates in Nevada (Cook and Taylor 1977) and from the Cow Head Group in Newfoundland (Coniglio 1986). In the

Cow Head, the folds are related to subsurface creep shear zones. The creep shear zones are parallel-to-bedding and syn-sedimentary in origin. The disrupted zones are 0.2 to 0.3 metres in thickness and consist of folded and fragmented mudstones set in a marl matrix. In most cases, the deformed zones do not extend more than 200 metres along strike, and attain thicknesses up to 1 metre. Elsewhere, intrafolial drag folds are developed within otherwise undisturbed sediment. This type of subsurface creep shear zone has been reported in the modern by Hill, et al. (1982) in slope sediments of the Canadian Beaufort Sea.

Facies 18 - Brecciated Limestone. Units of brecciated limestone average 1.55 metres thick, ranging from 0.10 - 5.5 metres in thickness (Table 3). This facies is common, accounting for 11% of the thickness of the cores in which it occurs (Table 3). In the 26 cores logged in detail during the present study, 19 of the cores had some development of the limestone breccia. Generally, the brecciated limestone units occur higher upsection, generally overlying the pisolitic/laminite (facies 16), and underlying the transitional interbedded limestone and evaporite unit (facies 20).

Breccia textures develop on all scales from millimetre to decimetre scales. There appears to be a continuum in textures from slightly disrupted laminated limestone, with small microfaults and fracture infillings (Figures 8 and 9) --> larger veins and cracks which clearly isolate and separate clasts (Figure 10) --> dispersed, reoriented clasts (Figure 10) -->

dispersed, folded, fractured, infilled and offset clasts, which have a chaotic fabric (Figures 12 and 13). Generally, the development of the breccia texture is more extreme higher upsection; although in a few cases the breccia occurs at the base of the Windsor limestone, overlying the Horton clastics (Enclosures 4 and 5).

In terms of descriptive aspects, the fabric criteria generally resemble Morrow's (1982) fabric spectrum, crackle-mosaic-rubble, which reflects an increasing degree of disturbance concomitant with breccia formation, for either diagenetic or depositional breccias. Similar textures have also been reported by Park and Jones (1985, 1987) for the genesis of breccia bodies in the Devonian Keg River Formation, Wood Buffalo Park, Alberta. In the Keg River example, there are a number of breccia types, including gypsum breccia, mixed breccia, dolomite breccia and shale breccia, which are interpreted as evaporite-solution-collapse breccias. In the Jubilee examples there is a paucity of dolomite, and no evidence for a dolomitization-dedolomitization history which commonly occurs in those breccias associated with evaporite-solution. Other structural features occur within the breccia and laminite facies, which may give some bearing to the origin of the breccia.

Most of the veins within the laminite and within the breccia are at high angles to bedding (i.e. 70 - 90^{o}) or parallel to bedding (Figures 8 and 9). The veins are very thin, generally less than a millimetre, rarely up to a centimetre across. The veining rarely broke grain boundaries. Other veining higher upsection within the breccia is later stage and clearly cross-cuts breccia clasts (Figure 12). Microfaults in core are at a high angle to bedding and are usually normal faults, although rare reverse faults do occur (Figures 8 and 9). Offsets where traceable are on the millimetre to centimetre-scale. Nests of faults common occur together within the breccia, although within the lower laminite limestone they are more isolated. Small deformation bands occur within the breccia, as shown by the re-orientation of clasts on both macro- and microscopic scales (Figures 10-13). Within some of the deformation bands there appears to be some reduction of clast size by cataclasis (Figure 10). Slickensides rarely occur, and are characterized by an orientation generally parallel to bedding, and undulating, rough form which mimics the outline of the enclosing laminae, striae are mainly curvilinear grooves. All of these structural features suggest that some of the deformation commenced prior to complete lithification of the sediment, and may represent syn-sedimentary or syn-diagenetic deformation (Guiraud and Seguret, 1987; Labaume, 1987; Petit and Laville, 1987).

Labaume (1987) reports the origin of a syn-diagenetic breccia in turbidite succession related to gravity nappe emplacement in the French Alps. The calcite veins, microfaults, deformation bands, slickensides, and the breccia have very similar features to those noted here for the Jubilee deposit. Further petrographic work and description of the breccia texture must be done before one can argue for a structural origin for the Jubilee breccia. However, on a gross scale the similarities are striking, and along with other stratigraphic evidence (see later section on lateral and vertical facies associations), the Jubilee limestone breccia may be due to brittle deformation of unlithified sediments, along with syn-depositional faulting of the area.

Facies 20 - Interbedded Limestone/Evaporite and Facies 21- Evaporite. The interbedded limestone/evaporite and evaporite facies were not the focus of this study, and in many of the cores this interval was missing, or the top was disrupted or dissolved when the cores were stored outside of the core-storage facility. Hence, these facies were only generally described to obtain thicknesses of the carbonate interval and to identify the top of the carbonate zone. In the core intervals measured, these facies account for 10-14% of the thickness of core in which they occur (Table 3). Core-logging stopped once the thick evaporite sequence (facies 21) was encountered, hence the thickness measurements for this facies are spurious. Bed thickness ranges from 1-1.5 metres. A single occurrence of a limestone, with a relict chickenwire texture (facies 19) was noted, which may represent dissolution of the original interbedded evaporite. Within the interbedded transitional limestone-evaporite (facies 20) the evaporites are mainly gypsum; in the overlying thick evaporite (facies 21) the evaporite is mainly a massive, blue anhydrite. Rare halite occurs in the cores examined in the present study. Stewart (1978) interpreted these evaporite sequences as due to evaporation within a deep (> 40 metre) silled basin.

Vertical and Lateral Facies Variation

Vertical Facies Patterns:

Stratigraphic logs for the cores (Enclosures 4 and 5) show that within the Horton clastic rocks and in the overlying Windsor carbonate and evaporite successions the facies described in the previous section tend to be interbedded on a decimetre to metre scale. Some of the cores show apparent cyclicity (i.e. fining-upward clastic sequences, associations between the convoluted and brecciated limestone, and transitions from inverse --> inverse-to-normal --> normal - graded conglomerate). In order to test for the significance of such transitions, and to ascertain the occurrence of other general patterns, a Markov Chain analysis was conducted on all of the cores. The Horton and Windsor successions were analyzed separately (see Methods section). In addition, the structural and deformation features were analyzed in relation to the undeformed conglomerate, undeformed limestone, and brecciated limestone. The Horton clastic successions involved 378 transitions; the Windsor carbonate and interbedded evaporite successions were based on 168 transitions; and the structural analysis involved 286 transitions.

The results of the Markov Chain analysis are shown as facies-relationship diagrams in Figures 14 (Horton clastics), 15 (Windsor carbonates and interbedded evaporites), and 16 (structural features). For the Horton clastic succession several significant patterns occur in the vertical sequences (Figure 14).

(1) There is a preferred association from the inverse--> inverse-to- normally graded --> normally graded conglomerate (3 --> 4 --> 5). This trend reflects a proximal to distal trend in sediment gravity flow deposition for resedimented conglomerates. This trend has been well documented in deep-water submarine channel and fan settings (Walker 1984), and also occurs in confined subaerial valleys dominated by mass-flow deposition (Morrison and Hein, 1987).

(2) There is a preferred trend of mudstone --> sandstone --> ungraded, conglomerate (12 --> 8 --> 2); and from parallel-stratified sandstone --> stratified conglomerate --> ungraded conglomerate (9 --> 6 --> 2). These associations reflect increasing energy conditions, and most likely represent the superposition of flood deposits on overbank (12 --> --> 2) or proximal alluvial channel deposits (9 --> 6 --> 2). Similar trends occur in the White Channel gravels of the Yukon, and are interpreted as representing gravelly flood flow deposits which blanket floodplain and channel deposits (Morrison and Hein, 1987). (3) Rare occurrences of brecciated limestone are associated with the ungraded conglomerate (4 transitions occurred) (18 --> 2), and also with the trough cross-bedded

clastics (2 transitions occurred) (18 --> 7). Despite these rare associations, they appear to be significant in that they are the only occurrences that show an possible interbedded relationship between the limestone and clastic units. This suggests that there may be some interfingering between the Horton and Windsor Groups, at least on a local scale, and that the upper Horton clastics may be deposited at the same time as some of the lower Windsor carbonate.

For the Windsor carbonate and interbedded evaporite succession several significant patterns occur in the vertical sequences (Figure 15).

(1) There is a tendency for the convoluted limestone to be succeeded by the laminated limestone (17 --> 14) and for the stromatolitic limestone to be succeeded by the laminated limestone (15 --> 14). The laminated limestone is followed by the pisolitic/laminated limestone (14 --> 16). Such transitions may possibly reflect proximal to distal trends within a deep carbonate basin, with the convoluted facies developed in high slope areas susceptible to mass-wasting, and the pisolitic/laminated limestone due to microbial mat deposition in more quite water conditions towards the basin centre. The pisolitic/laminated limestones show variable grading patterns suggestive of deposition from fine-grained sediment-gravity flows. As such this preferred sequence may represent deepening of the basin through time.

(2) There is a tendency for the interbedded limestone and evaporite to be associated with the evaporite succession (20 <--> 21). This reflects the gradational upper contact between the carbonates and the evaporites, and using Stewart's (1978) model would also suggest deepening of the basin through time.

For structural and deformation features patterns are somewhat less ordered (Figure 16):

(1) Within the Horton clastics, chloritic gouge tends to be succeeded by stretched pebbles and calcite veined conglomerate is overlain by undeformed conglomerate. These may involve multiple, very late stage deformation along the modern faults.

(2) Within the Windsor succession, brecciated limestone is overlain by undeformed limestone (in cores with multiple stages of brecciation) and convoluted/folded limestone is also overlain by undeformed limestone. These trends suggest that the origin of the deformation associated with the development of the breccia and the convolution is very early -- perhaps syn-depositional or syn-diagenetic. It is difficult to know if the slickenside/ vein association is also early, or if it merely reflects preferential deformation of the lower carbonates along the Windsor/Horton contact.

Lateral Facies Associations:

(a) Restored cross-sections

As shown by other workers, significant palaeotopography may have existed on the pre-Windsor landscape prior to deposition of the Windsor carbonates (c.f. Hamblin, 1988; Smith and Collins, 1979, among others). For this reason, it was thought to be inappropriate to use the Windsor/Horton contact as a datum in constructing cross-sections of the Jubilee area. Detailed core logging within the Horton clastics show extreme variability in facies character (c.f. Enclosures 4 and 5) and no markers are persistent within the clastic succession to use as datum. Isenor (1979) in his summary reports presents a number of cross-sections and longitudinal sections of the Jubilee area. On these sections are a number of thin limestone interbeds within the upper Windsor evaporite succession. Many of these limestones are quite persistent across the study area, and discussions with Isenor (Seabright Resources Inc., Sackville, NS, personal communication, 1988) indicate that the limestone interbeds are suitable datum in the Jubilee region.

In the following cross-sections, correlations across modern faults were made by matching the limestone interbeds within the upper evaporite succession -- this corrects for late movement across the faults in the area. The resulting cross-sections give a "restored" view of the subsurface at the time of deposition of the thin limestone interbeds -- and hence a view of the structure which may have affected Windsor deposition. Three typical "restored" cross-sections are illustrated (Figures 17, 20, and 23). The lithologic logs in the present study do not extend up to the marker limestone beds within the evaporite succession; we used Isenor's (1978) sections for these horizons.

The "restored" subsurface elevation to the Windsor/Horton contact was determined from the "restored" cross-sections. To properly orient the lithologic logs, the "restored" subsurface elevation of the Windsor/Horton contact was then replotted on the detailed lithologic logs. The resulting correlations (Figures 18, 21, and 24) adequately account for the enhanced carbonate section in some of the cores, which is interpreted as reflecting deposition on the downthrown side of growth faults which were active during deposition of the Windsor, and possibly upper Horton groups. The facies percentages on the cross-sections are given in Figures 19, 22 and 25.

<u>(1) "Restored" Cross-section C1:</u> cores ATG 41-77, 43-78, 44-77, 39-77. The correlations from cores 41- to 44-77 are straightforward (Figures 17 and 18). A simple succession occurs of mass-flow and fluvial cross-bedded and stratified conglomerate in the Horton group (Figure 19). These clastics are overlain by thin laminated and pisolitic/laminated carbonate, capped by a thin transitional interbedded carbonate/evaporite --> evaporite succession of the Windsor Group. The "restored" Windsor/Horton contact in core 39-77 is about 11 metres deeper than in the other cores, and there is a much thicker (i.e. about 17 metre as opposed to 4-6 metre) carbonate Windsor succession. The clastic facies in core 39-77 have a higher proportions of mass-flow conglomerates (i.e. 75%, as opposed to 50-75% in the other cores) and no "overbank" material. The carbonate facies have proportionately much thicker percentage of breccia (i.e.

about 65%, compared to 15-30% in cores 43-77 and 44-77), and a correspondingly thinner unit of laminated and pisolitic/laminated carbonates (Figure 19). The enhanced carbonate thickness is interpreted as representing deposition along a growth-fault (between 44-77 and 39-77), which was active during sedimentation. The more chaotic and less-stratified or cross-bedded nature of the conglomerate within the upper Horton in core 39-77 suggests that the faulting may have been active during deposition of the upper Horton clastics. The occurrence of the breccia on both sides of the fault suggest that it was not solely syn-depositional in origin - it is not a talus breccia developed at the base-of-scarp on the downthrown side of the fault (the textural features of this unit also suggest that it is not a talus breccia, see facies description). Re-activation along the fault after initial deposition, but prior to lithification, may have favoured the development of the breccia as a syn-diagenetic fault breccia in zones of increased thicknesses of carbonate.

<u>(2) "Restored" Cross-section C2:</u> cores ATG 53-78, 51-78, 49-78. The correlations from cores 53- to 51- to 49-78 are not as simple (Figures 20 and 21). The "restored" Windsor/Horton contact in core 51-78 is about 6 metres deeper than in the other cores, and there is a much thicker (i.e. about 20 metres as opposed to 3.5 - 6 metres) Windsor carbonate succession. Within the Horton, mass-flow and fluvial cross-bedded and stratified conglomerate, with overbank fines occur in cores 53-78 and 49-78 (Figures 21 and 22). In core 51-78 there is an absence of

overbank material (Figure 22). These clastics are overlain by laminated, stromatolitic and pisolitic/laminated carbonate and breccia of the Windsor Group. Within the Windsor succession, the facies are not laterally persistent and thicknesses change drastically (Figures 21 and 22). In addition, in core 51-78 there are upper conglomerate units, which are associated with the carbonate breccia. Observations in the core clearly show that these are not fault-repeated sections, nor due to coring of the foot-wall, as was originally interpreted during the drilling programme.

The enhanced carbonate thickness in core 51-78 is interpreted as representing deposition between two growth faults (between 53-78 and 51-78; and between 51-78 and 49-78), which were active during sedimentation. The more chaotic, less-stratified and cross-bedded nature of the conglomerate, and the absence of overbank material within the upper Horton in core 51-78 also suggests that the faulting may have affected deposition of the upper Horton clastics. The occurrence of 51-78 within a minor graben structure would also explain the upper clastic and breccia units within 51-78. These upper units are absent in the other cores, presumably due to non-deposition or subsequent removal of material on original horsts (53-78 and 49-78). Exhumation of the horsts, associated with later uplift could have easily been a local source for the upper clastics within core 51-78.

<u>(3) "Restored" Cross-section C3:</u> cores ATG 33-77, 70-79,72-79,71-79. The correlations from cores in this cross-section are fairly straightforward (Figures 23 and 24). A simple succession occurs of mass-flow and stratified conglomerate in the Horton group (Figure 23). In core 33-77, the clastics are overlain by thin laminated and pisolitic/laminated carbonate, capped by a thin transitional interbedded carbonate/evaporite of the Windsor Group. The "restored" Windsor/Horton contact in core 70-79 is about 11 metres deeper than the subsurface elevation of this contact in core 33-77. The Windsor/Horton contact then rises about 4 metres in core 72-79, and drops 4.5 metres in core 71-79. In cores 72-79 and 71-79 there is a much thicker (i.e. about 12.5 -14 metre as opposed to 5 metres in core 33-77) carbonate Windsor succession. The clastic facies in cores 33-77 and 72-79 have about 25-30% stratified "fluvial" facies, and in core 72-79 some overbank material is preserved. In cores 70-79 and 71-79 the proportion of mass-flow facies dominates (about 80%) and no "overbank" material is preserved. The carbonate facies in cores 72-79 and 71-79 have a proportionately much greater percentage of breccia (i.e. about 50%, compared to 0% in core 33-77), and a correspondingly thinner unit of laminated and pisolitic/laminated carbonates (Figure 25). The drop in elevation of the Windsor/Horton contact between cores 33-77 and 70-79 and the enhanced carbonate thickness in cores 72-79 and 71-79, compared with 33-77, are interpreted as representing deposition along two growth faults (i.e. between 33-77 and 70-79;

and between 79-79 and 72-79). These growth faults were active during sedimentation. The thicker occurrences of matrix-supported conglomerates and mass-flow facies in cores 70-79, 72-79, and 71-79, the absence of cross-bedding in the conglomerates and the relatively poor development of stratification suggests that the faulting may have been active during deposition of the upper Horton clastics. The timing of brecciation is difficult to ascertain from this cross-section.

(b) Structure Map:

The structure on top of the Horton was determined by contouring the subsurface elevation of the Windsor/Horton contact (i.e. subsea elevation to conglomerate, Table 2). The data were contoured at a 10 metre contour interval (Enclosure 10). Drastic changes in subsea elevation are interpreted to represent fault offsets. The resulting map shows a major horst trending to the northeast from the Jubilee dome. A second horst occurs on the southeast flank of the central conglomerate outcrop area. This feature diminishes to the northwest, although the structural contours indicate that possible channels or valleys drain off this feature to the northwest. The northern edge of the horst is more pronounced, with the fault extending half-way across the study area. A smaller fault trends perpendicular to this northern bounding fault in the southeastern corner of the study area.

(c) Isopach maps of limestone facies:

Three isopach maps were constructed of the limestone facies, including, laminated limestone (Enclosure 7), breccia (Enclosure 8), and total limestone (Enclosure 9). Contouring was done on a 5 metre contour interval and respected the faults as determined from the structure map (Enclosure 10). The simplest pattern is the isopach of the breccia. Thick pods of the breccia parallel the northwest-trending horst which extends from the Jubilee dome. Another thick pod of breccia occurs to the east, nested in a small fault basin flanking the smaller horst. Minor pods of breccia, up to 15 metres relief, extend in two bands perpendicular or oblique to the major bounding faults from the structure map. These features suggest that the distribution of the breccia, in particular the very thick accumulations, are related to faulting which affected the Windsor/Horton contact. It is most likely that these sites correspond to the growth faults interpreted on the restored cross-sections, and that subsequent faulting was along the same lineaments.

The laminated limestone isopach map (Enclosure 7) is more complicated. Two thick patterns reflect the pattern of enhanced thickness of the breccia -- namely a belt parallel to the bounding fault of the horst extension of the Jubilee dome, and seconding a small pod in the eastern fault basin. These correlations suggest that the breccia development in part corresponds to zones of increased laminated carbonate thickness. In addition, some of the enhanced laminated limestone section may correspond to the sites of the original growth faults, which were reactivated during subsequent faulting. Other accumulations of the laminated limestone, in the central part of the study area near Green Pond, are small patches, which do not respect the faults. This indicates that portions of the faults mapped on the structural map were not active during deposition of the lower Windsor laminated limestone. The total limestone isopach map (Enclosure 9) is a complex "interference" pattern, reflecting the trends of both the breccia and laminated limestone isopach maps.

Palaeogeographic Model

The simplest palaeogeographic model for the local study area which accounts for all of the facies variations, vertical sequences, and isopach trends consists of sedimentation within an active "mini" half-graben of a larger rift (?) basin (Figure 26). During active tectonism small alluvial fan/deltas build up a series of mass flow deposits along the boundary faults of small horsts. During periods of active rifting, roll-over structures could develop, which serve as a local source for the upper coarse conglomerates noted in the northwest part of the study area. In deeper, central parts of the "mini" half-graben, laminated limestones and pisolitic/laminated limestones were deposited during Windsor time. There is some interfingering of the Windsor and Horton conglomerates, and intraclasts of Macumber lithologies within the upper Horton conglomerates. This suggests that during part of the time of deposition of the Macumber that Horton clastics were being deposited along boundary faults or roll-over structures. Later during periods of tectonic quiescence, and associated with a change in base level, more widespread interbedded evaporites and limestones were deposited.

The model shown here is virtually identical to the simple half-graben structure for the Tertiary to Recent sequences of great East African rift system (Frostick and Reid, 1987). A similar half-graben model has been developed in the subsurface for Triassic sediments of the Inner Moray Firth of Scotland (Frostick et al, 1988). At present it is not known if the proposed "mini" half-graben model for the Jubilee deposit represents a sub-basin within a larger rift basin (Figure 2B) or within a major strike-slip basin (Figure 27). Along the present San Andreas Fault, the Ridge Basin model (Crowell, 1974) shows a number of smaller sub-basins, some of which compare in scale to the "mini" half-graben proposed for Jubilee.

Reactivation along the bounding faults of the "mini" half-graben during post-depositional stages (? syn-diagenetic) probably accounts for the formation of the Pembroke breccia in areas of enhanced carbonate section. Later reactivation along similar structural lineaments in the area account for the present faulting seen on the surface and in the subsurface. The scale of the Jubilee half-graben corresponds to a third-order basin of Large (1983). Such third-order basins have lateral dimensions varying from several hundreds of metres to several kilometres, and can serve as morphological traps in which stratiform sulphides may accumulate.

Mineralization

Several reports of grade and tonnage of Zn-Pb mineralization are noted in the assessment literature (e.g. Sugden, 1979) but only the informal estimation of Graham (1979) was available for this study. No grade and tonnage estimate was attempted in this study. The estimated ore resource is illustrated on Enclosure 6 after Graham's map and report of 1979. With a cut-off grade of 3.5% Zn+Pb over 8 feet (2.43 metres) the inferred ore describes an elongated zone along and to the northeast of the Jubilee fault from outcrop near Green Pond dipping to the northwest at approximately 28 degrees. This zone is approximately 1500 metres long, 60 metres wide, and 6 to 7.5 metres thick. Within this inferred area Graham estimates a probable ore zone which is approximately 500,000 tonnes of 6 % Zn+Pb. Thickness and grade variation of intersections is great, the maximum grade being 29.37% Zn+Pb over 12.5 feet (3.8 metres). Continuity of tonnage and grade would require considerable infill drilling. Post-ore karst is important in controlling the present geomorphology of the Jubilee area. Karst in the top 150 metres would be an important consideration in development planning (Isenor, personal communication, 1988).

Assays for individual holes are provided in Table 4. Zinc is the most abundant commodity with lead being of secondary but significant importance.

Though Ag has been mentioned frequently in assessment reports none of the reported assays have shown detectable silver. Limited microprobe analyses of galenas was done in this study (Table 7) with no detectable Ag being found. Detection limits of all methods used is relatively high however (0.01 weight % for microprobe analyses).

Other minor commodities of interest are Cd reported both in assay results (Table 4) and in this study in sphalerite (Table 8), Bi in galena (Table 7), and Sr in barite (Table 6). Chalcopyrite is a common mineral in the deposit but only as trace amounts with pyrite.

The ore minerals are sphalerite and galena. Other sulphide minerals are pyrite/marcasite and chalcopyrite. Sparry calcite and occasional barite are associated spatially with ore minerals. Calcite and anhydrite predate and postdate the ore mineralization. Fluorite was also observed in the core.

Vug fillings, joint coatings, and fluid inclusions of liquid hydrocarbons and bituminous matter is ubiquitous in the core. It is particularly common in zones of both high present porosity and zones of mineralization. Hydrocarbon fluid inclusions and bitumen solid inclusions were observed abundantly in all sphalerite examined. It was reported (G.P. Isenor, personal communication, 1988) that one of the drillholes left open for a day to allow a downhole geophysics experiment filled with and flowed liquid hydrocarbons (see Gaucher, 1977).

The sphalerite is very pale yellow to white in colour and transparent with the occasional light reddish band. It occurs most commonly disseminated as small crystals on the periphery of cavities filled mostly with calcite, though in higher grade zones sphalerite predominates over calcite. Its pale colour makes visual estimation of grade difficult. Sphalerite also occurs as reddish banded fans growing from pyrite or limestone walls into calcite filled cavities. In this latter form it tends to be more strongly yellow and to have more solid bitumen inclusions. The red bands are high in Fe.

Galena occurs as euhedral and equant crystals of various sizes almost universally with sphalerite. It is most commonly associated with sphalerite-galena-calcite-(barite) veins.

Pyrite is common as a cavity filling with calcite. Some core exhibits what has been described as 'massive' pyrite/marcasite mineralization. The internal texture of these pyrite-rich zones is a delicate colloform lacework of pyrite and calcite.

Chalcopyrite though reported with vigour, especially from the conglomerate, is very minor trace mineral. Limited assays for Cu in the conglomerates early in the drilling programme were low.

Barite occurs as a minor mineral in several cores and as a significant mineral in core ATG-51-78. There it occurs as postsulphide cavity-filling radiating aggregates and is accompanied by earlier sphalerite and galena.

The paragenesis is simple and universal in the deposit: pyrite -> sphalerite -> galena -> barite, (anhydrite) with calcite throughout though most common after the sulphides. The paragenetic position of the hydrocarbons is uncertain: they fill present day porosity and occur as fluid inclusions in both sphalerite and barite. Galena and sphalerite are common as small inclusions in each other. Fractured sphalerite fans growing on pyrite and cemented together with sparry calcite are a common texture.

The literature on Jubilee considers the deposit to be zoned both vertically and laterally mostly on referring to Stewart's (1978) work. Vertical zoning upwards of Cu (chalcopyrite+pyrite in veins) -> Zn>Pb (sphalerite>galena) -> increasing galena is not marked. The footwall conglomerate and laminated limestone contain very minor sulphide mineralization in calcite veins. Pyrite is the most common sulphide mineral in these veins though both sphalerite and galena were observed. Chalcopyrite is common as inclusions in pyrite but nowhere was seen to a significant phase. In general galena increases with increasing sphalerite content and becomes more visible and coarser grained only when the breccia porosity is great enough for significant sulphide mineralization. Ratios of Pb/Zn are erratic vertically as well as laterally.

Lateral zoning was tenuous in Stewart's work and no further evidence for significant lateral zoning was developed in this study. Graham (1979) notes that the northern most drillcore along the Jubilee fault are more pyritiferous and that this could indicate lateral zoning of Fe. It was difficult to assess this observation as no quantitative record of Fe content or pyrite content was included in company logs and a full longitudinal section along the fault was not logged in this study.

Fluid inclusion temperatures reported by Stewart from sphalerite and barite from the main surface showing are in excess of 300 degrees C. These temperatures were not confirmed quantitatively in this study but qualitatively several significant observations on fluid inclusion samples collected from ATG-51-78 were made. Fluid vapour ratios in sphalerite two phase inclusions are inconsistent with low temperature filling temperatures (less than 150 degrees C). Barite filling temperatures will be less than sphalerite temperatures. Fluid inclusions in sphalerite fall into several populations:

a. very common small (around 1 micron) inclusions of uncertain composition,

b. abundant liquid (or possibly liquid-gas) inclusions of hydrocarbons,

c. common two phase liquid-gas inclusions, presumably of water,

d. very rare 3 phase solid-liquid-gas inclusions of salt (presumable halite-water in composition).

Inclusions in paragenetically later barite are mostly 2 phase inclusions, though hydrocarbon inclusions were observed.

Though the stage of fluid inclusion investigation is early, some useful limitations to fluid composition are clear. Fluids during sphalerite, galena, and barite precipitation were greater than low temperature Mississippi Valley type deposits and possibly much higher. Liquid hydrocarbons were present at the time of sphalerite precipitation. Salinities of fluids entrapped during sphalerite and barite precipitation were not saline enough to result in common halite/sylvite solid phase in water inclusions.

While the investigation of mineral equilibria and fluid temperature and composition is at a primitive stage we provide a tentative model for discussion.

The critical event to establish at this stage is the age of brecciation of the host limestone to provide a host for mineralization. We have some indication that at least some brecciation is early before total lithification of the rock (convolute to brittle textures in the breccias) but incomplete evidence to date the bulk of the breccia formation. Certainly growth fault motion predated and postdated initial carbonate sedimentation. Both breccia and laminated carbonate thicknesses are greater along the growth faults documented in this study though the pattern of laminated limestone distribution is different in detail from breccia distribution.

It is proposed that fluids venting at points along the growth faults provided nutrient loci to localize thicker accumulation of biogenic carbonate. As carbonate deposition continued, positions along the growth faults were continued sites of preferred carbonate production and synchronous and/or later brecciation through both mechanical granulation and dissolution by venting fluids. Liquid hydrocarbon migration occurred at least in part after brecciation to fill porosity (and possibly as methane early in the history which provided nutrients for the carbonate forming biota). Mineralizing fluids deposited sphalerite and galena followed by barite and calcite into hydrocarbon-filled porosity. After initial carbonate sedimentation and subsequent growth fault activation, the deposit is a site of not only focussed flow from below along the growth fault itself, but discharge of fluids from the Horton aquifer along the faces of the growth fault.

RECOMMENDATIONS FOR FUTURE EXPLORATION

Both Isenor (1979) and Graham (1979) propose specific locations for future drilling on the property in their final summary reports. All have merit in continuing evaluation of the property but most are limited in their ability to substantially increase tonnage (though grade and grade continuity are not well established). The suggestion of both to test the extension of the Jubilee fault against the basement fault to the northwest has some potential to produce a larger tonnage target.

More interesting is the general target that Jubilee provides in the basal Windsor Group. The usual model has been to search for biohermal carbonate buildups on sub-Windsor basement highs on the model of the Gays River deposit, Halifax County, (Akande and Zentilli, 1984). The growth fault setting over thick Horton clastic sub-Windsor basement opens much more of the Horton/Windsor surface for potential mineralization. If the same structural and sedimentological setting that is responsible for the localization of sedimentary exhalative (hereafter referred to as 'sedex' after, for example, Large, 1983) vent fluids can assist in providing localization of benthic carbonate-producing vent biology, the identification of this sedimentological environment is fundamental in successful exploration for deposits of this type. We have provided an example of a valuable tool usually ignored in drill exploration: the facies analyses of a considerable thickness (at least 10 metres) of footwall clastics to help determine the palaeogeography at the time of initial host carbonate sedimentation.

The role of liquid hydrocarbons is uncertain in the deposition of ore minerals. They could provide a reductant for ore fluids, a media for biogenic sulphur production at the deposition site, or merely a media to preserve porosity for mineralizing fluids. If the hydrocarbons prove to be essential to the deposition of ore minerals, joint exploration for ore minerals and hydrocarbons may be a fruitful line of investigation. If the temperature of ore fluids proves to be elevated with respect to formation fluids elsewhere, the hydrocarbons could preserve in their maturation history and distribution, significant exploration clues to deposit location.

Despite two adits being driven on the property early in its history, no underground assessment of the deposit has occurred. It is likely that neither adit penetrated bedrock in that they are reported to lie at the till/bedrock interface (Labaw, 1937; MacNeil,1947b), nor were they sunk along the plunge of the mineralization (Enclosure 3; also MacNeil, 1947c).

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LIST OF TABLES

ERA	PERIOD OR EPOCH	FORMATION OR GROUP	LITHOLOGY
CENOZOIC	RECENT		Stream allivium, gravels.
	PLEISTOCENE		Till, glacial debris.
	UNCONFORMITY		
	PENNSYLVANIAN MISSISSIPPIAN	MABOU FORMATION	Red and grey sandstone, siltstone, minor limestone.
PALAEOZOIC	MISSISSIPPIAN	WINDSOR GROUP (includes Grantmire)	Red siltstone, mudstone, sandstone, conglomerate, limestone, anhydrite and salt.
		STRATHLORNE-AINSLIE FORMATION	Red and grey sandstone, siltstone, conglomerate, grey siltstone, shale and sandstone.
		FISSET BROOK FORMATION	Andesites and minor rhyolitic rocks, conglomerate and sandstone.
	UNCONFORMITY		
	DEVONIAN		Granitic and dioritic stocks, batholiths, minor gabbroic and dioritic dykes.

Table 1 Table of formations in the Little Narrows area, Victoria County, Cape Breton, Nova Scotia (after Weeks 1954, Kelley 1967).

Table 2a: Jubilee Zn-Pb Deposit, Victoria County, NS; Elevation of Drill Collars and Limestone/Conglomerate Contact

hole number	elevation in meters: drill collar	elevation in meters: limestone/ conglomerate contact
TG 1 75	47.64	40.02
TG 2 75	41.24	28.90
TG 3 75	39.59	22.52
TG 4 75	55.29	46.60
TG 5 75	51.97	36.12
TG 6 75	48.92	27.28
TG 7 75	59.04	55.08
TG 8 75	44.04	31.55
TG 9 75	37.98	23.04
TG 10 75	32.77	28.10
TG 11 75	28.74	13.20
TG 12 75	19.32	-12.56
TG 13 75	19.42	-2.07
TG 14 75	19.51	-41.45
TG 15 75	22.10	-90.37
TG 16 75	18.84	-63.61
TG 17 75	18.84	
ATG 1 76	47.18	14.72
ATG 2 76	47.24	-4.69
ATG 3 76	32.80	-28.86
ATG 4 76	48.95	-43.71
ATG 5 76	53.49	-56.08
ATG 6 76	30.48	15.09
ATG 7 76	32.00	11.22
ATG 8 76	39.17	-81.93
ATG 9 76	42.73	14.39
ATG 10 76	27.83	-64.22
ATG 11 76	35.05	-59.25
ATG 12 76	36.27	-3.35
ATG 13 76	37.76	6.07
ATG 14 76	37.80	-2.44
ATG 15 76	32.77	-107.75
ATG 16 76	27.40	-53.31
ATG 17 76	47.24	-38.71
ATG 18 76	38.10	
ATG 19 77	24.35	-136.37
ATG 20 77	50.29	-28.19
ATG 21 77	38.10	20.91
ATG 22 77	39.62	-6.77
ATG 23 77	30.45	-154.26
ATG 24 77	22.01	-133.14
ATG 25 77	5.06	-147.31
ATG 26 77	22.10	-22.56
ATG 27 77	29.08	-92.17
ATG 28 77	29.60	-149.47
ATG 29 77	35.08	-159.53
ATG 30 77	36.64	-94.18
ATG 31 77	38.10	-14.94
ATG 32 77	30.48	-16.22
ATG 33 77	52.94	-8.02
ATG 34 77	54.53	-55.96
ATG 35 77	26.46	-136.76
ATG 36 77	36.48	-188.40
ATG 37 77	34.41	-75.01
ATG 38 77	19.96	-201.02
ATG 39 77	30.54	-229.15
ATG 40 77	42.67	-36.27
ATG 41 77	32.00	-165.35
ATG 42 77	13.72	
ATG 43 77	8.44	-150.82
ATG 44 77	25.48	-116.40
ATG 45 77	29.99	-249.60
ATG 46 78	21.34	-97.14
ATG 47 78	38.10	16.15
ATG 48 78	38.10	
ATG 49 78	28.71	-264.66
ATG 50 78	36.06	-255.33
ATG 51 78	20.42	-259.38
ATG 52 78	15.70	-211.93
ATG 53 78	17.01	-218.60
ATG 54 78	17.62	-262.59
ATG 55 78	17.83	-259.38
ATG 56 78	20.73	-85.19
ATG 57 78	17.22	-273.25
ATG 58 78	20.82	-73.97
ATG 59 78	33.53	-83.91
ATG 60 78	33.53	-96.74
ATG 61 78	33.53	-88.03
ATG 62 78	11.58	-340.92
ATG 63 79	26.85	-105.43
ATG 64 79	25.12	-136.12
ATG 65 79	22.86	-138.23
ATG 66 79	70.81	-40.75
ATG 67 79	65.20	56.81
ATG 68 79	35.60	-157.79
ATG 69 79	68.70	54.07
ATG 70 79	53.13	49.62
ATG 71 79	65.96	-113.26
ATG 72 79	47.95	-125.79

Table 2b: Thickness of Limestone Units
Jubilee Zn-Pb Deposit, Victoria County, Nova Scotia

HOLE NUMBER	<------------- total limestone ft	thickness limestone m	laminated limestone m	other limestone m ------------->	elevation base of limestone m
TG 1 75					40.0
TG 2 75		20	11.1	8.9	28.9
TG 3 75		27.5	17.7	9.8	22.5
TG 4 75					46.6
TG 5 75					36.1
TG 6 75					27.3
TG 7 75					55.1
TG 8 75					31.5
TG 9 75	20	6.1			23.0
TG 10 75					28.1
TG 11 75		9.3	8.8	0.5	13.2
TG 12 75		13.2	12.2	1.0	-12.6
TG 13 75		9.9	9.9	0.0	-2.1
TG 14 75	43	13.1			-41.5
TG 15 75	17	5.2			-90.4
TG 16 75	20	6.1			-63.6
TG 17 75					
ATG 1 76	30	9.1			14.7
ATG 2 76	15	4.6			-4.7
ATG 3 76	14	4.3			-28.9
ATG 4 76		14.3	13.2	1.1	-43.7
ATG 5 76	19	5.8			-56.1
ATG 6 76					15.1
ATG 7 76					11.2
ATG 8 76	21	6.4			-81.9
ATG 9 76	21	6.4			14.4
ATG10 76	12	3.7			-64.2
ATG11 76	53	16.2			-59.3
ATG12 76					-3.4
ATG13 76					6.1
ATG14 76	22	6.7			-2.4
ATG15 76	33	10.1			-107.7
ATG16 76	12	3.7			-53.3
ATG17 76		12.5	7.6	4.9	-38.7
ATG18 76					
ATG19 77	64	19.5			-136.4
ATG20 77	8	2.4			-28.2
ATG21 77					20.9
ATG22 77					-6.8
ATG23 77	52	15.8			-154.3
ATG24 77	43	13.1			-133.1
ATG25 77	16	4.9			-147.3
ATG26 77	29	8.8			-22.6
ATG27 77	14	4.3			-92.2
ATG28 77	23	7.0			-149.5

Table 2b (continued)

	<-------------- thickness ------------->				elevation
HOLE NUMBER	total limestone ft	limestone m	laminated limestone m	other limestone m	base of limestone m
ATG29 77	16	4.9			-159.5
ATG30 77	25	7.6			-94.2
ATG31 77	16	4.9			-14.9
ATG32 77	15	4.6			-16.2
ATG33 77		6.1	6.1	0.0	-8.0
ATG34 77	22	6.7			-56.0
ATG35 77	64	19.5			-136.8
ATG36 77					-188.4
ATG37 77	32	9.8			-75.0
ATG38 77	41	12.5			-201.0
ATG39 77		33.6	10.4	23.2	-229.1
ATG40 77		14.4	14.4	0.0	-36.3
ATG41 77		5.9	5.9	0.0	-165.4
ATG42 77					
ATG43 77		3.8	2.8	1.0	-150.8
ATG44 77		4.3	3.7	0.6	-116.4
ATG45 77	48	14.6			-249.6
ATG46 78	31	9.4			-97.1
ATG47 78					16.2
ATG48 78					
ATG49 78		11.4	9.0	2.4	-264.7
ATG50 78		14			-255.3
ATG51 78		57	10.5	46.5	-259.4
ATG52 78		19.9	10.1	9.8	-211.9
ATG53 78		6.8	1.0	5.8	-218.6
ATG54 78		24.9	9.0	15.9	-262.6
ATG55 78		17.7	7.5	10.2	-259.4
ATG56 78		11.3	7.7	3.6	-85.2
ATG57 78	8	2.4			-273.3
ATG58 78		14	12.6	1.4	-74.0
ATG59 78	5	1.5			-83.9
ATG60 78	14	4.3			-96.7
ATG61 78	8	2.4			-88.0
ATG62 78	18	5.5			-340.9
ATG63 79		2.6	2.6	0.0	-105.4
ATG64 79	28	8.5			-136.1
ATG65 79	33	10.1			-138.2
ATG66 79	9	2.7			-40.8
ATG67 79	2.1	0.6	2.1		56.8
ATG68 79	12	3.7			-157.8
ATG69 79					54.1
ATG70 79	3.9	1.2	3.9		49.6
ATG71 79		25.4	11.1	14.3	-113.3
ATG72 79		24	14.9	9.1	-125.8

note: other limestone by subtraction (total-laminated)

Table 3: Facies Bed-Thickness and Frequency Variation

	Facies Description	<---- Thickness (m)	Range (m)	---> (%)	# of beds	# of core
1	Matrix-supported Conglomerate	0.35	.07 - 0.6	5	28	11
2	Ungraded Conglomerate/ Pebble Sandstone	0.42	.02 - 1.9	21	235	26
3	Inverse-graded Conglomerate	0.53	.25 - 1.6	5	18	10
4	Inverse-to-Normally Graded Conglomerate	0.46	.23 - 0.7	4	9	7
5	Normally-graded and Graded-Stratified Conglomerate	0.52	.15 - 1.6	8	84	21
6	Stratified Conglomerate/ Pebble Sandstone	0.50	.13 - 1.5	9	75	22
7	Cross-bedded Conglomerate/ Pebble Sandstone	0.22	.08 - 1.5	2	9	7
8	Structureless Sandstone	0.25	.05 - 7.2	4	30	14
9	Stratified Sandstone	0.22	.05 - 1.3	2	19	11
10	Cross-bedded Sandstone	0.25	.25 - 0.3	3	5	3
11	Burrowed Siltstone/Mudstone	0.12	.08 - 0.2	1	2	2
12	Structureless Siltstone/ Mudstone	0.09	.08 - 0.3	2	20	9
13	Structureless Limestone	0.15	---------	1	1	1
14	Laminated Limestone	1.16	.25 - 2.0	13	65	26
15	Stromatolitic Limestone	0.37	.25 - 0.6	4	4	3
16	Pisolitic/Laminated Limestone (w/intraclasts)	1.09	.30 - 2.6	12	42	21
17	Convoluted Limestone	0.66	.25 - 3.3	8	12	7
18	Brecciated Limestone	1.55	.10 - 5.5	11	48	19
19	Limestone with relict "Chickenwire Texture"	1.00	--------	5	1	1
20	Interbedded Limestone & Evaporite (mainly gypsum)	1.48	.50 - 2.9	14	18	15
21	Evaporite (mainly massive anhydrite, minor gypsum)	1.09	.50 - 2.1	10	21	15

TABLE 4: Summary of Reported Assay Data
from the Jubilee Deposit, Victoria County, Nova Scotia

hole	interval in ft		<---Reported Assay in Weight % --->						
#	top	base	Zn	Pb	Cu	Ag	S	Cd	Ba
7501	3.00	11.00	0.04	0.05		0.00			
7502	21.00	24.00	0.36	0.14		0.00			
7502	24.00	29.00	1.86	0.27		0.00			
7502	29.00	34.00	0.31	0.12		0.00			
7502	34.00	39.00	0.68	0.01		0.00			
7502	39.00	40.50	1.08	0.03		0.00			
7503	15.00	18.00	3.62	1.62		0.00			
7503	18.00	21.00	2.74	0.23		0.00			
7503	21.00	26.00	1.00	0.52		0.00			
7503	26.00	30.00	0.38	0.19		0.00			
7503	30.00	35.00	0.46	0.29		0.00			
7503	35.00	39.00	0.38	0.16		0.00			
7503	39.00	44.00	0.94	0.28		0.00			
7503	44.00	49.00	0.27	0.11		0.00			
7503	49.00	54.00	0.42	0.05		0.00			
7504	23.50	28.50	0.47	0.08		0.00			
7505	14.00	35.00	0.08	0.02		0.00			
7505	35.00	39.00	0.26	0.13		0.00			
7505	39.00	42.00	0.13	0.08		0.00			
7506	51.00	56.00	0.52	0.42		0.00			
7506	56.00	61.00	0.64	0.07		0.00			
7508	23.00	25.00	2.08	0.22		0.00			
7508	25.00	28.00	10.40	0.58		0.00			
7508	28.00	31.00	0.94	0.74		0.00			
7511	45.50	50.50	1.64	0.10		0.00			
7512	91.00	94.00	0.60	0.09		0.00			
7512	97.00	100.00	1.44	1.18		0.06			
7512	101.50	104.60	1.32	1.36		0.04			
7512	104.60	109.60	0.68	0.52		0.00			
7512	109.60	114.60	1.04	0.48		0.00			
7514	164.00	169.00	1.46	0.34		0.00			
7514	169.00	174.00	2.74	0.59		0.00			
7514	174.00	179.00	3.32	0.82		0.00			
7514	179.00	184.00	1.10	0.44		0.00			
7514	184.00	189.00	2.75	0.06		0.00			
7514	189.00	194.00	1.34	0.36		0.00			
7514	194.00	200.00	2.08	0.94		0.02			
7514	200.00	205.00	1.10	0.77		0.00			
7514	205.00	210.00	1.44	0.52		0.00			
7601	77.00	81.00	1.08	0.40					
7601	81.00	83.00	3.36	0.14					
7601	83.00	85.80	0.62	0.29		0.00			
7601	85.80	87.00	1.72	0.52					
7601	87.00	97.00	0.06	0.10					
7601	97.00	102.00	0.53	0.11					
7601	102.00	106.20	6.08	1.08	0.02				
7601	106.50	112.00	0.20	0.06	0.02				

Table 4 continued

hole #	interval in ft top	base	<---Reported Assay in Weight % ---> Zn	Pb	Cu	Ag	S	Cd	Ba
7601	112.00	117.00	0.14	0.02					
7604	279.00	281.00	0.72	0.01					
7604	290.30	297.80	1.04	0.02					
7604	297.80	302.00	0.46	0.01					
7604	302.00	304.00	0.06	0.03					
7604	304.00	309.00	0.08	0.03					
7608	338.50	342.00	0.03	0.01					
7608	360.00	361.50	0.13	0.02					
7608	361.50	365.20	2.00	0.41					
7608	365.20	376.80	0.00	0.01					
7608	376.80	386.20	1.08	0.18					
7608	386.20	391.00	0.56	0.02					
7608	391.00	397.50	0.10	0.04					
7608	397.50	402.50	0.06	0.01					
7609	72.30	77.00	1.34	0.01					
7609	77.00	82.00	0.38	0.18					
7609	82.00	88.00	1.18	0.07					
7609	88.00	93.00	0.42	0.04					
7611	256.00	257.00	14.70	3.74					
7611	257.00	264.60	0.84	0.30					
7611	264.60	274.00	4.88	0.29					
7611	274.00	284.00	1.97	0.15					
7611	284.00	294.00	1.12	0.16					
7611	294.00	299.60	0.25	0.20					
7611	299.60	309.40	0.49	0.22					
7611	309.40	315.00	0.14	0.10					
7614	110.00	113.00	0.04	0.02					
7614	113.00	116.00	0.05	0.04					
7614	116.00	119.00	0.07	0.03					
7614	119.00	124.00	0.04	0.03					
7614	124.00	129.00	0.04	0.02					
7614	129.00	132.00	0.02	0.02					
7614	132.00	137.00	0.06	0.02					
7615	424.00	428.80	0.00	0.00					
7615	428.80	434.00	4.12	0.04					
7615	434.00	439.00	2.28	0.06					
7615	439.00	444.00	3.12	0.66					
7615	444.00	448.60	0.42	0.07					
7615	448.60	454.00	0.11	0.05					
7615	454.00	461.00	0.04	0.01					
7615	461.00	471.00	0.13	0.13					
7616	226.00	253.00	0.01	0.01					
7616	253.00	260.40	0.02	0.02					
7616	262.00	264.80	0.03	0.01					
7617	257.00	263.00	0.02	0.01					
7617	263.00	269.00	0.02	0.01					
7617	269.00	277.00	0.12	0.03					
7617	277.00	282.00	0.11	0.04					

Table 4 continued

hole	interval in ft		<---Reported Assay in Weight % --->						
#	top	base	Zn	Pb	Cu	Ag	S	Cd	Ba
7719	162.50	163.50	0.01	0.05					
7719	412.50	414.50	0.02	0.00					
7719	420.00	421.50	1.91	0.16					
7719	435.00	438.50	0.00	0.00					
7719	438.50	441.50	0.01	0.04					
7719	441.50	443.00	1.96	6.62					
7719	443.00	446.00	18.50	12.50					
7719	446.00	448.00	16.90	1.84					
7719	448.00	450.00	0.00	0.01					
7719	450.00	455.00	0.00	0.00					
7719	455.00	460.00	0.00	0.00					
7719	460.00	462.50	0.01	0.00					
7719	462.50	467.50	1.50	0.33					
7719	467.50	472.00	3.18	0.27					
7719	472.00	475.00	6.74	1.83	0.00				
7719	475.00	480.00	1.98	1.01	0.00				
7719	480.00	485.00	1.56	0.81					
7719	485.00	490.00	2.27	0.34	0.00				
7719	490.00	495.00	2.28	0.60		0.00			
7719	495.00	504.00	3.38	1.44					
7719	500.00	505.00	3.38	1.54	0.00				
7719	505.00	510.00	0.62	0.42					
7719	510.00	513.00	0.91	0.32					
7719	513.00	516.00	0.69	0.07					
7719	516.00	521.00	0.10	0.03					
7719	522.00	525.00	0.08	0.02					
7719	525.00	527.30	0.04	0.02					
7719	527.50	530.00	0.05	0.01					
7719	530.00	535.00	0.05	0.06	0.00				
7719	537.50	539.00	0.71	0.40					
7719	547.00	550.00	0.87	0.33	0.02				
7719	550.00	557.00	0.28	0.43	0.02				
7720	211.00	214.00	0.31	0.03					
7720	235.00	238.00	0.00	0.00					
7720	256.50	257.50	1.91	0.16					
7723	553.50	556.00	0.19	0.04					
7723	556.00	560.00	8.83	0.39					
7723	560.00	565.00	0.07	1.89					
7723	565.00	568.00	0.46	0.98					
7723	568.00	570.00	3.32	9.23					
7723	570.00	575.00	0.28	1.22					
7723	575.00	580.00	0.36	2.29					
7723	580.00	585.00	0.19	0.77					
7723	585.00	588.00	0.13	2.09					
7723	588.00	589.00	7.70	0.73	0.01	0.00			
7723	589.00	593.00	0.19	0.18					
7723	593.00	596.50	0.02	0.08					
7723	596.50	600.00	0.62	0.12					

Table 4 continued

hole	interval in ft		<---Reported Assay in Weight % --->						
#	top	base	Zn	Pb	Cu	Ag	S	Cd	Ba
7723	603.00	606.00	0.06	0.03					
7724	243.00	245.00	0.02	0.01					
7724	463.50	466.50	0.00	0.00					
7724	466.50	469.00	13.70	3.93		0.00			
7724	469.00	471.50	23.60	4.66		0.00			
7724	471.50	474.00	32.00	15.20		0.00			
7724	474.00	477.00	30.00	5.10		0.00			
7724	477.00	479.00	14.40	0.10		0.00			
7724	479.00	482.00	4.05	0.09		0.00			
7724	482.00	485.00	1.40	0.08					
7724	485.00	488.00	1.95	0.11					
7724	488.00	490.00	0.03	0.06					
7724	490.00	492.00	0.73	0.08					
7724	492.00	495.00	0.43	0.03					
7724	495.00	497.00	0.08	0.05					
7724	497.00	500.00	0.51	0.06					
7724	500.00	503.00	0.09	0.02					
7724	503.00	505.00	8.37	2.00					
7724	505.00	507.00	0.19	0.06					
7724	507.00	509.00	0.09	0.02					
7724	515.00	517.00	2.70	0.65	0.02	0.00			
7724	517.00	520.00	0.65	0.16	0.02	0.00			
7724	520.00	523.00	0.97	0.35	0.02	0.00			
7724	528.00	532.00	0.74	0.27	0.02	0.00			
7725	463.20	466.50	1.89	0.03					
7725	483.50	487.00	0.74	0.18					
7725	487.00	489.00	6.64	0.01					
7725	489.00	492.00	4.30	0.02					
7725	511.50	515.40	0.59	0.12					
7726	118.00	120.50	1.02	0.14					
7726	120.50	123.00	5.49	0.44					
7726	123.00	125.00	0.49	0.02					
7726	125.00	127.50	0.01	0.00					
7726	127.50	130.00	0.02	0.00					
7726	130.00	132.50	0.00	0.00					
7726	132.50	135.00	2.25	0.01					
7726	135.00	140.00	0.47	0.04					
7726	140.00	143.00	0.02	0.03					
7726	143.00	146.00	0.02	0.01					
7726	146.00	152.00	0.04	0.03					
7728	565.00	566.00	4.31	0.26					
7728	566.00	568.00	1.42	0.76					
7728	568.00	571.00	5.93	0.71					
7728	571.00	572.30	1.64	0.15					
7728	572.30	575.00	0.83	0.07					
7728	575.00	578.00	0.38	0.08					
7728	578.00	580.00	0.70	0.02					
7729	605.00	607.50	2.24	0.04					

Table 4 continued

hole #	interval in ft top	base	<---Reported Assay in Weight % ---> Zn	Pb	Cu	Ag	S	Cd	Ba
7729	622.50	625.00	3.38	3.13					
7729	625.00	627.50	1.60	0.82					
7729	627.50	630.00	0.18	0.12					
7729	630.00	633.00	0.96	0.21					
7729	633.00	635.00	5.03	0.37					
7729	635.00	638.50	3.15	0.06					
7729	638.50	643.00	1.50	0.01					
7729	643.00	648.00	1.29	0.14					
7734	340.40	345.00	0.55	0.04					
7734	345.00	350.00	0.60	0.15					
7734	350.00	352.00	1.10	0.88					
7734	352.00	356.00	0.09	0.01					
7734	356.00	359.00	0.01	0.00					
7735	501.00	505.00	1.11	0.08					
7735	518.50	520.00	3.92	2.74					
7735	520.00	524.00	0.13	0.15					
7735	524.00	528.80	0.36	0.06					
7736	732.80	734.00	4.40	0.13					
7736	748.50	751.50	1.14	0.05					
7737	307.00	307.50	1.30	0.06					
7737	307.50	309.50	24.00	0.05					
7737	327.00	331.00	1.30	0.10					
7737	331.00	334.00	2.32	0.05					
7737	334.00	337.50	0.21	0.01					
7737	337.50	340.00	0.95	0.29					
7737	340.00	344.00	0.35	0.11					
7737	344.00	350.00	0.35	0.33					
7737	350.00	355.00	0.06	0.09					
7737	355.00	359.00	0.02	0.04					
7738	560.00	561.00	0.95	0.14					
7738	561.00	562.50	1.39	0.13					
7738	684.00	686.00	0.00	0.01					
7738	686.00	687.00	0.06	0.04					
7738	687.00	688.00	22.00	0.19					
7738	688.00	688.50	2.41	0.12					
7738	688.50	691.50	0.54	0.09					
7738	691.50	694.50	2.24	0.81					
7738	694.50	697.00	1.22	0.12					
7738	697.00	700.00	0.01	0.97					
7738	700.00	704.00	4.56	4.11					
7738	704.00	707.00	1.51	0.85					
7738	707.00	709.00	0.98	0.20					
7738	709.00	712.00	2.16	0.36					
7738	712.00	714.00	1.73	0.22					
7738	714.00	718.00	0.55	0.13					
7738	724.00	725.00	0.28	1.87					
7739	565.00	567.50	0.00	0.01					
7739	618.50	622.20	0.00	0.00					

Table 4 continued

hole	interval in ft		<---Reported Assay in Weight % --->						
#	top	base	Zn	Pb	Cu	Ag	S	Cd	Ba
7739	633.40	635.00	0.00	0.00					
7739	635.00	638.00	2.62	0.03					
7739	762.30	763.30	0.09	0.15					
7739	799.20	800.60	0.30	0.36					
7739	800.60	801.40	6.26	1.13					
7739	801.40	806.90	0.26	0.07					
7739	806.90	808.00	4.30	6.92					
7739	808.00	812.00	0.48	0.05					
7739	812.00	815.00	0.96	0.04					
7739	815.00	819.00	0.32	0.06					
7739	819.00	820.00	0.96	0.38					
7739	820.00	822.00	0.10	0.09					
7739	822.00	826.00	1.42	0.59					
7739	826.00	831.00	1.02	0.05					
7739	831.00	834.00	0.99	0.06					
7739	838.00	844.40	0.30	0.04					
7739	844.40	850.00	0.45	0.21					
7739	850.00	852.00	0.10	0.05					
7739	852.00	855.00	0.39	0.17					
7744	454.00	459.00	0.02	0.00					
7744	459.00	461.50	0.75	0.27		0.00			1.39
7745	862.50	863.50	0.86	0.07					
7745	869.50	871.00	4.31	2.36		0.00			
7745	871.00	872.00	1.90	0.87		0.00			
7745	872.00	873.00	6.27	0.70		0.00			
7745	873.00	875.00	3.55	1.94		0.00			
7745	875.00	878.00	6.19	3.84		0.00			
7745	878.00	882.00	4.43	1.08		0.00			
7745	882.00	886.00	3.17	1.51		0.00			
7745	886.00	887.50	4.26	1.64		0.00			
7745	887.50	889.00	0.45	0.64		0.00			
7745	889.00	891.00	0.69	2.17		0.00			
7745	891.00	892.50	0.81	0.93		0.00			
7745	892.50	894.50	2.30	1.88		0.00			0.65
7745	894.50	898.50	0.12	0.79		0.00			
7745	898.50	901.50	0.11	0.49		0.00			
7745	901.00	905.00	0.13	1.21		0.00			
7745	922.50	924.50	0.15	0.02	0.08	0.00			
7847	100.70	101.70	0.97	0.04					
7847	111.50	113.50	0.92	0.28					
7849	942.00	944.00	0.39	0.06					
7849	944.00	945.00	0.42	0.09					
7849	945.00	946.00	0.94	0.09					
7849	946.00	948.00	2.22	0.27					
7849	948.00	949.00	0.90	0.26					
7849	949.00	950.50	0.12	0.06					
7849	950.50	952.00	0.98	0.19					
7849	952.00	954.50	0.11	0.04					

Table 4 continued

hole #	interval in ft top	base	<---Reported Assay in Weight % ---> Zn	Pb	Cu	Ag	S	Cd	Ba
7849	954.50	956.00	0.11	0.02					
7849	956.00	957.70	0.02	0.01					
7849	957.70	958.70	0.70	0.05					
7849	970.00	971.00	0.05	0.04					
7851	614.00	616.00	0.56	0.04					
7851	650.30	653.00	0.04	0.02					
7851	653.00	656.00	0.00	0.02		0.00			
7851	656.00	658.00	0.00	0.02					
7851	716.00	716.70	4.10	0.79					
7851	720.50	721.50	0.06	0.02					
7851	721.50	723.50	2.10	0.22					
7851	723.50	727.00	0.95	0.47					
7851	727.00	731.00	0.69	0.07					
7851	731.00	732.00	2.78	0.04					
7851	737.00	738.50	0.06	0.04					
7851	821.00	821.50	4.80	2.22					
7851	821.50	823.50	22.00	6.67					
7851	823.50	826.50	6.48	3.20		0.00			
7851	826.50	830.50	8.45	1.10					
7851	830.50	833.00	3.62	1.61					
7851	833.00	836.00	0.19	0.10					
7851	836.00	837.00	0.06	0.06					
7851	837.00	839.50	0.09	0.10					
7851	839.50	843.50	3.17	1.47					
7851	843.50	845.00	3.03	3.36					
7851	845.00	850.00	0.28	0.28					
7851	850.00	851.50	0.02	0.23					
7851	851.50	855.50	7.98	0.35					
7851	855.50	860.00	13.00	0.16					
7851	860.00	862.00	7.44	0.02					
7851	862.00	865.00	0.00	0.00		0.00			50.50
7851	865.00	868.00	0.00	0.00		0.00			45.50
7851	868.00	871.70	0.00	0.00		0.00			37.00
7851	871.70	873.00	13.00	0.04					
7851	873.00	877.00	22.50	1.87					
7851	877.00	879.00	12.50	0.58					21.50
7851	879.00	883.50	0.02	0.00					27.00
7851	883.50	887.00	0.01	0.00					0.15
7851	887.00	888.50	0.03	0.01					
7851	888.50	893.50	0.00	0.00					
7851	893.50	896.50	0.00	0.00					
7851	896.50	898.00	1.98	0.24					
7851	898.00	903.00	0.12	0.04					
7851	903.00	904.50	8.35	0.07					
7851	904.50	907.00	0.54	0.07					
7851	907.00	908.50	0.47	0.01					
7851	908.50	912.00	0.03	0.03					
7851	912.00	915.00	1.24	0.08					

Table 4 continued

hole #	interval in ft top	base	<---Reported Zn	Assay in Pb	Weight % Cu	Ag	S	Cd	---> Ba
7851	915.00	917.00	0.44	0.10					
7851	917.00	918.00	0.15	0.06					
7851	918.00	920.00	0.26	0.01					
7852	710.00	712.00	0.01	0.00					
7852	715.00	716.00	0.01	0.00					
7852	716.00	718.00	3.61	0.10			7.50		
7852	718.00	719.00	5.48	1.03					
7852	719.00	721.50	32.00	1.17					
7852	721.50	723.50	3.66	1.17					
7852	723.50	725.00	0.74	1.01					
7852	725.00	728.00	0.08	0.03					
7852	728.00	729.50	0.18	0.16					
7852	729.50	732.00	0.02	0.01					
7852	732.00	735.00	0.25	0.05					0.40
7852	735.00	737.50	0.04	0.03					
7853	762.00	763.00	0.00	0.03					
7853	763.00	764.00	0.02	0.08					
7853	764.00	765.50	0.49	0.73					
7853	765.50	767.50	13.20	1.09		0.00		0.02	
7853	767.50	770.00	0.71	0.15					
7853	770.00	772.50	1.16	0.38					
7853	772.50	773.50	0.02	0.07					
7853	773.50	775.50	0.01	0.00					
7854	891.00	892.00	0.57	0.02					
7854	892.00	895.50	3.11	1.16		0.00			
7854	895.50	897.00	2.71	1.17					
7854	897.00	899.00	2.84	2.54		0.00	5.00	0.01	
7854	899.00	900.00	0.50	1.37					
7854	900.00	902.50	2.86	1.47		0.00	6.00		
7854	902.50	904.50	4.41	0.52		0.00	1.00		
7854	904.50	906.00	1.31	0.04					
7854	906.00	907.00	0.16	0.02					
7854	919.30	921.30	0.09	0.01					
7855	877.00	879.00	0.09	0.16					
7855	879.00	880.50	0.07	0.16					
7855	880.50	884.50	0.04	0.10					
7855	884.50	887.00	3.97	2.35					
7855	887.00	888.50	0.08	0.15					
7855	888.50	890.50	0.08	0.11					
7855	890.50	892.00	2.03	0.16					
7855	892.00	893.50	0.55	0.02					
7855	893.50	895.50	1.55	0.82					
7855	895.50	897.50	0.04	0.04					
7855	897.50	899.50	0.04	0.03					
7855	899.50	901.50	0.02	0.02					
7855	901.50	903.50	0.01	0.01					
7855	903.50	905.30	0.05	0.04					
7855	905.30	907.30	0.55	0.11					

Table 4 continued

hole	interval in ft		<---Reported Assay in Weight % --->						
#	top	base	Zn	Pb	Cu	Ag	S	Cd	Ba
7856	326.00	329.00	0.01	0.01					
7856	329.00	331.50	3.60	1.33					
7856	331.50	333.00	3.50	0.20					
7856	333.00	334.50	4.17	1.14					
7856	334.50	335.70	8.60	0.75					
7858	93.20	93.90	2.27	1.69					
7858	287.50	288.50	7.08	0.03					
7858	288.50	290.50	4.78	0.21					
7858	290.50	293.50	2.42	0.17					
7858	293.50	296.00	0.57	0.52					
7858	296.00	298.00	1.28	0.70					
7858	298.00	301.00	0.57	0.06					
7858	301.00	303.00	0.39	0.01					
7858	303.00	305.00	1.23	0.06					
7964	501.00	505.00	1.12	0.35					
7964	505.00	507.50	1.66	0.50					
7964	507.50	512.50	3.13	0.67		0.00	5.64		
7964	512.50	514.00	0.86	0.26					
7964	514.00	516.50	1.29	0.32					
7964	516.50	520.00	0.67	0.01					
7965	500.50	502.00	0.15	0.16					
7965	502.00	505.00	0.88	0.52					
7965	505.00	506.00	0.05	0.09					
7965	506.00	507.00	7.52	0.94					
7965	507.00	508.50	0.80	0.27					
7965	508.50	511.00	1.44	0.32					
7965	511.00	514.00	0.15	0.11					
7968	621.00	622.00	3.20	0.29					
7968	627.00	627.50	1.68	0.07					
7968	635.50	638.00	0.58	0.08					
7968	638.00	641.00	0.85	0.52					
7971	556.50	557.50	0.00	0.01					
7971	557.50	558.20	0.37	0.02					
7971	558.20	560.20	7.67	0.02				0.02	
7971	560.20	563.00	0.18	0.08					
7971	563.00	568.00	0.39	0.09					
7971	568.00	569.50	0.08	0.22					
7971	569.50	571.50	1.43	0.19				0.07	
7971	571.50	572.50	0.14	0.18					
7971	572.50	575.00	0.51	0.18					
7971	575.00	577.00	0.03	0.06					
7971	577.00	580.00	0.01	0.06					
7972	534.50	535.50	0.68	0.05					
7972	535.50	540.50	0.06	0.16					
7972	540.50	543.00	0.18	0.08					
7972	543.50	545.50	0.55	0.43					
7972	545.50	547.50	0.43	0.02					
7972	547.00	548.00	0.08	0.09					

Table 4 continued

hole #	interval in ft top	base	<---Reported Assay in Weight % ---> Zn	Pb	Cu	Ag	S	Cd	Ba
7972	548.00	550.00	0.02	0.01					

Table 5: Jubilee - Weighted Grades for Each Hole with Reported Assays.

hole #	avg grade/hole Zn	Pb	Zn/(Zn+Pb)
7501	0.04	0.05	0.44
7502	0.87	0.13	0.87
7503	0.96	0.34	0.74
7504	0.47	0.08	0.85
7505	0.11	0.04	0.72
7506	0.58	0.25	0.70
7508	4.77	0.55	0.90
7511	1.64	0.10	0.94
7512	0.98	0.68	0.59
7514	1.93	0.55	0.78
7601	1.14	0.25	0.82
7604	0.56	0.02	0.97
7608	0.47	0.08	0.85
7609	0.84	0.08	0.92
7611	1.78	0.27	0.87
7614	0.05	0.03	0.65
7615	1.12	0.12	0.90
7616	0.01	0.01	0.53
7617	0.07	0.02	0.76
7719	2.02	0.87	0.70
7720	0.41	0.04	0.92
7723	1.20	1.26	0.49
7724	5.88	1.42	0.81
7725	2.38	0.08	0.97

hole #	avg grade/hole Zn	Pb	Zn/(Zn+Pb)
7726	0.75	0.06	0.93
7728	2.12	0.30	0.87
7729	1.99	0.45	0.82
7734	0.44	0.15	0.75
7735	0.88	0.37	0.70
7736	2.07	0.07	0.97
7737	1.97	0.13	0.94
7738	2.00	0.80	0.71
7739	0.73	0.25	0.75
7744	0.26	0.09	0.75
7745	2.24	1.37	0.62
7847	0.94	0.20	0.82
7849	0.58	0.10	0.86
7851	3.32	0.50	0.87
7852	4.19	0.35	0.92
7853	2.36	0.35	0.87
7854	2.22	0.95	0.70
7855	0.63	0.32	0.66
7856	3.18	0.65	0.83
7858	1.89	0.28	0.87
7964	1.64	0.38	0.81
7965	1.16	0.32	0.78
7968	1.15	0.30	0.79
7971	0.96	0.10	0.90
7972	0.23	0.13	0.63

Table 6:
Jubilee deposit barite compositions
Electron microprobe analyses
April 14, 1988
Normalized data

sample	spot	Ba	SO_4	Sr	total
J032	A24	58.65	40.01	1.34	100
J032	A25	55.89	41.14	2.97	100
J031	B26	56.37	41.01	2.62	100
J031	C27	56.57	40.94	2.49	100
J050	D30	55.45	40.66	3.89	100
J050	E31	55.35	41.66	2.99	100

Raw data

sample	spot	Ba	SO_4	Sr	total
J032	A24	57.82	39.44	1.32	98.58
J032	A25	56.32	41.46	2.99	100.77
J031	B26	54.93	39.96	2.55	97.44
J031	C27	57.25	41.44	2.52	101.21
J050	D30	54.26	39.79	3.81	97.86
J050	E31	56.29	42.36	3.04	101.69

no detectable Pb

grain A spots between analyzed galena grains

grain B spot between pyrite and analyzed galena

grain C spot between analyzed sphalerite and analyzed galena grains

grain D spot adjacent analyzed sphalerite crystal termination

grain E spot adjacent sphalerite/pyrite grain boundary

sample	drillcore	sample interval in meters from	to	description
J032	ATG 51 78	267.08	267.15	ore texture; ga/sph
J031	ATG 51 78	266.56	266.63	ore texture; ga/sph
J050	ATG 51 78	267.38	267.46	sph>ga>py in barite

Table 7: Jubilee deposit galena compositions
Electron microprobe analyses; April 14, 1988
Normalized data

sample	spot	Pb	S	Bi	Cu	Fe	Cd	total
J045	A2	86.24	13.72	0.04	0.00	0.00	0.00	100
J045	A1	86.26	13.54	0.20	0.00	0.00	0.00	100
J045	A3	86.23	13.64	0.10	0.03	0.00	0.00	100
J032	B4	86.17	13.72	0.11	0.00	0.00	0.00	100
J032	C5	86.56	13.39	0.00	0.05	0.00	0.00	100
J032	D6	85.85	14.05	0.04	0.06	0.00	0.00	100
J031	E7	86.05	13.75	0.13	0.05	0.00	0.02	100
J031	E8	86.27	13.68	0.00	0.05	0.00	0.00	100
J039	F9	86.45	13.42	0.11	0.00	0.03	0.00	100

grain A surrounded aby calcite and near similar sized sphalerite
spot 1 interior of grain
spot 2 edge of grain
spot 3 grain interior adjacent to sphalerite inclusion
grain B spot edge of large galena in barite
grain C spot centre of small galena in barite
grain D spot centre of small galena in sphalerite
grain E surrounded by barite with adjacent pyrite and sphalerite
spot 7 clear rim
spot 8 pitted centre
grain F large grain in anhydrite, calcite, and pyrite

		sample interval in meters		
sample	drillcore	from	to	description
J045	TG 12 75	33.18	33.25	ga-calcite-fl in cgl
J031	ATG 51 78	266.56	266.63	ore texture; ga/sph
J032	ATG 51 78	267.08	267.15	ore texture; ga/sph
J039	ATG 51 78	252.37	252.47	clast cavity geometry
J050	ATG 51 78	267.38	267.46	sph>ga>py in barite

Raw data

sample	spot	Pb	S	Bi	Cu	Fe	Cd	total
J045	A1	84.31	13.41	0.04				97.76
J045	A2	86.60	13.59	0.20				100.39
J045	A3	86.32	13.65	0.10	0.03			100.10
J032	B4	85.00	13.53	0.11				98.64
J032	B5	86.50	13.38		0.05			99.93
J032	C6	85.33	13.97	0.04	0.06			99.40
J031	D7	86.39	13.81	0.13	0.05		0.02	100.40
J031	D8	85.69	13.59		0.05			99.33
J039	E9	87.70	13.61	0.11		0.03		101.45

no detectable Ag, Sb, As, or Mn (detection limits approximately 0.02 weight %)

Table 8: Sphalerite compositions
Jubilee deposit, Victoria County, Nova Scotia
Electron microprobe analyses
Compositions recalculated to 100 Weight %

sample	spot	Zn	S	Fe	Cd	Cu	Bi	total
J032	A1	66.49	33.06	0.05	0.40	0.00	0.00	100
J032	A2	66.04	33.23	0.73	0.00	0.00	0.00	100
J032	A3	66.49	32.96	0.00	0.55	0.00	0.00	100
J032	B4	65.88	33.46	0.65	0.00	0.00	0.00	100
J032	B5	66.81	33.16	0.03	0.00	0.00	0.00	100
J032	B6	66.16	33.25	0.00	0.59	0.00	0.00	100
J032	C7	66.69	32.64	0.67	0.00	0.00	0.00	100
J032	C8	66.41	33.11	0.49	0.00	0.00	0.00	100
J032	D10	66.44	33.00	0.56	0.00	0.00	0.00	100
J093	E11	65.55	33.33	0.84	0.11	0.17	0.00	100
J093	F12	66.74	32.78	0.37	0.04	0.07	0.00	100
J045	G10	66.26	33.07	0.03	0.54	0.00	0.10	100
J045	G11	66.45	32.79	0.40	0.36	0.00	0.00	100
J045	H13	66.37	33.27	0.05	0.32	0.00	0.00	100
J050	K14	65.62	33.33	1.01	0.00	0.00	0.04	100
J050	K15	64.45	33.37	2.18	0.00	0.00	0.00	100
J050	K17	66.59	32.90	0.41	0.06	0.00	0.04	100
J039	L22	66.63	32.97	0.04	0.33	0.00	0.03	100
J031	M23	66.70	32.86	0.44	0.00	0.00	0.00	100

grain A adjacent to barite (with significant Sr content)
- spot 1 intermediate between spots 1 and 2
- spot 2 furthest from sphalerite/barite grain boundary
- spot 3 closest to sphalerite/barite grain boundary

grain B within barite
- spot 4 grain centre
- spot 5 between spots 4 and 5
- spot 6 grain rim

grain C is zoned with reddish brown bands
- spot 7 coloured band
- spot 8 adjacent to spot 7 in pale yellow sphalerite

grain D adjacent galena grain

grain E small and surrounded by calcite scattered with disseminated pyrite

grain F abuts pyrite grain sharply

grain G surrounded by calcite near analyzed galena
- spot 10 grain centre
- spot 11 adjacent pyrite inclusion

grain H spot in grain centre in inclusion in analyzed galena

grain K zoned and banded fragment on pyrite in barite
- spot 14 adjacent pyrite
- spot 15 narrow red band in pale yellow sphalerite
- spot 17 adjacent barite

grain L spot in grain centre; grain in calcite and anhydrite

grain M in analyzed barite near analyzed galena

Table 8 continued

sample	drillcore	sample interval in meters from	to	description
J032	ATG 51 78	267.08	267.15	ore texture; ga/sph
J093	ATG 44 77	140.26	140.36	py-sph in ls breccia
J045	TG 12 75	33.18	33.25	ga-calcite-sph in cgl
J050	ATG 51 78	267.38	267.46	sph>ga>py in barite
J039	ATG 51 78	252.37	252.47	clast cavity geometry
J031	ATG 51 78	266.56	266.63	ore texture; ga/sph

Raw data

sample	spot	Zn	S	Fe	Cd	Cu	Bi	total
J032	A1	66.06	32.85	0.05	0.40			99.36
J032	A2	66.21	33.32	0.73				100.26
J032	A3	67.57	33.49		0.56			101.62
J032	B4	66.45	33.75	0.66				100.86
J032	B5	66.78	33.14	0.03				99.95
J032	B6	66.21	33.27		0.59			100.07
J032	C7	67.11	32.85	0.67				100.63
J032	C8	67.00	33.40	0.49				100.89
J032	D10	66.19	32.88	0.56				99.63
J093	E11	64.34	32.72	0.82	0.11	0.17		98.16
J093	F12	67.59	33.20	0.37	0.04	0.07		101.27
J006	G10	66.00	32.94	0.03	0.54		0.1	99.61
J006	G11	65.97	32.55	0.40	0.36			99.28
J006	H13	64.82	32.49	0.05	0.31			97.67
J050	K14	64.69	32.86	1.00			0.04	98.59
J050	K15	63.48	32.87	2.15				98.50
J050	K17	65.87	32.54	0.41	0.06		0.04	98.92
J039	L22	66.51	32.91	0.04	0.33		0.03	99.82
J031	M23	66.24	32.63	0.44				99.31

(detection limits approximately 0.02 weight %)

FIGURE CAPTIONS

Fig. 1. Selected lithological sections of the Horton and Lower Windsor Groups, Nova Scotia (from Smith and Collins, 1979).

Fig. 2. A) Generalized geological map and measured sections; B) Horton depositional setting and megafacies (from Hamblin, 1988).

Fig. 3. Lithostratigraphic section correlating the Walton Barite Mine, Kaiser Celestite Mine and Coxheath Hills area (from Smith and Collins, 1979).

Fig. 4. Trace element compositions.

Fig. 5. Low magnification photomicrograph of pisolitic/laminated limestone. Sample TG-17-4C.

Fig. 6. Low magnification photomicrograph of pisolitic/laminated limestone, showing dispersed intraclasts. Sample ATG-15-519.

Fig. 7. Low magnification photomicrograph of convoluted limestone. Sample ATG-15-413.3.

Fig. 8. Low magnification photomicrograph of laminated limestone, minor fracture offset, with microfaults, both normal and reverse. Sample TG-9-3A.

Fig. 9. Higher magnification photomicrograph, illustrating the grain-contacts between the slightly-disrupted laminated limestone, and the calcite-infilling between the disrupted "clasts." Sample TG-9-3A.

Fig. 10. Higher magnification photomicrograph of topmost conglomerate, with large pebbles and granular quartz matrix. ATG-17-1B.

Fig. 11. Low magnification photomicrograph of breccia clasts within interbedded transitional evaporite/limestone horizon. Note dispersed nature, and reorientation of limestone clasts. Calcite veining surrounds some of the clasts, and other veining is within individual clasts, suggesting that calcite veining occurred early (prior to brecciation), as well as after dispersion of the breccia clasts . These features suggest that some of the breccia may be syn-diagenetic in origin. Sample ATG-17-3B.

Fig. 12. Low magnification photomicrograph of breccia clasts within interbedded transitional evaporite/limestone horizon. Note the fracture offset of individual clasts, and the reorientation and bent shape to limestone clasts. Sample TG-17-5b.

Fig. 13. Low magnification photomicrograph of breccia clasts within interbedded transitional evaporite/limestone horizon. Note the sheared appearance to the remaining limestone clasts, and their dispersed texture. Sample TG-17-7A.

Fig. 14. Facies relationship diagram for clastic successions of the Horton Group, subsurface cores, Jubilee area (n = 378 transitions).

Fig. 15. Facies relationship diagram for carbonate and interbedded carbonate/evaporite successions of the Windsor Group, subsurface cores, Jubilee area (n = 168 transitions).

Fig. 16. Associations of structural features in the clastic successions of the Horton Group and in the carbonate successions of the Windsor Group, subsurface cores, Jubilee area (n = 286 transitions).

Fig. 17. Restored cross-section C1, corrected across faults: cores ATG 41-77, 43-78, 44-77, 39-77 (for location of cores see Enclosures 2 and 3).

Fig. 18. Restored lithologic correlations, corrected across faults: cores ATG 41-77, 43-78, 44-77, 39-77.

Fig. 19. Facies percentages (on the basis of thickness percentages per core); cores ATG 41-77, 43-78, 44-77, 39-77.

Fig. 20. Restored cross-section C2, corrected across faults: cores ATG 53-78, 51-78, 49-78 (for location of cores see enclosures 2,3).

Fig. 21. Restored lithologic correlations, corrected across faults: cores ATG 53-78, 51-78, 49-78.

Fig. 22. Facies percentages (on the basis of thickness percentages per core); cores ATG 53-78, 51-78, 49-78.

Fig. 23. Restored cross-section C3, corrected across faults: cores ATG 33-77, 70-79, 72-79, 71-79.

Fig. 24. Restored lithologic correlations, corrected across faults: cores ATG 33-77, 70-79, 72-79, 71-79.

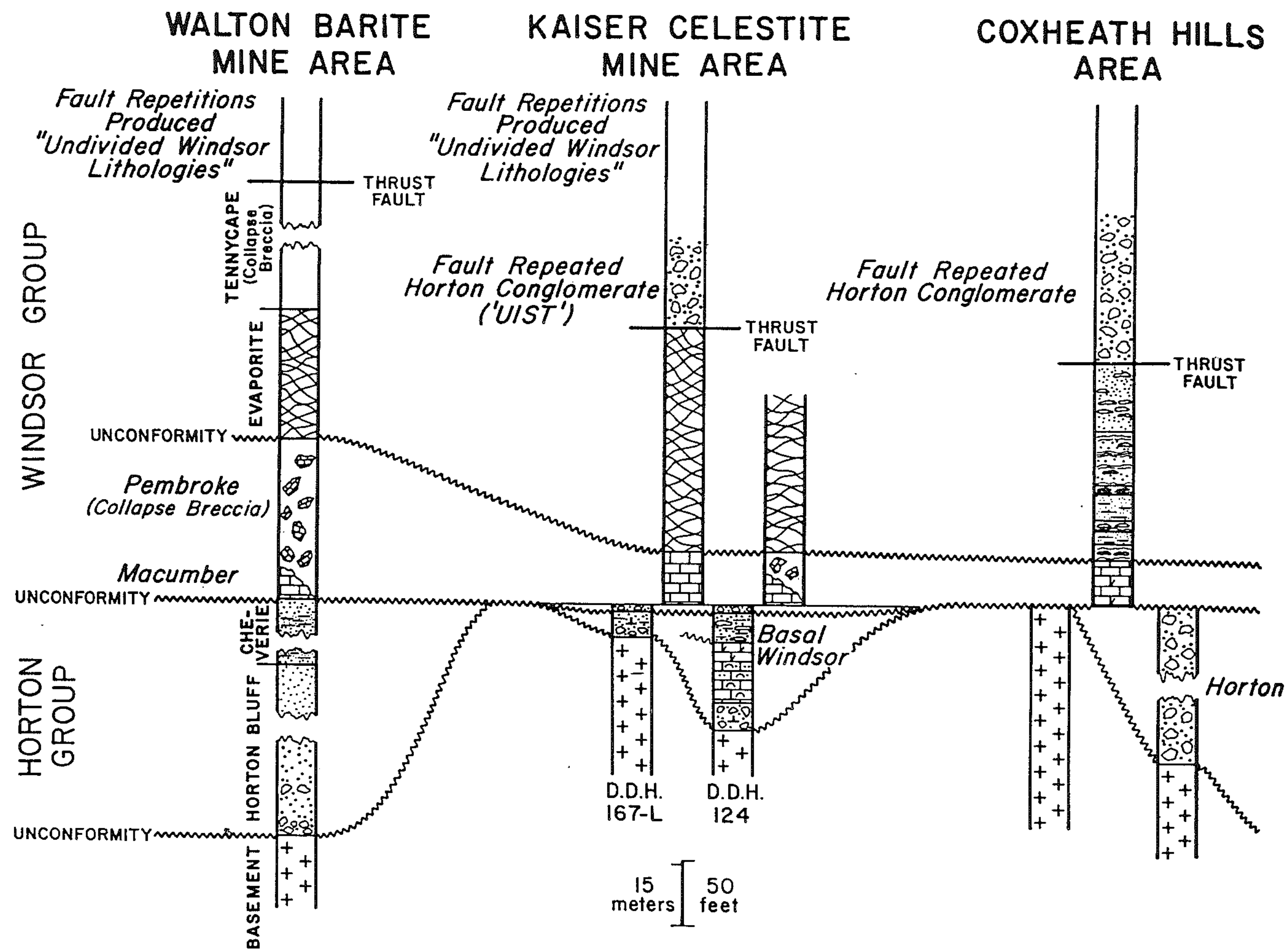

WALTON BARITE MINE AREA
KAISER CELESTITE MINE AREA
COXHEATH HILLS AREA
Fault Repetitions Produced "Undivided Windsor Lithologies"
THRUST FAULT
Fault Repetitions Produced "Undivided Windsor Lithologies"
Fault Repeated Horton Conglomerate ('UIST')
THRUST FAULT
Fault Repeated Horton Conglomerate
THRUST FAULT
WINDSOR GROUP
TENNYCAPE (Collapse Breccia)
EVAPORITE
UNCONFORMITY
Pembroke (Collapse Breccia)
Macumber
UNCONFORMITY
CHE-VERIE
HORTON GROUP
HORTON BLUFF
HORTON
UNCONFORMITY
BASEMENT
Basal Windsor
Horton
D.D.H. 167-L
D.D.H. 124
15 meters
50 feet

FIGURE 1

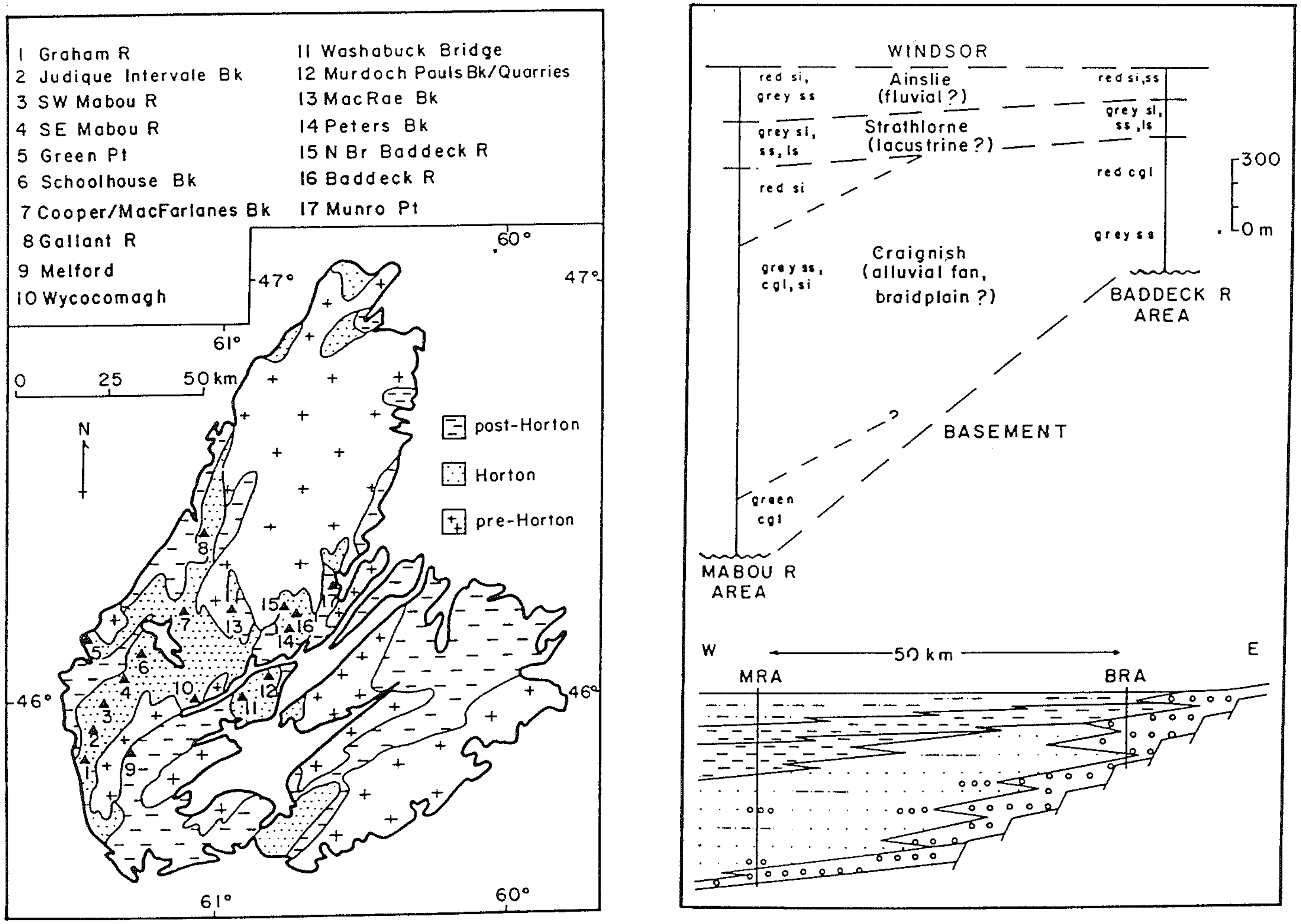

1 Graham R
2 Judique Intervale Bk
3 SW Mabou R
4 SE Mabou R
5 Green Pt
6 Schoolhouse Bk
7 Cooper/MacFarlanes Bk
8 Gallant R
9 Melford
10 Wycocomagh
11 Washabuck Bridge
12 Murdoch Pauls Bk/Quarries
13 MacRae Bk
14 Peters Bk
15 N Br Baddeck R
16 Baddeck R
17 Munro Pt
0 25 50 km
N
post-Horton
Horton
pre-Horton
61°
60°
47°
46°
WINDSOR
Ainslie
(fluvial ?)
Strathlorne
(lacustrine ?)
Craignish
(alluvial fan,
braidplain ?)
BASEMENT
red si,
grey ss
grey si,
ss, ls
red si
grey ss,
cgl, si
green
cgl
red si,ss
grey si,
ss, ls
red cgl
grey ss
300
0 m
MABOU R
AREA
BADDECK R
AREA
W
E
50 km
MRA
BRA

FIGURE 2

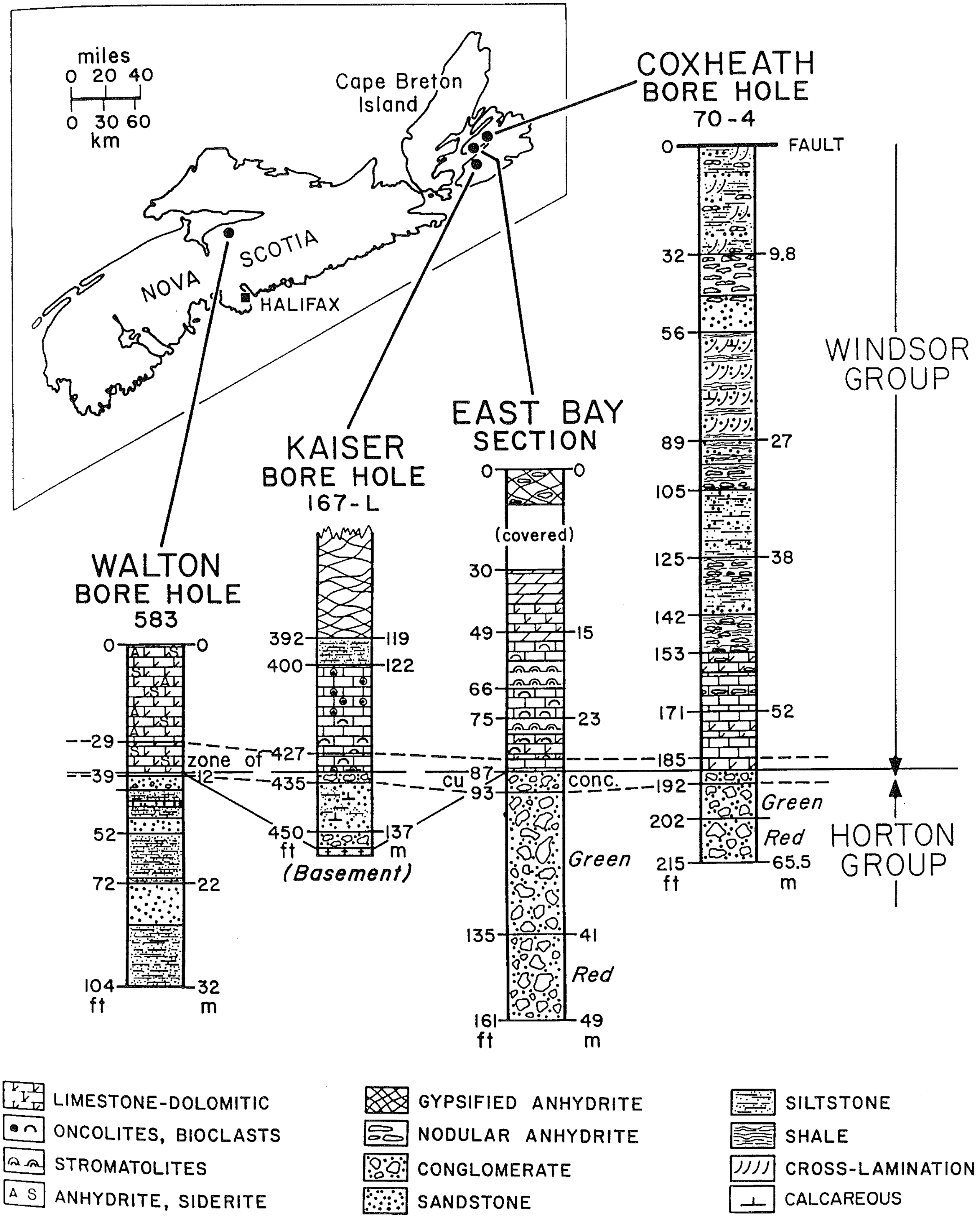

miles
0 20 40
0 30 60
km
Cape Breton Island
NOVA SCOTIA
HALIFAX
COXHEATH BORE HOLE 70-4
FAULT
WINDSOR GROUP
HORTON GROUP
Green
Red
EAST BAY SECTION
(covered)
conc.
cu
Green
Red
KAISER BORE HOLE 167-L
(Basement)
WALTON BORE HOLE 583
zone of
ft
m
LIMESTONE-DOLOMITIC
ONCOLITES, BIOCLASTS
STROMATOLITES
ANHYDRITE, SIDERITE
GYPSIFIED ANHYDRITE
NODULAR ANHYDRITE
CONGLOMERATE
SANDSTONE
SILTSTONE
SHALE
CROSS-LAMINATION
CALCAREOUS

FIGURE 3

Trace Element Compositions

Microprobe Analyses

Jubilee Zn-Pb Deposit

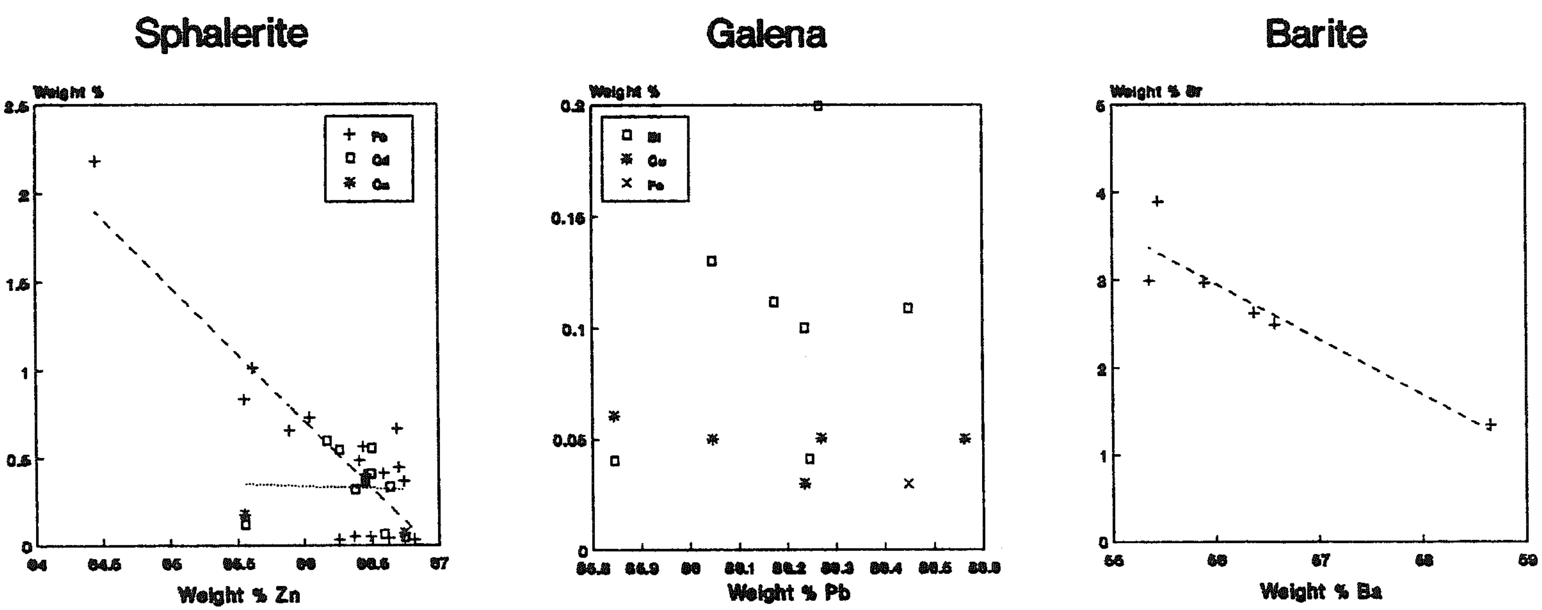


FIGURE 4

Fig. 5.

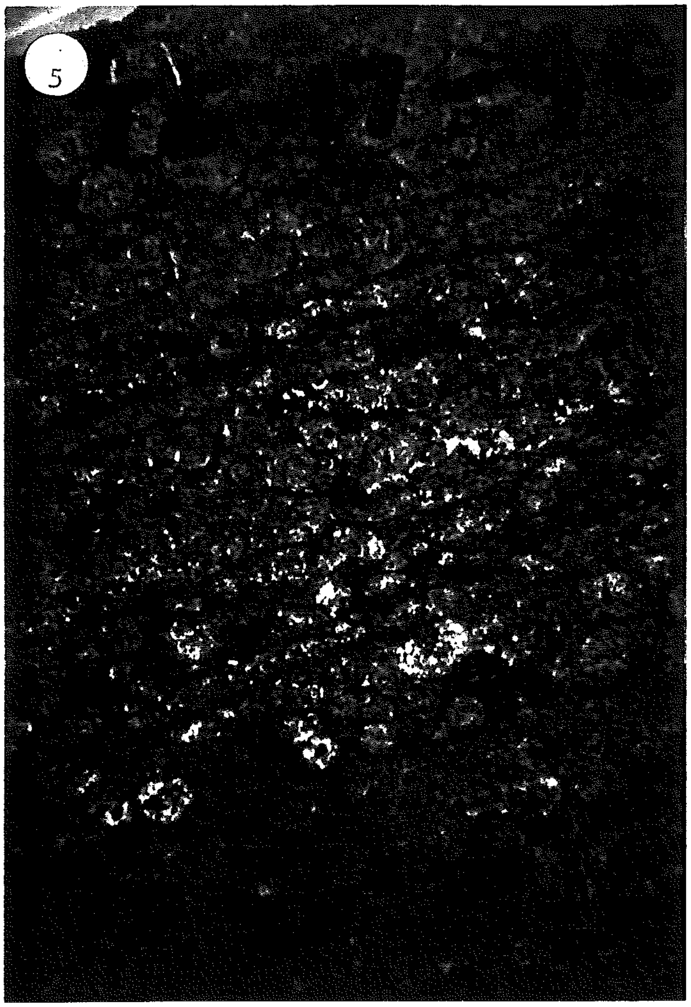
Low magnification photomicrograph of pisolitic/laminated limestone. Sample TG-17-4C

Fig. 6.

Low magnification photomicrograph of pisolitic/laminated limestone, showing dispersed intraclasts. Sample ATG-15-519

Fig. 7.

Low magnification photomicrograph of convoluted limestone. Sample ATG-15-413.3


5


6


7

Fig. 8.

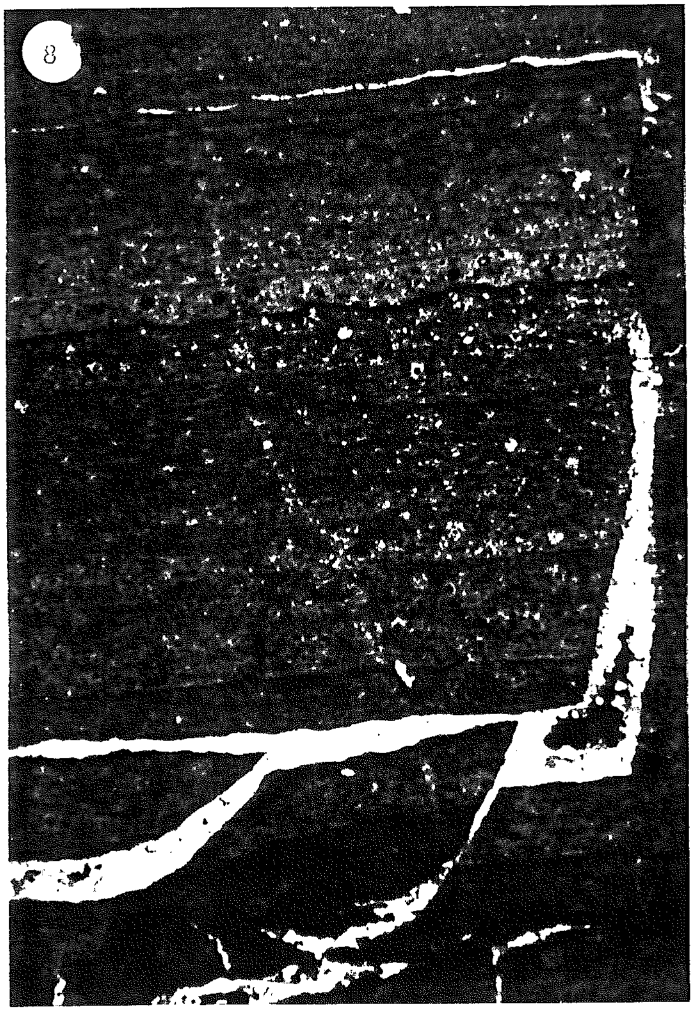
Low magnification photomicrograph of laminated limestone, minor fracture offset, with microfaults, both normal and reverse.
Sample TG-9-3A (Roll #1, #16)

Fig. 9.

Higher magnification photomicrograph, illustrating the grain-contacts between the slightly-disrupted laminated limestone, and the calcite-infilling between the disrupted "clasts."
Sample TG-9-3A

Fig. 10.

Higher magnification photomicrograph of topmost conglomerate, with large pebbles and granular quartz matrix.
Sample ATG-17-1B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9

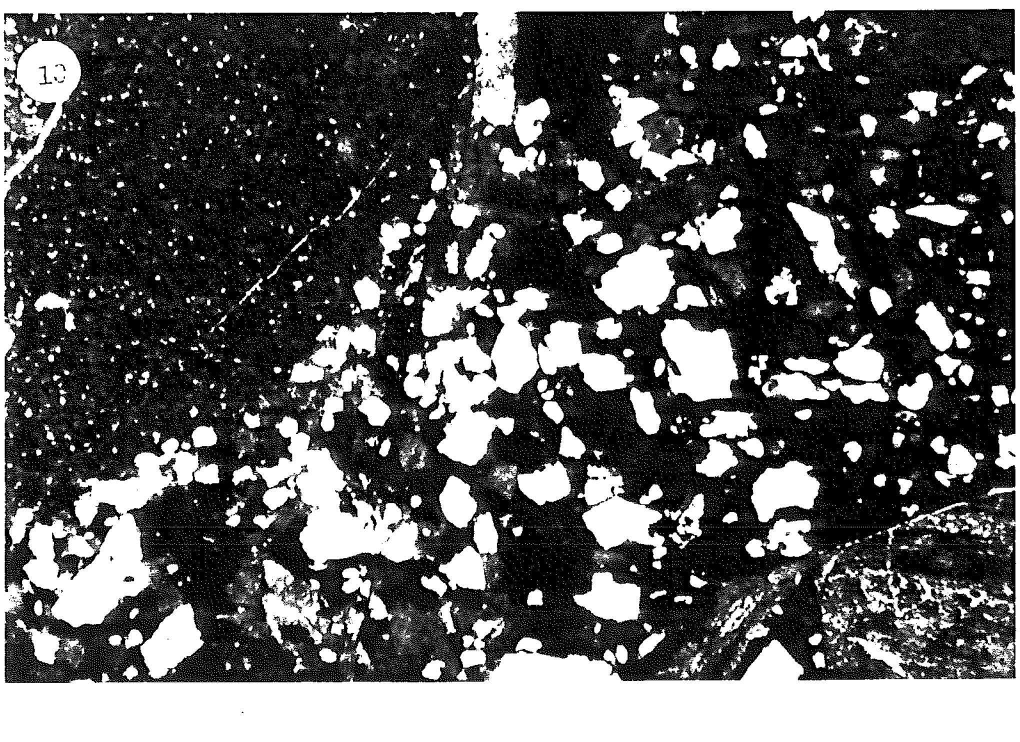

10

Fig. 11.

Low magnification photomicrograph of breccia clasts within interbedded transitional evaporite/limestone horizon. Note dispersed nature, and reorientation of limestone clasts. Calcite veining surrounds some of the clasts, and other veining is within individual clasts, suggesting that calcite veining occurred early (prior to brecciation), as well as after dispersion of the breccia clasts. These features suggest that some of the breccia may be syn-diagenetic in origin.
Sample ATG-17-3B.

Fig. 12.

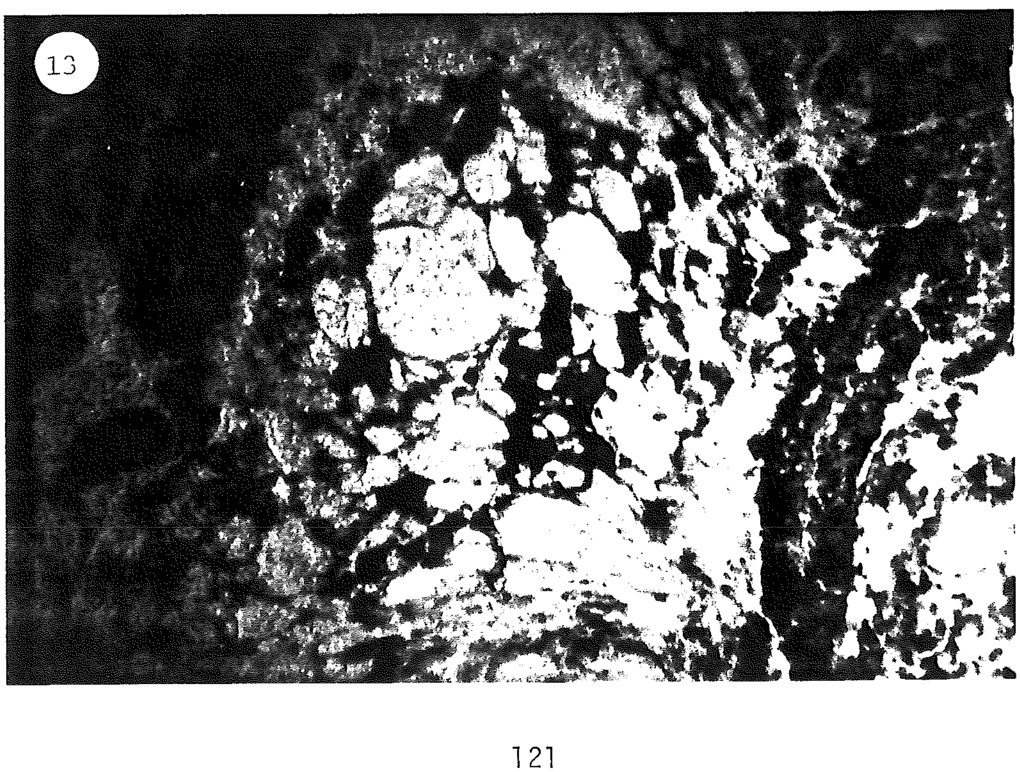
Low magnification photomicrograph of breccia clasts within interbedded transitional evaporite/limestone horizon. Note the fracture offset of individual clasts, and the reorientation and bent shape to limestone clasts.
Sample TG-17-5B

Fig. 13.

Low magnification photomicrograph of breccia clasts within interbedded transitional evaporite/limestone horizon. Note the sheared appearance to the remaining limestone clasts, and their dispersed texture.
Sample TG-17-7A


11


12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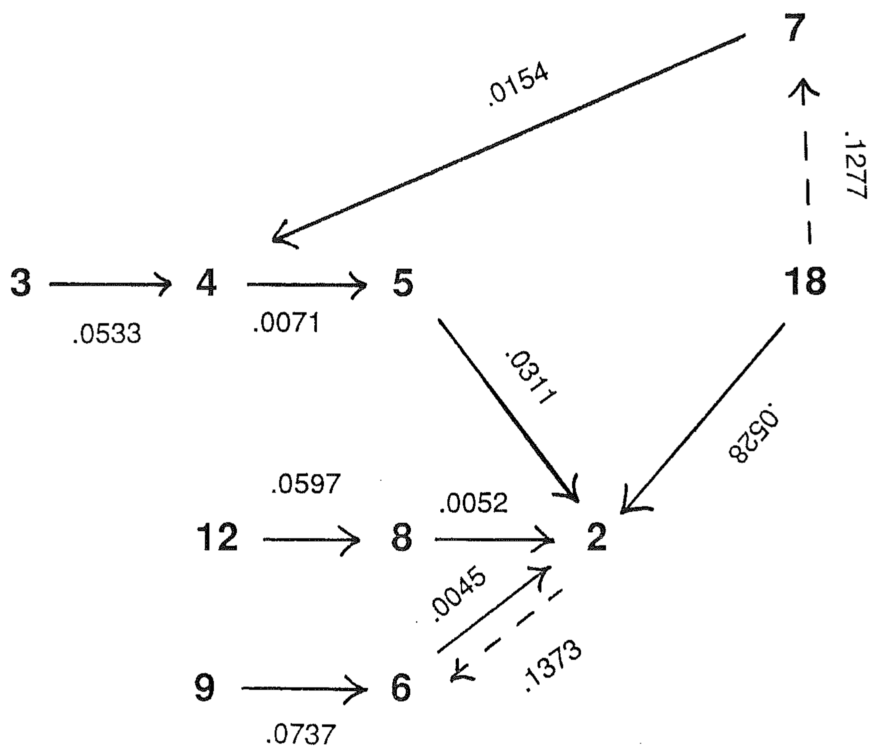
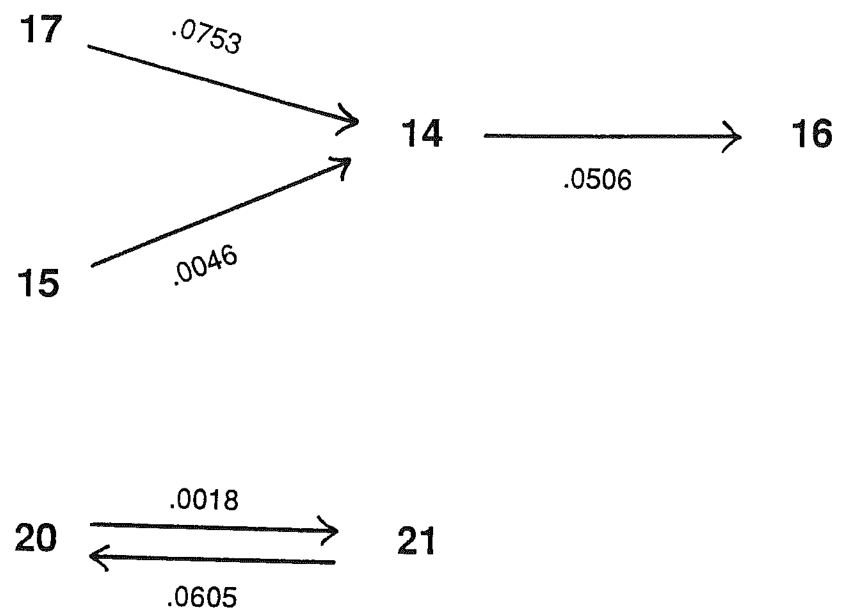


HORTON CONGLOMERATE

Markov chain of the most significant lithofacies transitions for the clastic facies association. Gingerich-Read method of row-scaling with Harper's binomial probability test of significance. Level of significance is the probability of the observed frequency of transitions if the thransitions were truly random. Transitions shown have a significance at the 90% confidence level (i.e. cutoff= 0.10).

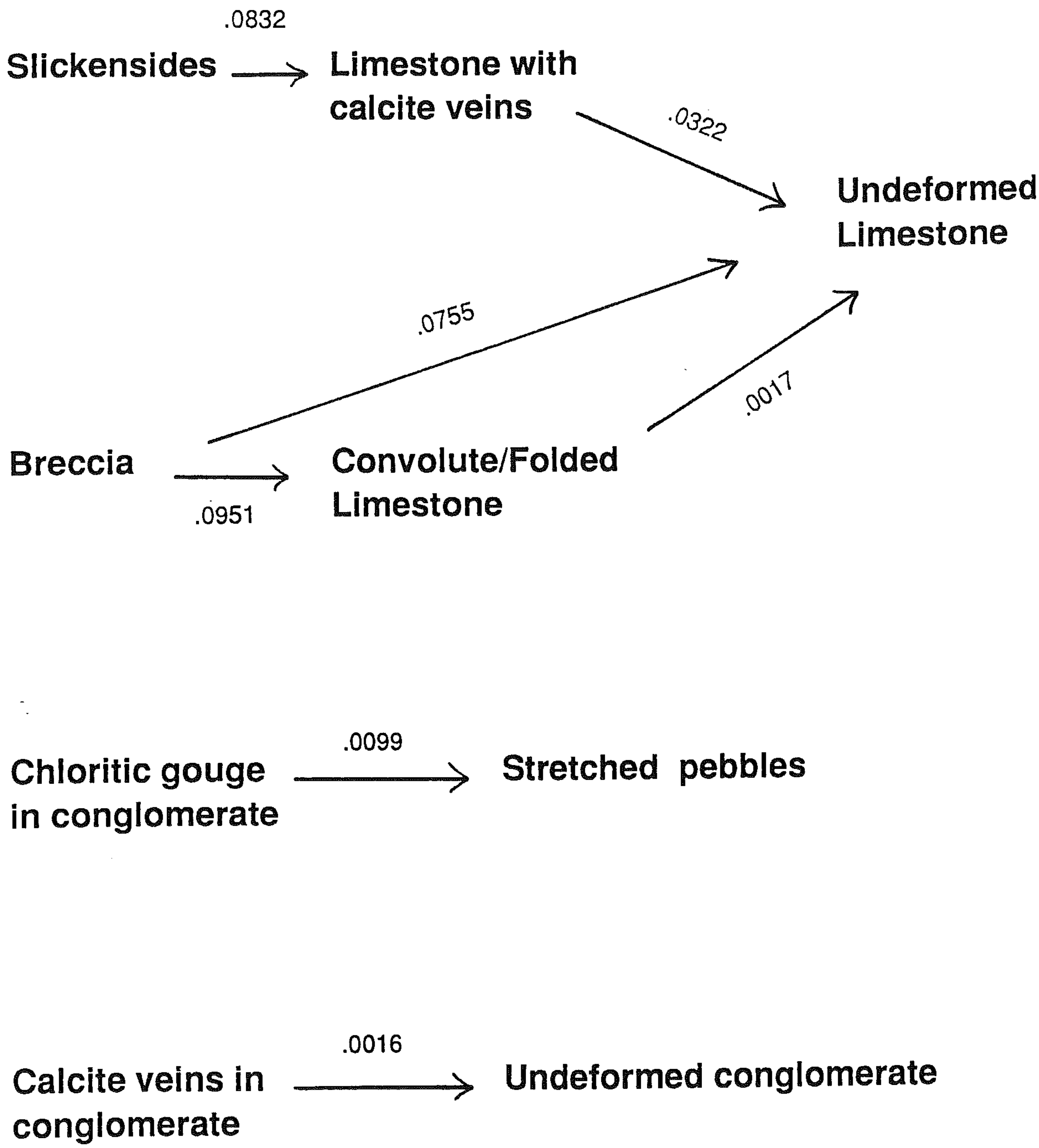
FIGURE 14



WINDSOR CARBONATE

Markov chain of the most significant lithofacies transitions for the carbonate and interbedded evaporite facies associations. Gingerich-Read method of row-scaling with Harper's binomial probability test of significance. Level of significance is the probability of the observed frequency of transitions if the thransitions were truly random. Transitions shown have a significance at the 90% confidence level (i.e. cutoff= 0.10).

FIGURE 15



Markov chain of the most significant transitions for structural features in the carbonate and interbedded evaporite facies associations (topmost), and the clastic facies association (middle and lower). Gingerich-Read method of row-scaling with Harper's binomial probability test of significance. Level of significance is the probability of the observed frequency of transitions if the thransitions were truly random. Transitions shown have a significance at the 90% confidence level (i.e. cutoff= 0.10).

FIGURE 16

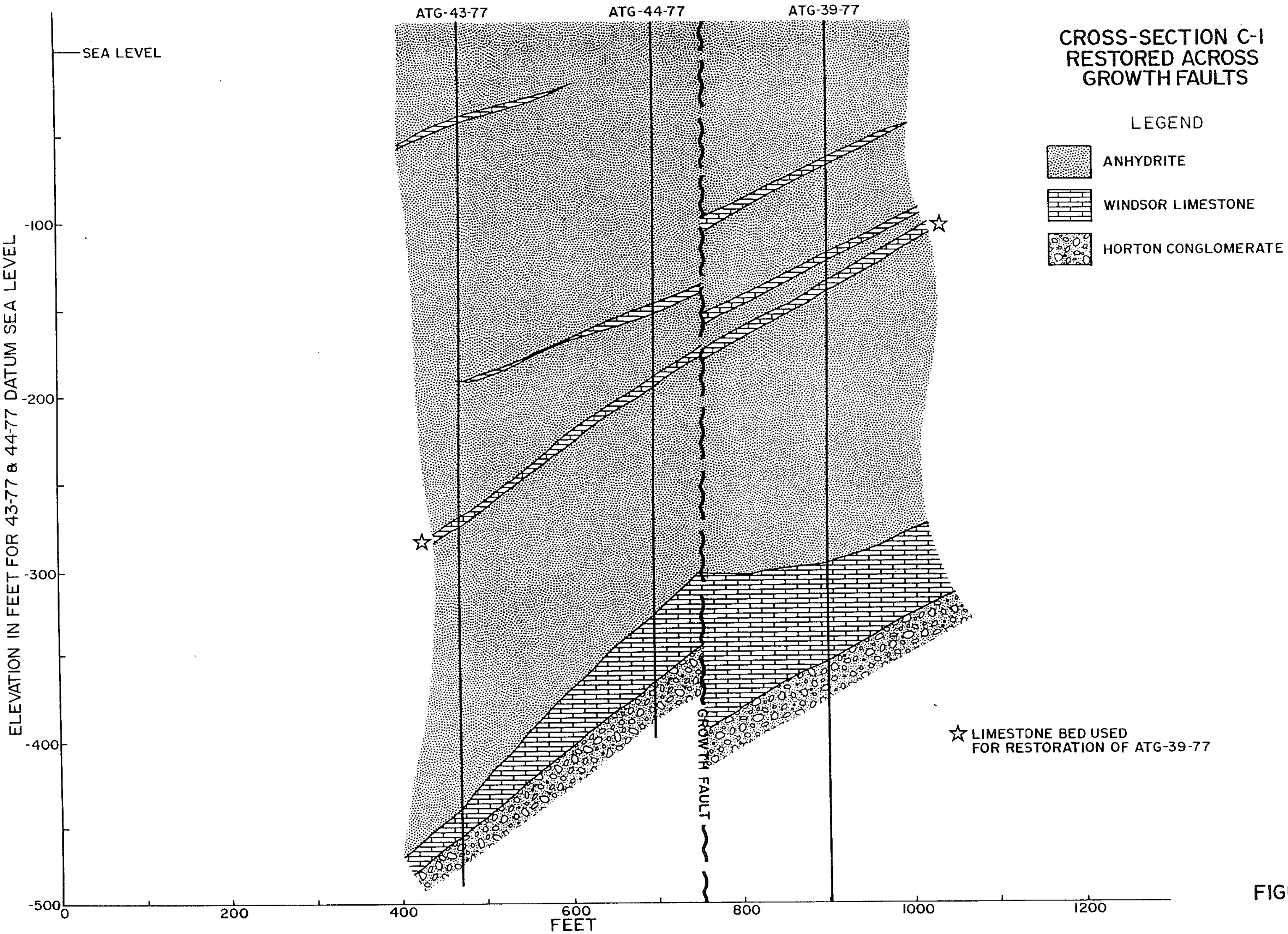

CROSS-SECTION C-1
RESTORED ACROSS
GROWTH FAULTS
LEGEND
ANHYDRITE
WINDSOR LIMESTONE
HORTON CONGLOMERATE
ATG-43-77
ATG-44-77
ATG-39-77
SEA LEVEL
GROWTH FAULT
☆ LIMESTONE BED USED
FOR RESTORATION OF ATG-39-77
ELEVATION IN FEET FOR 43-77 & 44-77 DATUM SEA LEVEL
-100
-200
-300
-400
-500
0
200
400
600
800
1000
1200
FEET

FIGURE 17

RESTORED
LITHOLOGIC CORRELATIONS C-1
CORRECTED ACROSS GROWTH FAULT
CORRECTED FOR REGIONAL DIP

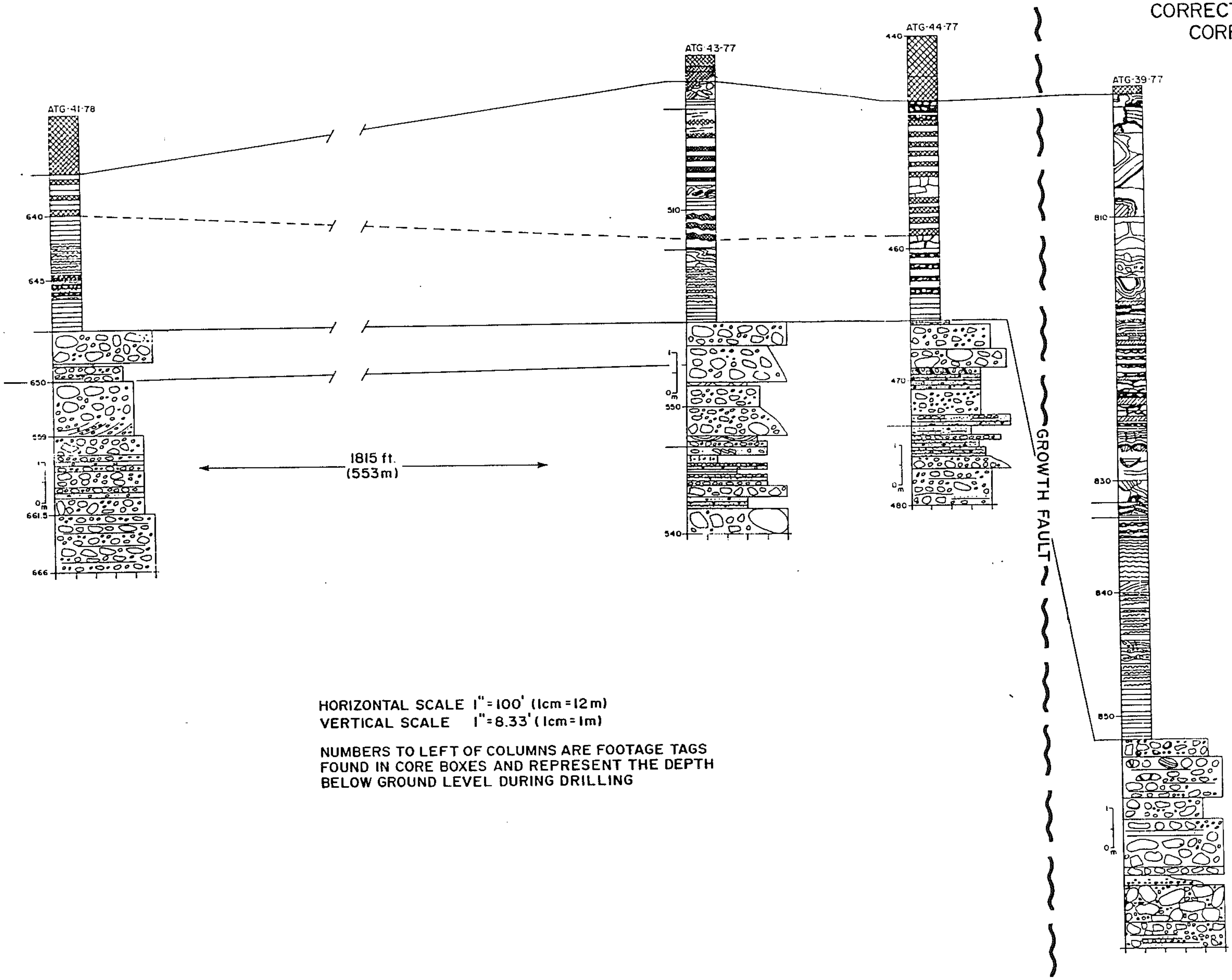
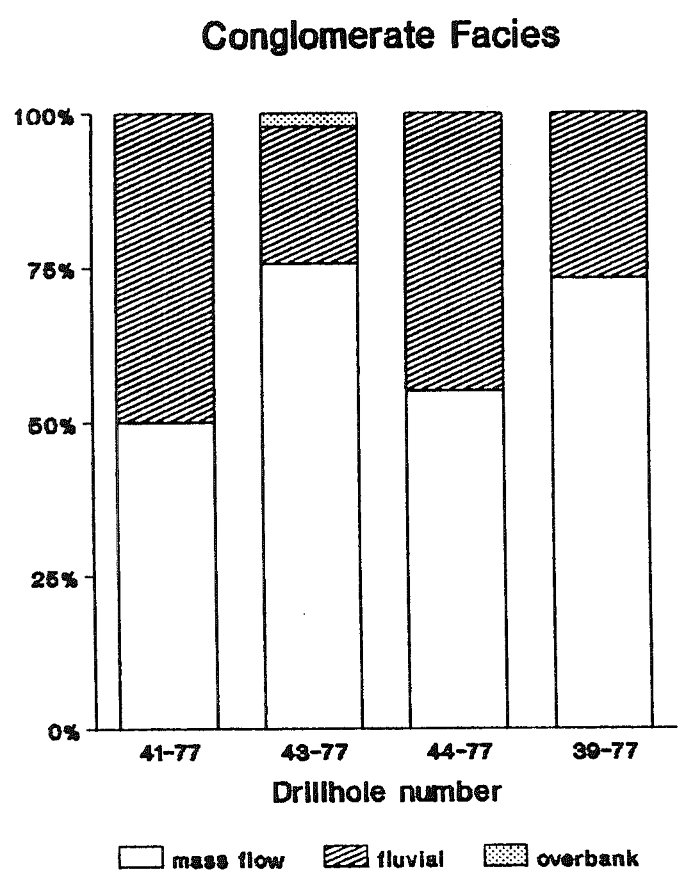


FIGURE 18

Facies Percentage (percentage of thickness per core)

Cross Section C1



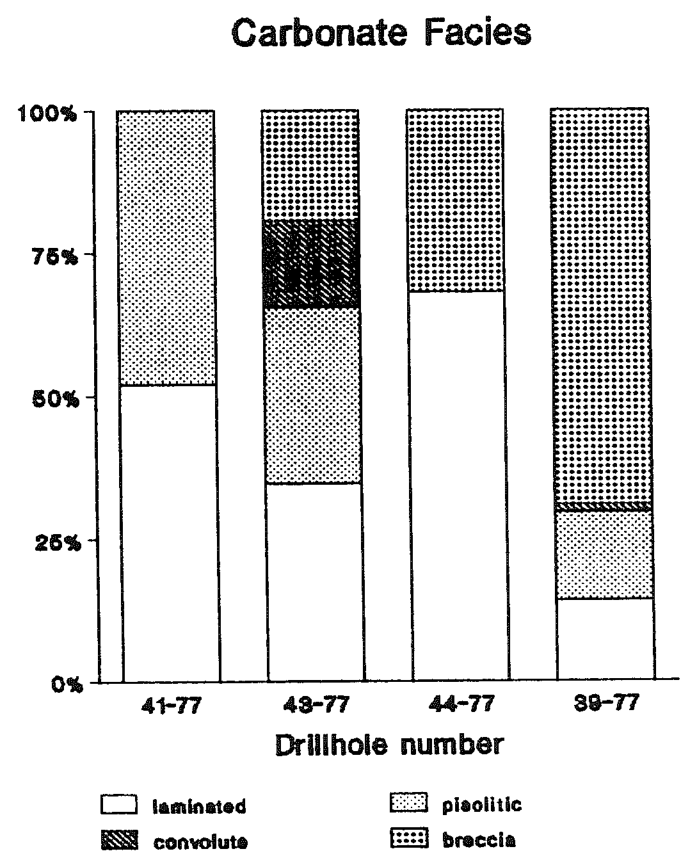
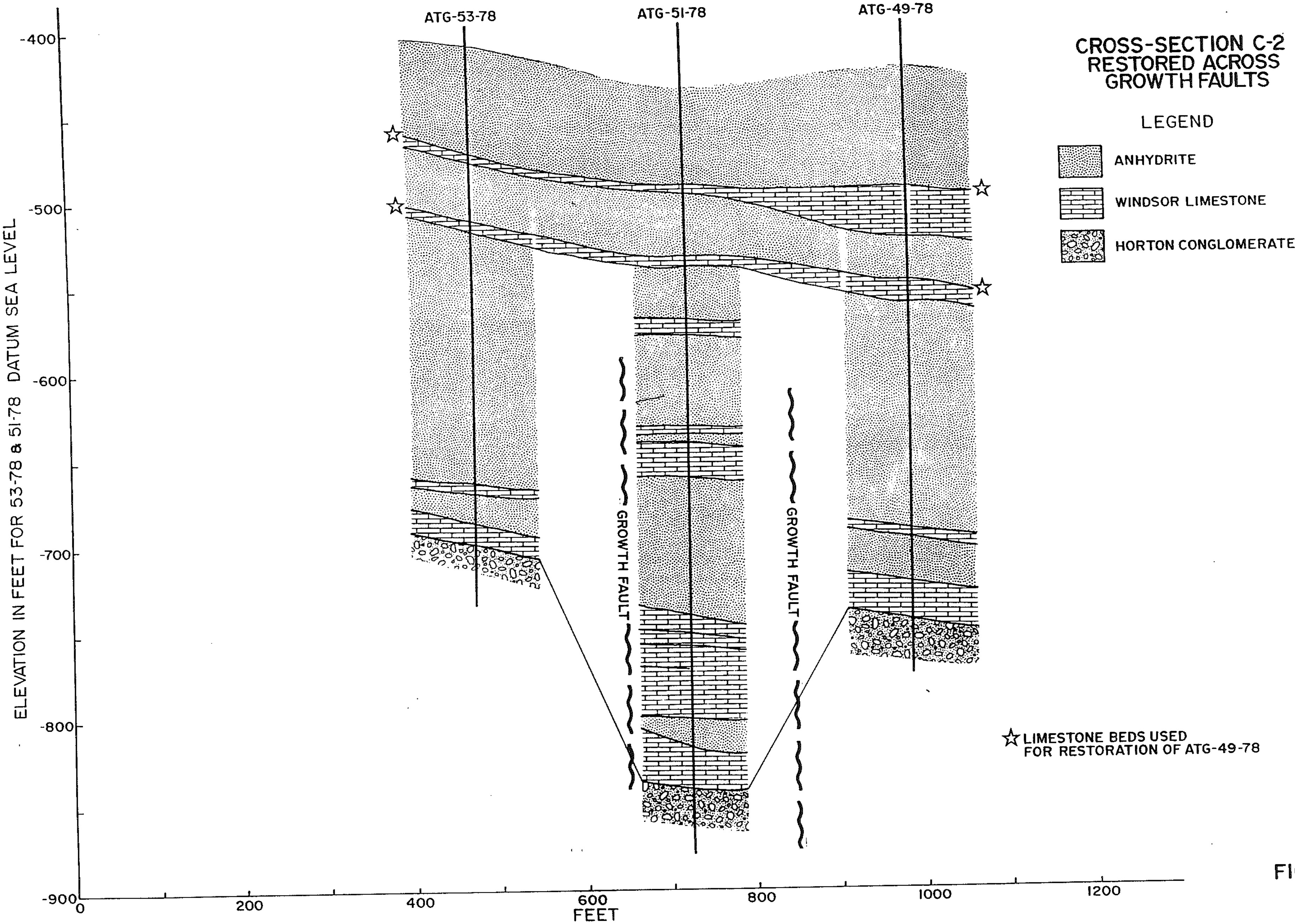


FIGURE 19



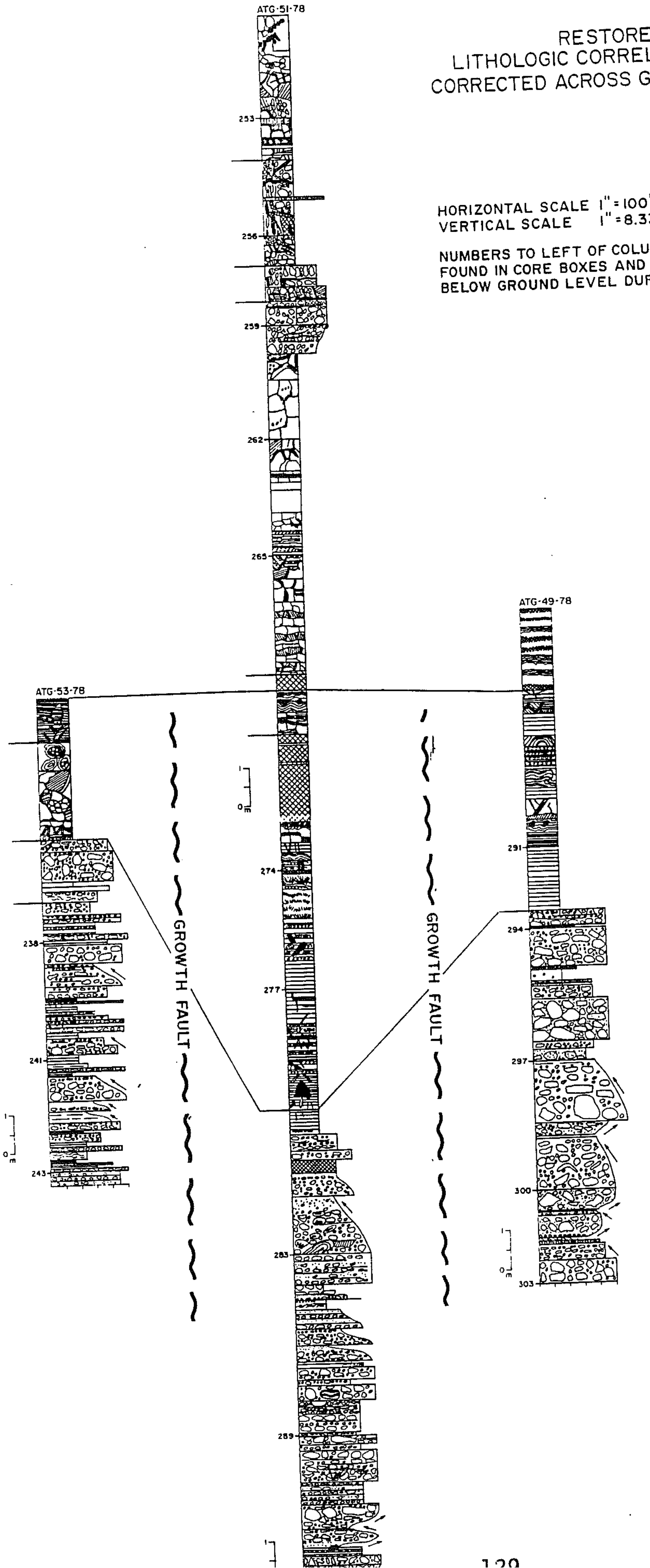
CROSS-SECTION C-2
RESTORED ACROSS
GROWTH FAULTS
LEGEND
ANHYDRITE
WINDSOR LIMESTONE
HORTON CONGLOMERATE
ATG-53-78
ATG-51-78
ATG-49-78
GROWTH FAULT
GROWTH FAULT
LIMESTONE BEDS USED
FOR RESTORATION OF ATG-49-78
ELEVATION IN FEET FOR 53-78 & 51-78 DATUM SEA LEVEL
-400
-500
-600
-700
-800
-900
0
200
400
600
800
1000
1200
FEET

FIGURE 2

RESTORED
LITHOLOGIC CORRELATIONS C-2
CORRECTED ACROSS GROWTH FAULT

HORIZONTAL SCALE 1" = 100' (1cm = 12m)
VERTICAL SCALE 1" = 8.33' (1cm = 1m)

NUMBERS TO LEFT OF COLUMNS ARE FOOTAGE TAGS FOUND IN CORE BOXES AND REPRESENT THE DEPTH BELOW GROUND LEVEL DURING DRILLING

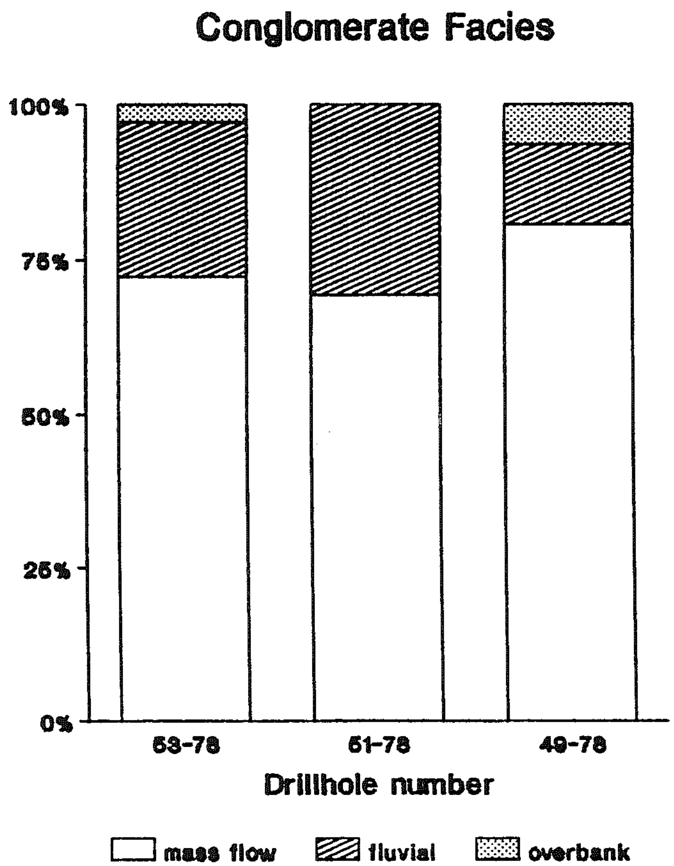


RESTORED
LITHOLOGIC CORRELATIONS C-2
CORRECTED
ACROSS GROWTH FAULT

FIGURE 21

Facies Percentage (percentage of thickness per core)

Cross Section C2



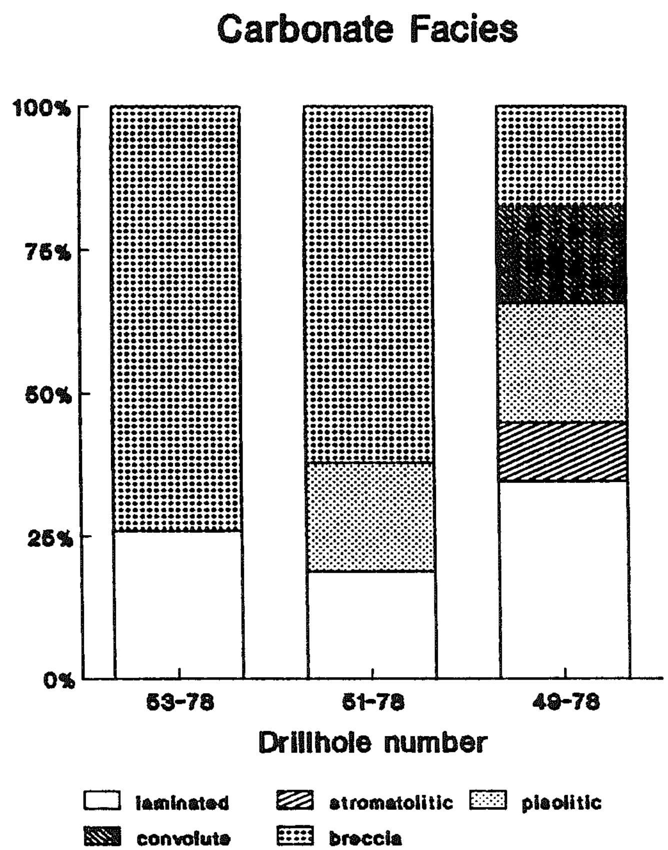


FIGURE 22

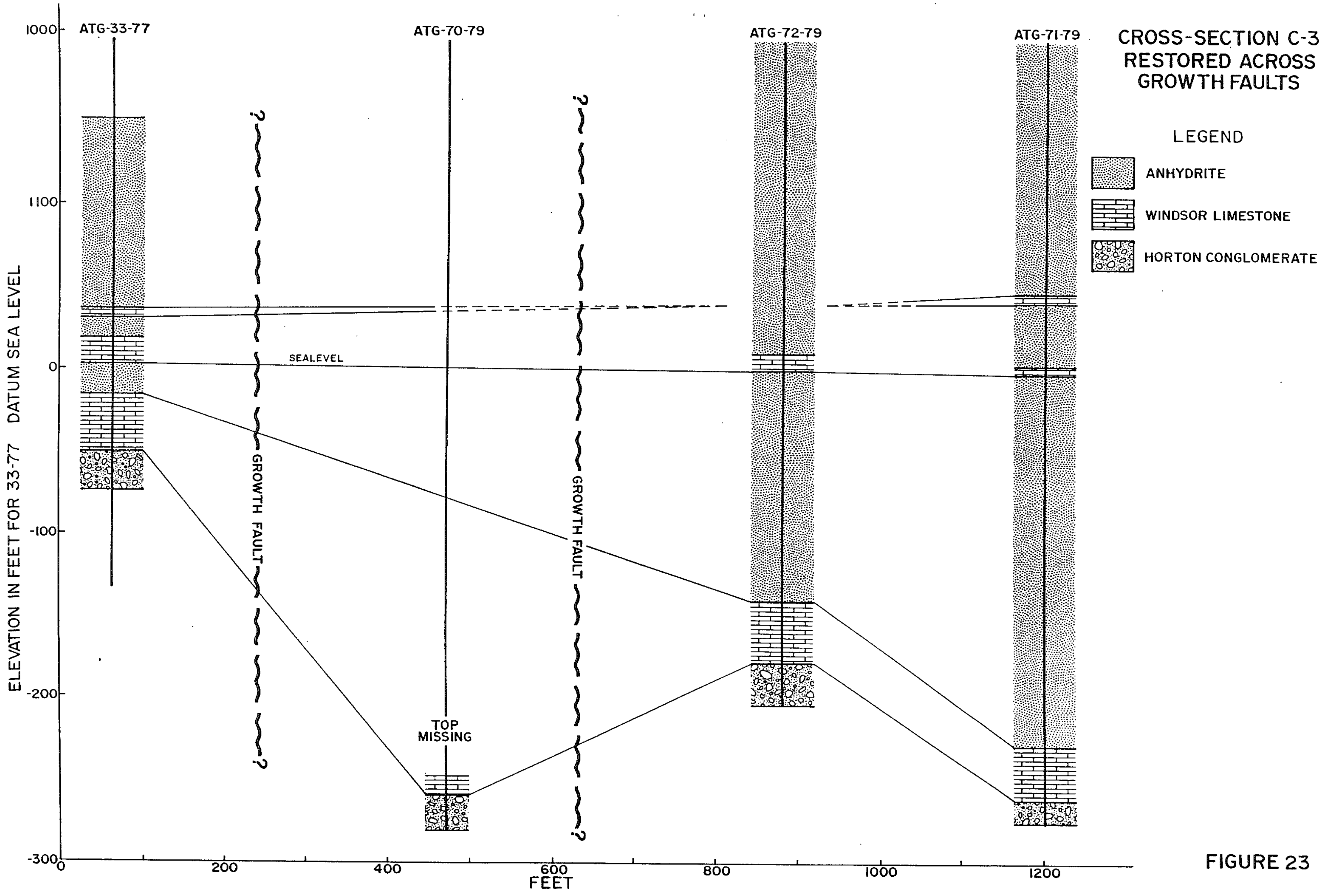

CROSS-SECTION C-3
RESTORED ACROSS
GROWTH FAULTS
LEGEND
ANHYDRITE
WINDSOR LIMESTONE
HORTON CONGLOMERATE
ATG-33-77
ATG-70-79
ATG-72-79
ATG-71-79
SEALEVEL
GROWTH FAULT
GROWTH FAULT
TOP
MISSING
ELEVATION IN FEET FOR 33-77 DATUM SEA LEVEL
1000
1100
0
-100
-200
-300
0
200
400
600
800
1000
1200
FEET

FIGURE 23

RESTORED FENCE
LITHOLOGIC CORRELATIONS C-3
CORRECTED ACROSS
GROWTH FAULT(S)

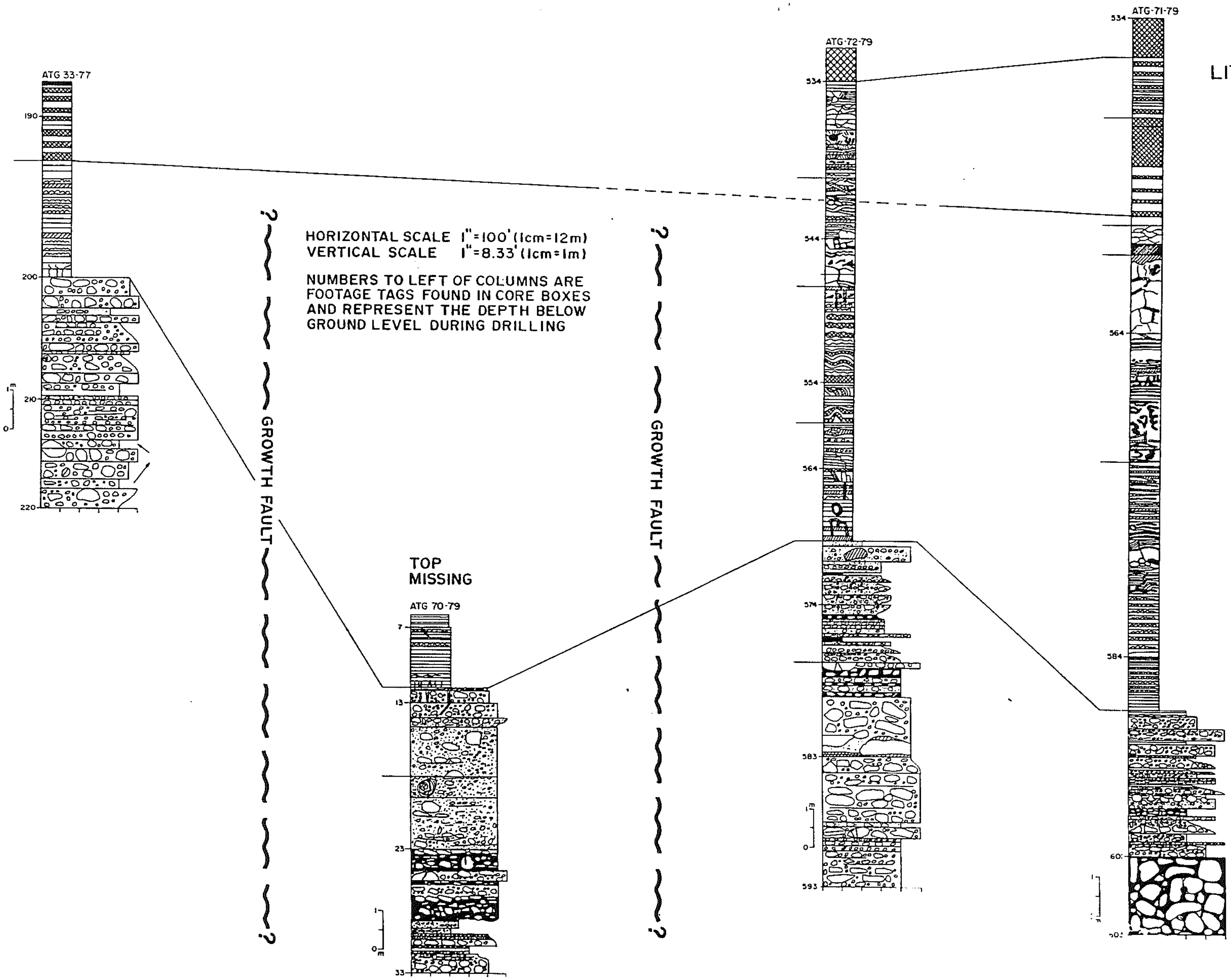
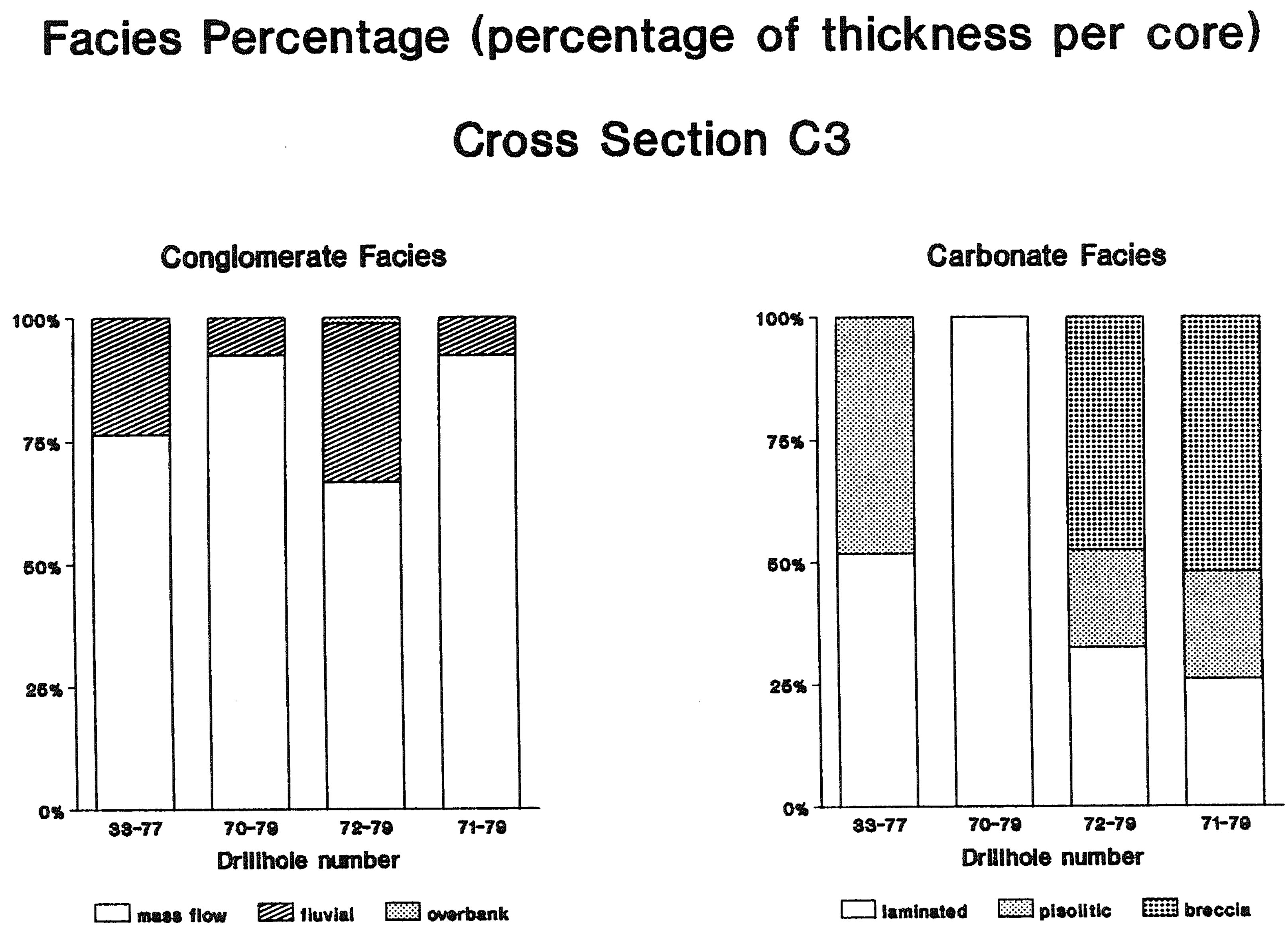


FIGURE 24



Facies Percentage (percentage of thickness per core)
Cross Section C3
Conglomerate Facies
100%
75%
50%
25%
0%
33-77
70-79
72-79
71-79
Drillhole number
mass flow
fluvial
overbank
Carbonate Facies
100%
75%
50%
25%
0%
33-77
70-79
72-79
71-79
Drillhole number
laminated
pisolitic
breccia

FIGURE 25

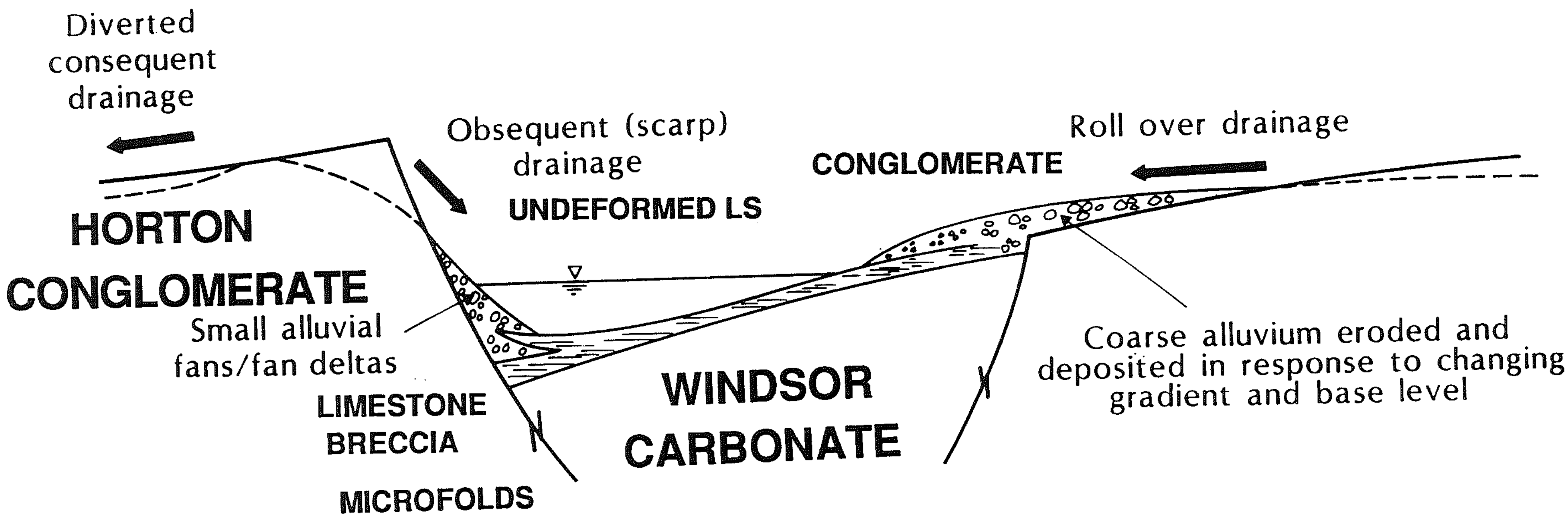

Diverted consequent drainage
Obsequent (scarp) drainage
UNDEFORMED LS
CONGLOMERATE
Roll over drainage
HORTON CONGLOMERATE
Small alluvial fans/fan deltas
LIMESTONE BRECCIA
MICROFOLDS
WINDSOR CARBONATE
Coarse alluvium eroded and deposited in response to changing gradient and base level

FIGURE 26

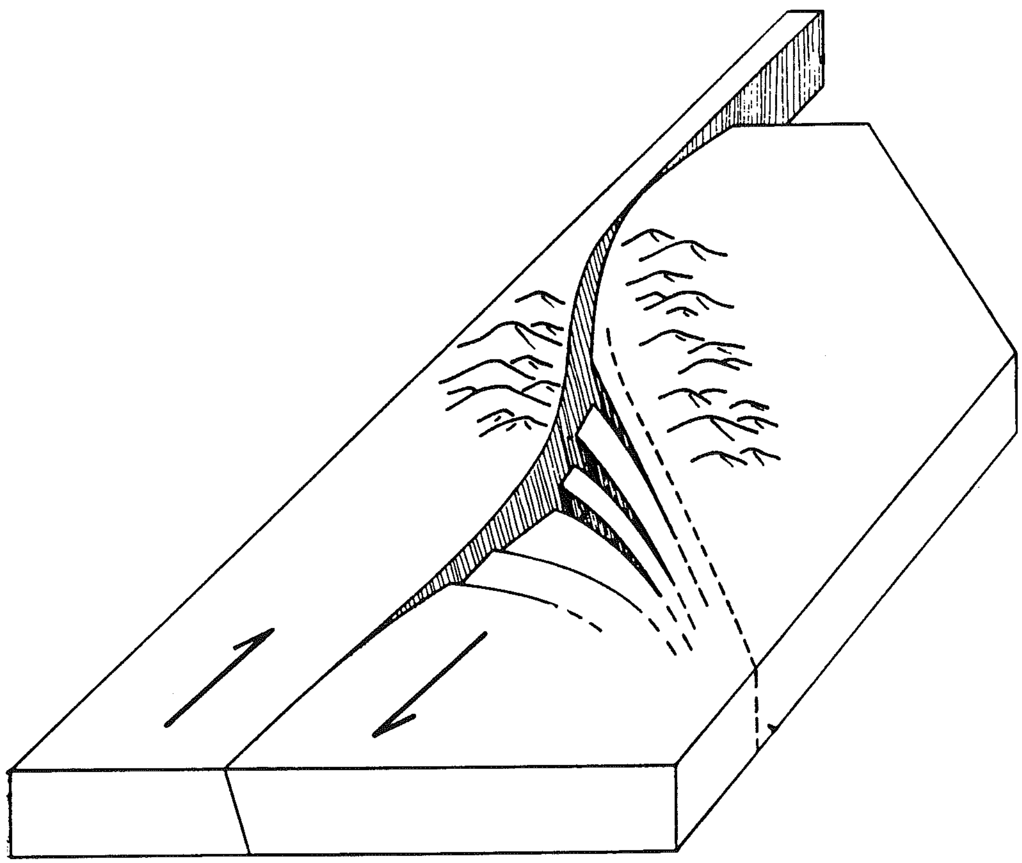


FIGURE 27