GEOLOGY OF CARBONIFEROUS STRATA IN THE DEER LAKE (12H/3) AND RAINY LAKE (12A/14) MAP AREAS, NEWFOUNDLAND

by

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INTRODUCTION

Carboniferous rocks in the Deer Lake region of western Newfoundland were deposited in an intermontane trough called the Deer Lake Basin. A thorough knowledge of the stratigraphy and structure of the basin is important because of the presence of energy-related resources such as uranium, coal, shale oil, and natural gas (Hayes, 1949; Baird, 1950; Fleming, 1970; Hyde, 1979; Hyde and Ware, 1980). This paper summarizes the results of geologic mapping of Carboniferous strata in the central and southern portions of the Deer Lake Basin (within the Deer Lake (12H/3) and Rainy Lake (12A/14) map areas). The entire basin has now been mapped at a 1:50,000 scale. Pre-Carboniferous rocks marginal to and within the basin are also briefly discussed.

Two major Carboniferous stratigraphic units are present in the area mapped, namely, the Anguille Group (Tournaisian) and the overlying Deer Lake Group (Visean-Westphalian A). Hyde (1979) subdivided the Anguille Group into six informal units, three of which occur in the area mapped in 1980. These three units were first delineated by Popper (1970). From stratigraphic bottom to top, these are: (1) a siltstone + lithic sandstone + tan carbonate unit; (2) a siltstone + lithic sandstone unit; and (3) a siltstone + lithic sandstone + arkose unit. Estimated maximum thicknesses for the three units in the map area are 1000 m, 1500 m, and 1000 m, respectively. Werner (1955), Baird (1959), and Belt (1969) have subdivided the Deer Lake Group into four formations, all of which outcrop in the map area. These are, from bottom to top: (1) the North Brook Formation; (2) the Rocky Brook Formation; (3) the Humber Falls Formation; and (4) the Howley Beds (Howley Beds may be partially equivalent to the Humber Falls Formation).

Physiographically, the Deer Lake Basin is rimmed by an upland area underlain by pre-Carboniferous rocks. Internally, the basin is marked by two up-faulted highland areas which are mainly underlain by Anguille Group rocks, called the Birchy Ridge - White Bay block and the Glide Mountain block. These structural blocks are largely surrounded by lowlands that are underlain by the Deer Lake Group.

Significant findings in 1980 are: (1) geographic extension of uranium occurrences in the Deer Lake Group; (2) discovery of bituminous rocks and minor copper mineralization in the Deer Lake Group; (3) confirmation of Popper's (1970) subdivision of the Anguille Group; (4) discovery of an area underlain by the Howley Beds on the western side of Grand Lake; and (5) subdivision of the Glide Mountain block into three smaller blocks, one of which contrasts structurally with the other two.

In addition to these findings, the contact between the North Brook and Rocky Brook Formations is redefined.

STRATIGRAPHY

ORDOVICIAN OR OLDER

Quartz-mica schist, quartzite, phyllite (Unit 1a)

These rocks occur in a fault-bounded slice and are probably part of the Fleur dy Lys Supergroup. A prominent cleavage

LEGEND

CARBONIFEROUS

DEER LAKE GROUP

11 **Howley Beds:** 11a, Red and gray pebble conglomerate, minor cobble-boulder conglomerate, gray, red, tan, and green, very fine to very coarse grained sandstone, red, gray, and green siltstone and mudstone, minor gray microcrystalline limestone, coal, ironstone; arranged in poorly defined fining upward sequences; 11b, gray and green, medium to very coarse grained sandstone and pebble conglomerate, red, gray brown, and green, very fine to fine grained sandstone and siltstone, minor gray microcrystalline limestone; arranged in well-defined fining upward sequences.

10 **Humber Falls Formation:** Gray and red, coarse to very coarse grained sandstone, red, gray, and light green pebble and granule conglomerate, red, fine to medium grained sandstone.

9 **Rocky Brook Formation:** 9a, Calcareous, red and gray siltstone, gray and green mudstone,,gray, microcrystalline and stromatolitic limestone, minor red and gray, fine to medium grained sandstone, oil shale; 9b, calcareous, gray siltstone, gray and green mudstone, gray microcrystalline, stromatolitic, and oolitic limestone, dark brown oil shale.

8 **North Brook Formation:** 8a, Mainly red, pebble to cobble conglomerate, also gray conglomerate and red, medium to very coarse grained sandstone; 8b, mainly red, brown, and reddish gray, medium to very coarse grained sandstone, minor conglomerate and siltstone; 8c, mainly gray and greddish gray, medium to very coarse grained sandstone and siltstone arranged in well-defined fining upward sequences; 8d, mainly red, very fine to medium grained sandstone and red siltstone.

ANGUILLE GROUP

7 **Coarse grained arkose unit:** Mainly very fine to medium grained, dark gray sandstone, dark gray siltstone, black mudstone, but with thick bedded, gray and pink, coarse to very coarse grained arkose and pebble conglomerate, minor gray microcrystalline limestone.

6 **Gray sandstone unit:** Very fine to fine grained, dark gray sandstone, dark gray siltstone, and black mudstone; all of above alternating with light gray, medium to very coarse grained sandstone; minor pebble conglomerate, calcareous siltstone and sandstone, gray microcrystalline limestone, limestone breccia.

5 **Tan carbonate unit:** Mainly very fine to fine grained, dark gray sandstone, dark gray siltstone, black mudstone, and light gray, medium to coarse grained sandstone, but with thin to medium bedded, tan and orange carbonate interbedded with dark gray siltstone and black mudstone.

PRE-CARBONIFEROUS (?)

4 Green and gray schistose metaconglomerate, metasandstone, green chloritic schist.

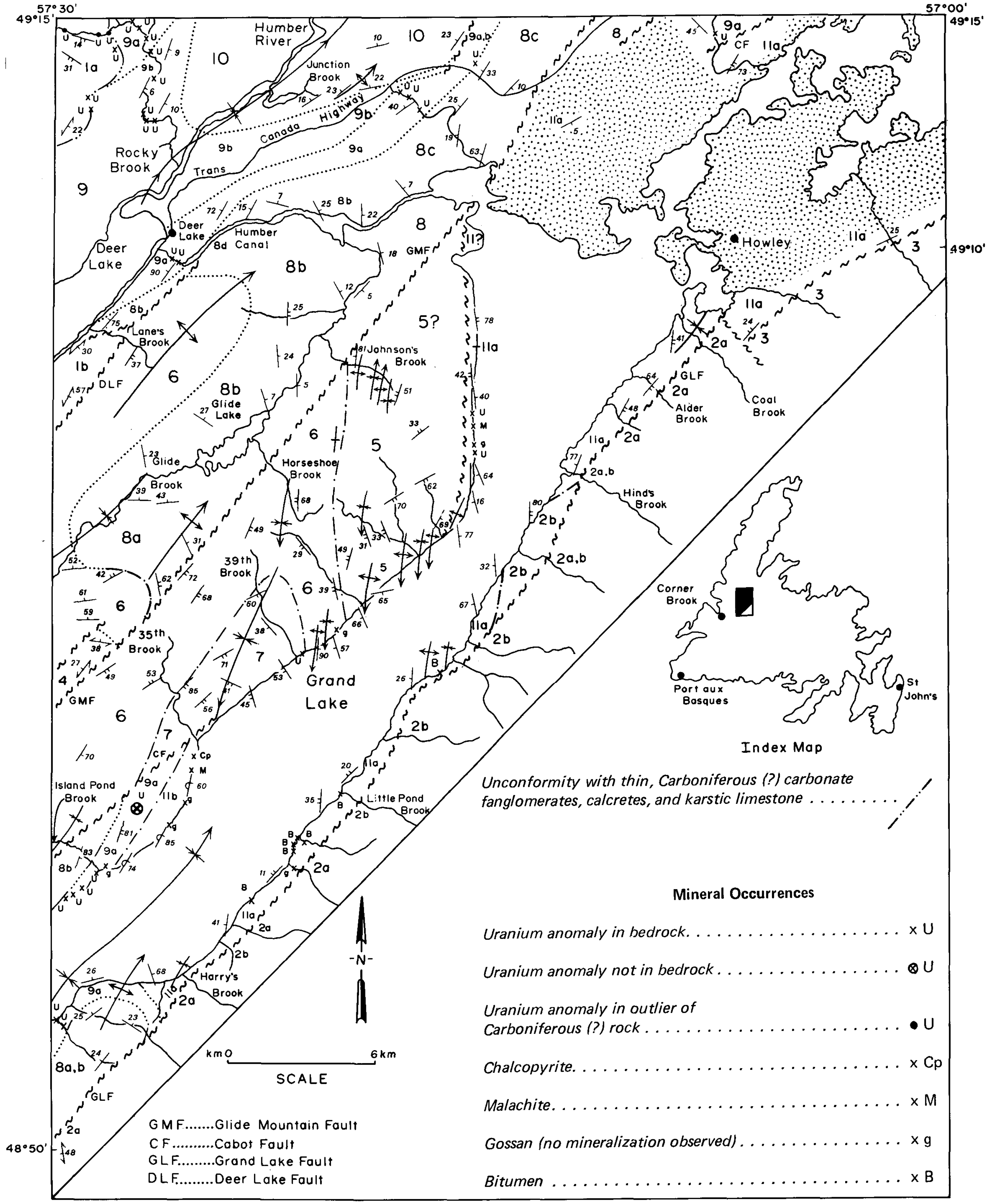
SILURIAN-DEVONIAN

3 Fine to medium grained, gray and pink, equigranular granite with minor amounts ofmuscovite and hornblende.

2 2a, Massive and pillowed, amygdaloidal, dark gray and green, mafic to intermediate volcanic rocks, some feldspar phyric varieties; 2b, red, pink, and gray felsic to intermediate volcanic rocks, mainly welded tuff, nonwelded lapilli tuff and agglomerate; minor sandstone.

ORDOVICIAN AND/OR OLDER

1 1a, Gray, buff, and black marble, minor chlorite schist; 1b, quartz-mica schist, quartzite, phyllite.


57°30'
49°15'
57°00'
49°15'
49°10'
48°50'
Humber River
Junction Brook
Rocky Brook
Trans Canada Highway
Deer Lake
Humber Canal
Lane's Brook
Glide Lake
Glide Brook
Johnson's Brook
Horseshoe Brook
39th Brook
35th Brook
Grand Lake
Island Pond Brook
Little Pond Brook
Harry's Brook
Howley
Coal Brook
Alder Brook
Hind's Brook
GMF
GLF
DLF
CF
Index Map
Corner Brook
Port aux Basques
St John's
Unconformity with thin, Carboniferous (?) carbonate fanglomerates, calcretes, and karstic limestone
Mineral Occurrences
Uranium anomaly in bedrock . . . x U
Uranium anomaly not in bedrock . . . ⊗ U
Uranium anomaly in outlier of Carboniferous (?) rock . . . ● U
Chalcopyrite . . . x Cp
Malachite . . . x M
Gossan (no mineralization observed) . . . x g
Bitumen . . . x B
km 0
6 km
SCALE
-N-
GMF.......Glide Mountain Fault
CF..........Cabot Fault
GLF........Grand Lake Fault
DLF........Deer Lake Fault

is subparallel to bedding, and consistently dips towards the east. Examination of thin sections shows that these rocks have reached biotite grade metamorphism.

Carbonate rocks (Unit 1b)

Carbonate rocks, probably Cambrian in age, are in most places thoroughly recrystallized to a gray to buff, homogeneous, fine grained marble. However, marbles with quartz clasts up to 30 cm in size and laminated marbles with thin chloritic selvages are also present. Two small areas show preservation of stromatolites and trough crossbeds.

Silurian-Devonian volcanic rocks (Unit 2)

Green and gray, mafic to intermediate volcanic rocks (2a) are characteristically massive and amygdaloidal; the amygdules are usually on the order of 1-5 mm in long dimension (1.5 cm, the largest observed). The vesicles are usually filled with calcite, but some are filled with quartz and others are unfilled. Some of the rocks contain isotropically oriented plagioclase phenocrysts up to 2 mm in length. We also noted pillowed lavas and broken pillow breccias.

Felsic to intermediate volcanic rocks (2b) adjacent to the Deer Lake Basin are red, pink, and gray. Pinhead-size quartz and flesh-colored feldspars 1 mm in length are present in some rocks as phenocrysts. Many of the rocks appear to be pyroclastic, and include welded tuffs (very abundant), nonwelded lapilli tuffs, and agglomerates. Fragments in the agglomerates reach up to 5 cm in size and include mafic volcanic fragments and partially collapsed pumice. A felsite dike, oriented parallel to a foliation cutting mafic volcanic rocks, occurs in the extreme southwestern part of the map area. Quartz-feldspar porphyry (intrusive?) is present as a thin strip separating granitic rocks from Carboniferous strata southeast of Howley.

Our observations of texture suggest largely subaerial volcanism. This, in turn, suggests that these volcanic rocks are correlative with Silurian-Devonian volcanic rocks that are exposed along strike to the northeast of the map area (Mic Mac Lake Group, Springdale Group; Hyde, 1979, Taylor *et al.*, 1980).

Silurian-Devonian granitic rocks (Unit 3)

Pink and gray, equigranular granitic rocks are well exposed along the brook between Howley and Coal Brook. The granitic rocks are fine to medium grained and contain muscovite and amphibole.

Pre-Carboniferous metasedimentary rocks (Unit 4)

Foliated metaconglomerates and minor metasandstones and chloritic schists were previously regarded by Popper (1970) as the basal unit of the Anguille Group. In the Corner Brook map area, west of the present map area, Hyde (1970) also assigned similar rocks to the Anguille Group. These rocks are now, however, interpreted to be pre-Carboniferous in age based on the following points: (1) they are restricted to a beltlike region as an extension of a fault-bounded strip containing pre-Carboniferous volcanic rocks to the southwest in the Corner Brook map area (Hyde, 1979, Unit 14); (2) petrographic study of rocks from Unit 14 (Corner Brook map area, Hyde, 1979) revealed the presence of metasediments interbedded with felsic volcanic rocks; (3) the metaconglomerates are more deformed than the typical sedimentary rocks of the Anguille Group; and (4) chlorite grade metamorphism in the metaconglomerates has not been seen elsewhere in the Anguille Group.

CARBONIFEROUS

Anguille Group (Units 5-7)

Within the map area, the Anguille Group (Tournaisian) outcrops in the Glide Mountain structural block. This block is geographically bounded in this area by Deer and Grand Lakes on its flanks, and the Humber Canal to the northeast. We agree with Popper's (1970) subdivision of the Anguille Group in the map area, and wish to emphasize (as did Popper) that: (1) contacts between the units are gradational and (2) thin to medium bedded, dark gray, very fine to medium grained sandstones, dark gray siltstones, and black carbonaceous mudstones are the most common lithologies in each of the three units. Rather than repeat these lithologies throughout the text, these will be termed the common facies association (CFA). Southeast of the Glide Mountain Fault, the following succession, in ascending order is recognized.

Tan carbonate unit (Unit 5)

Interbedded with siltstones and mudstones of the CFA beds are laminae and beds (range: <1 mm to 50 cm thick, average about 5 cm) of tan and orange weathering, gray carbonate rocks. These carbonates are commonly impure, and grade compositionally into calcareous siltstones. The carbonate fraction consists of micrite and microspar of a probable iron-rich carbonate mineral (Popper, 1970, stated that the carbonate is a ferroan dolomite, but we found many examples in the field that fizzed readily with cold, 10% HCl, suggesting that some of the carbonate is calcite). Layers of the carbonate show sharp but irregular boundaries with the interbedded siltstones and mudstones. Internally, the beds are laminated, cross-laminated, or massive. In some areas, the carbonate layers have been pulled apart, broken, and slumped due to soft-sediment deformation.

In the CFA, sandstones are dominantly fine grained and micaceous. Some beds are plant bearing, whereas others contain tan carbonate nodules up to 2 cm in diameter. Bedding in the CFA beds tends to be even and persistent, and bed thicknesses are usually 5-20 cm. Graded bedding is present, but uncommon. Sedimentary structures include symmetric and asymmetric, straight-crested ripples, ripple cross-lamination, climbing ripple lamination, and parallel lamination. More rarely occurring structures are sole marks such as load casts, grooves, prod marks, flute marks, and longitudinal ridges. Siltstones and mudstones in the CFA beds are micaceous, carbonaceous and, rarely, contain pyrite nodules. Pyrite nodules up to 10 cm in diameter occur on Johnson's Brook.

In addition to the carbonates and CFA beds, light gray, coarse to very coarse grained sandstones, pebbly sandstones, and conglomerates are also present. The sandstones usually occur as thick, massive beds. Trough cross-stratification occurs in places, and sets are usually greater than 10 cm thick. The conglomerates contain clasts up to 10 cm in apparent long axis. Quartz is the most common clast type; we also observed clasts of felsic and mafic volcanics, pink granite and jasper.

Paleoflow reconstructions for the tan carbonate unit showed general sediment transport in a northerly to northeasterly direction. This agrees with the results obtained by Popper (1970).

Before discussing the depositional environment of this unit, it is first noted that no marine beds have been documented for the Anguille Group in the Deer Lake Basin, and previous authors (Belt, 1969; Popper, 1970; Hyde, 1979) have regarded the Anguille Group as mainly lacustrine in origin. Accepting this interpretation, it is evident from the description above that the tan carbonate unit was deposited in a relatively quiet-water environment in which deposition of fine sand and mud prevailed. Some of the facies in the carbonate unit (*i.e.*, CFA beds, carbonates, and coarse sandstone-conglomerate) appear to be arranged in coarsening-upward sequences, ranging from about 5-20 m thick. It is suggested that these coarsening-upward sequences are related to prograding, lacustrine deltas. Some of the coarse grained sandstones exhibit sharp, erosive basal contacts which we interpret as representing deposition in distributary channels.

Some of the finer grained beds are interpreted as turbidites based on the presence of sharp basal contacts, graded bedding, and current-induced sole marks. Popper (1970) first interpreted these beds as turbidites, but we feel that Popper (1970) overemphasized the amount of turbidity current activity. Our estimate of the percentage of turbidite beds is no more than 5% of the entire stratigraphic unit. The turbidites and associated fine grained clastic sediments are here placed in prodelta and delta-fringe subenvironments. Fine to coarse grained sandstones probably originated as nearshore sands (distributary mouth bars, bay mouth bars). Carbonate rocks are regarded as inorganic precipitates. Their occurrence and mineralogy was probably controlled by reduced clastic sedimentation and lake water chemistry.

<u>Gray sandstone unit (Unit 6)</u>

In this unit, the CFA beds are similar to those in the tan carbonate unit except that sole marks and graded bedding are very rare in the gray sandstone. The CFA beds, as is the case in the tan carbonate unit, are interbedded with thick beds of medium to coarse grained, light gray sandstone and minor conglomerate. These coarser grained sandstones are mostly massive, but medium-scale (greater than 10 cm in thickness) trough crossbeds are not uncommon. Conglomerates contain clasts up to 15 cm in apparent long axis. Clast rock types are dominated by vein quartz and felsic volcanics. Rarely, gray, microcrystalline limestone layers are interbedded with the CFA beds. One bed 70 cm thick contains angular carbonate fragments up to 1.5 cm in size set in a carbonate matrix.

Only a few paleocurrent measurements were made, and these were on structures which do not permit polarity to be established (parting lineation, symmetric ripples, groove marks). Generally, these measurements indicate a north-south paleoflow. Popper (1970) measured 23 crossbeds in the gray sandstone unit in the Deer Lake map area. Although we observed numerous crossbeds, none were considered to be sufficiently well exposed for accurate measurements.

Popper (1970) suggested that the gray sandstone unit was fluvial and lacustrine in origin. Hyde (1979) inferred that the coarse grained sandstones and conglomerates represented distributary channels of a lacustrine delta, and that the CFA beds were the product of associated deltaic subenvironments (*e.g.*, prodelta, interdistributary bay). This latter interpretation for the gray sandstone unit is adopted in this report. In general, the depositional environment for the gray sandstone unit is not very different from that of the tan carbonate unit, but two differences can be noted: (1) less turbidity current activity in the gray sandstone unit, and (2) much less deposition of carbonate sediment in the gray sandstone unit.

<u>Arkose unit (Unit 7)</u>

The third, and highest, stratigraphic unit is here termed the arkose unit. Popper (1970) named this the red arkose suite, but this overemphasizes the redness of the arkoses. In fact, the arkoses, although some of them have a pink cast, are usually gray, and lack a brick-red color.

The arkoses are thick bedded, medium to coarse grained sandstones and pebbly sandstones. Only a few medium-scale, trough crossbeds were observed. Graded beds are also rare. The arkoses commonly have sharp top and bottom contacts, and we observed scouring and channeling of arkoses into CFA beds. Quartz and feldspar grains in the arkose are quite angular. Conglomerates are also present in which clasts reach 50 cm in apparent long axis. The clasts are subrounded and consist largely of quartz, flesh-colored feldspar, and felsic volcanic debris.

The arkoses and conglomerates are interbedded with the CFA beds, which are broadly similar to those in the other units. In the arkose unit, however, the amount of cross-stratification, particularly in medium grained sandstone, is more abundant and the CFA beds lack grading and sole marks.

Very few paleocurrent measurements were obtained from this unit, but we agree with Popper (1970) that the source area was to the south and east. This is the only region which could have supplied large angular feldspars.

Popper (1970) concluded that the arkoses and conglomerates were deposited on alluvial fans. Our interpretation is different, for much more deposition of bouldery material and examples of debris flows ought to be present if the coarse sediment was deposited on normal, alluvial fans in arid climactic conditions. We suggest fluvial deposition on the subaerial portion of deltas. Graded arkose beds and a paucity of cross-stratification in arkoses are interpreted as reflecting flood deposition. The abundance of feldspar in the coarse grained sandstones also marks a change in provenance to more granitic source rocks. The CFA beds probably represent nearshore, deltaic deposition in a variety of subenvironments. Close stratigraphic association of the coarse arkoses and fine grained CFA beds in coarsening upward sequences suggests progradation followed by abandonment of deltaic lobes.

Deer Lake Group (Units 8-11)

North Brook Formation (Unit 8)

The contact between the North Brook Formation and the underlying Anguille Group is problematical, largely because of insufficient age data and nonexposure of the contact. Southwest of Glide Lake, there is almost a 90 degree difference in strike direction, which may be due to an angular unconformity. No debris from the Anguille Group was observed in the basal part of the North Brook Formation. The contact between the North Brook Formation and the overlying Rocky Brook Formation is here redefined such that the base of the Rocky Brook Formation is marked by the first appearance of gray or green siltstone or mudstone. Previously, a succession of red siltstones and red, very fine to fine grained sandstones were regarded as the basal part of the Rocky Brook Formation (Hyde, 1979), but these red strata are now placed in the upper part of the North Brook Formation.

The North Brook Formation as a whole represents a well defined, fining upward megasequence (< 1-5 km thick) which is present in all areas. Thus, we have subdivided the North Brook Formation into informal units based on the most prevalent rock type and the presence or apparent absence of medium-scale (1-5 m thick) fining upward sequences.

Unit 8a is characterized by red-matrix conglomerates interlensed with red, medium to very coarse grained sandstones. Scouring and cross-stratification accompany this interlensing. In places (*e.g.* Lane's Brook), sandstones and the matrix of conglomerates are gray. Clasts in the conglomerate are mostly pebbles, but apparent long axes up to 45 cm are present. Clast rock types vary with geographic position, and are governed largely by those rock types in adjoining pre-Carboniferous terrains and to a lesser extent by size. For example, the predominant clast rock types in North

Brook Formation conglomerates along Lane's Brook are quartz (mostly present in fine pebbles), quartz-mica schist, and phyllite. In contrast, southwest of Harry's Brook, most clasts are granitic types, feldspars, and pink felsic volcanics.

Unit 8b is dominated by red and gray, medium to coarse grained sandstone, and minor conglomerate and siltstone. The sandstones are, in places, micaceous and calcareous, and contain gray and green reduction spots. Medium scale, trough and planar crossbeds are common. Parting lineation and intraclasts are also present.

Fining upward sequences (1-5 m thick) occur in the relatively well exposed section along Junction Brook, and are mapped (Unit 8c) separately. Medium to coarse grained sandstone and minor pebble conglomerate are present at the base of each sequence, and grade upward into siltstone. Sandstones are gray to grayish red in color, whereas siltstones are red. Parting lineations are very common in the sandstones, which are also abundantly cross-stratified (both planar and trough types). Scours and channels are abundant, and include an exhumed channel 5 m wide by 1 m deep that is preserved on a small stream north of Junction Brook. Other features noted include intraclasts, reduction spots, and fossil roots.

Unit 8d consists chiefly of fine grained red sandstone and siltstone, and forms the top portion of the North Brook Formation. The sandstones are calcareous (nodules and cements), micaceous, and contain gray and green reduction spots. Structures in these beds include dessication cracks, trough crossbeds, ripple marks, ripple cross-laminations and parallel laminations.

Also included in the North Brook Formation are limestones, which are present at the unconformity between the Deer Lake Group and Lower Paleozoic marbles. These limestones could be of any age from Ordovician to Carboniferous, but are here presumed to be Carboniferous. Two types of rudite occur. The first type contains clast-supported conglomerates and breccias in which clasts are overwhelmingly carbonate. These clasts are up to 20 cm in size, and are cemented by calcite, although in some places the clasts are set in a green sandstone matrix. The second type of rudite is a breccia, in which fragments of Lower Paleozoic marble are set in a calcareous matrix. The fragments are coated by laminated calcite. Nonrudaceous limestones at the unconformity are bituminous, laminated, brecciated and contain scattered ooids.

Paleoflow directions within the North Brook Formation vary with position in the depositional basin (Hyde, 1979). In the Junction Brook area, southwesterly to northwesterly paleocurrent directions were obtained. East of Grand Lake, paleoflow was directed towards the north and northwest, away from the basin margin. A few paleocurrent measurements from the area southwest of Glide Lake suggest paleoflow towards the northeast to northwest.

Depositional environments in the North Brook Formation are dominantly fluvial, with some alluvial fan sedimentation. Superb examples of Scott-type, braided stream deposits (Miall, 1978) occur southwest of Glide Lake. Fining upward sequences are interpreted as meandering stream deposits. On Lane's Brook, debris flow conglomerates suggest deposition on alluvial fans. These fan deposits grade upward into sandstones probably deposited within braided channels located near alluvial fan toes. Carbonate clasts cemented by calcite near the unconformity with Lower Paleozoic carbonate rocks are also regarded as alluvial fan deposits (for a recent analogue see Lattman, 1973).

In addition to calcareous fanglomerates, inferred calcretes and karstic limestones are present at the unconformity with Lower Paleozic carbonate rocks. The calcrete limestones show a clotted texture in thin section, with peloids and disseminated ooids. These ooids contain only one or two concentric layers. In many places, micrite has recrystallized to microspar. One other characteristic microscopic feature is wispy, curvilinear zones of microspar. The calcretes are also studded with silt-size quartz grains. The carbonates deposited under karstic conditions are best exposed in a large quarry in the northwestern part of the map area. Here, the breccias with coated fragments occur. Carbonate deposits in the form of cave pearls, flowstone, and straws (speleological terms) also occur. Large fractures 50 cm wide and 1 m long and small caves up to 1 m in diameter within the Lower Paleozoic marbles are filled and lined with laminated, inorganically precipitated calcite. Other fractures in the marble are up to 15 m in length and are filled with green sandstone.

Rocky Brook Formation (Unit 9)

The Rocky Brook Formatin is estimated to be about 600 m thick on Junction Brook. We estimate a maximum thickness of about 1000 m near Island Pond Brook. In the northern part of the map area, the Rocky Brook Formation can be subdivided into two informal members; namely, the red-gray unit (9a) and the gray unit (9b). The red-gray unit contains a wide variety of lithologies which include very fine to fine grained sandstone, siltstone, mudstone and various types of limestones. The siliciclastic rocks are red, brown, gray and green, and are commonly calcareous. We observed mudcracks, cross-laminations, wrinkle marks, and bioturbation in red beds. Gray and green beds contain current ripples, cross-lamination, and bioturbation. Contacts between red/brown and gray/green strata are either gradational or sharp. We saw one erosional contact with trough cross-stratified, fine grained red sandstone cutting down into gray siltstone. Carbonate rocks are usually massive, microcrystalline limestones which, in thin sections, show homogeneous micrite in varying stages of recrystallization to microspar. Spar-filled fenestrae (bird's eye structure), which are common elsewhere in Rocky Brook limestones in the Deer Lake Basin, are rare in the 1980 map area. Some limestones show clastic textures in the form of wavy and lenticular bedding and flat-pebble conglomerates. Other laminated limestones may have had an algal origin, and some carbonates contain stromatolite-like domes.

The gray unit, which is absent in the Grand Lake area due to nondeposition, overlies the red-gray unit. The contact between them is placed at the highest occurrence of red strata. Lithologies in the gray unit are dominated by gray and green siltstones and mudstones, which are normally calcareous. These fine grained beds also contain large carbonate concretions with calcite and barite-filled shrinkage cracks, pyrite cubes and nodules, and larger sulphide nodules up to 40 cm in size. Blue-gray and chocolate-brown weathering oil shales occur along Rocky Brook. These oil shales have a light brown streak and petroliferous odor. Many different types of limestone occur in the well-exposed section along Rocky Brook. There are bands of oolitic limestone, 2-5 cm thick, containing abundant fossil fish debris (mostly scales and bones, some fins and headplates). Other limestones are microcrystalline and concretionary but form layers parallel to bedding. Finally, domical stromatolitic limestones are common with relief up to 25 cm. One bedding plane showed colonies of stromatolites two by three square metres in area distributed on the bedding plane as patches. Another bedding plane showed raised rings 10-20 cm wide of algal(?) growths varying from 30-70 cm in outside diameter.

Belt (1969) and Hyde (1979) have previously interpreted the Rocky Brook Formation as a mixed fluvial and lacustrine deposit. This interpretation can now be refined by noting the widespread presence of dessication features (mudcracks, bird's eyes) in the red-gray unit *in all rock types*. This indicates that all types of sediment were subject to periodic subaerial exposure. We interpret the red strata as sheets of fine grained alluvial sediment and soil, deposited adjacent to a lake which periodically contracted. The lacustrine deposits are mostly represented by the gray carbonates and the gray and green beds. These deposits were at times buried by red, alluvial sediment following contraction of the lake margin, and through time the alternating sequence of red, gray, and green strata with carbonates was constructed. The gray unit, however, lacks red strata and dessication features, but contains abundant fossil fish debris and oil shale. For these reasons, we interpret the lake at this period of time to be perennial, but not more expansive as suggested by Hyde (1979), for it is now realized that the gray unit is not present in the Grand Lake area. Abundant pyrite in the gray unit indicates much more reducing conditions than during the lake's ephemeral stage. Because of the presence of carbonate rocks and diagenetic calcite in the siliciclastic lithologies, the entire hydrologic system in the basin was decidedly alkaline.

Humber Falls Formation (Unit 10)

In the Deer Lake area, this formation consists of light green and gray, pebble conglomerates, and red and gray, fine to very coarse grained sandstones. Pebbles in the conglomerate range up to 15 cm in apparent long axis. Many of the pebbles are sedimentary rocks, such as green, red, and gray sandstones, dark gray siltstones, and pink limestones. The source of these sedimentary clasts cannot be pinned down, but the presence of sedimentary clasts represents a marked difference in pebble composition from the Humber Falls Formation conglomerates farther north, where volcanic clasts are abundant (Hyde and Ware, 1980). Sandstones in the Humber Falls Formation in the Deer Lake map area are extensively cross-stratified and parallel-laminated, and are inter-lensed with the conglomerate. A maximum thickness of 250 m is assigned to the Humber Falls Formation (Hyde and Ware, 1980).

Paleocurrent measurements on some crossbeds yielded paleo- currents towards the southeast to south-southwest. Fifteen measurements on parting lineations revealed a bimodal pattern with line of motion modes oriented northeast-southwest and nortwest-southeast. It is unclear whether this change in paleoflow direction was related to time or due to areal position.

We interpret the Humber Falls Formation as a fluvial deposit. The presence of trough crossbeds up to 3 m in thickness indicates that channels were of considerable depth and, by implication, of substantial width. By combining the paleocurrent measurements above with those obtained in 1979 (Hyde and Ware, 1980), it becomes apparent that paleoflow orientations were quite variable. In light of all the available data, we feel the most plausible type of fluvial system is that of a coarse grained, meandering type (see Nijman and Puigdefabregas, 1978 for an ancient example).

Howley Beds (Unit 11)

The Howley Beds consist of conglomerates, sandstones, siltstones, mudstones, minor limestones, and coals. Based on spore assemblages these strata appear to range in age from Visean/Early Namurian to Westphalian A (Hacquebard *et al.*, 1960; Belt, 1969; p. 741; Barss, 1980, personal communication). It is likely, however, that deposition was intermittent rather than continuous during this time interval. A thickness estimate is difficult to establish for the Howley Beds but, for the area northeast of Howley, Hyde (1979) suggested at least 3100 m if there was no repetition of strata. Previous workers (Belt, 1965; Baird, 1959) have mapped the Howley Beds only on the eastern side of Grand Lake. However, there are rocks in two areas on the western side of the lake which we interpret as belonging to the Howley Beds. Strata in the more southern of these two areas gradationally overlie the red-gray unit of the Rocky Brook Formation. Subdivision of the Howley Beds is based on the presence of poorly defined, fining upward sequences (11a) and well defined fining upward sequences (11b).

Unit 11a is characterized by a wide diversity of rock types. Red and, to a lesser extent, gray pebble conglomerates are present, with clasts up to 20 cm. Clasts are mainly felsic and mafic volcanic rocks, muscovite granitic rocks, orange feldspars, and quartz. Quartz is the most abundant clast rock type in granule and fine-pebble conglomerates. Red cobble-boulder conglomerates, with clasts up to 50 cm, were seen twice near the contact with pre-Carboniferous rocks. Conglomerates in Unit 11a are usually massive, but some are cross-stratified.

Sandstones are predominantly gray, friable, and medium to coarse grained, but sandstones of all grain sizes occur and, in addition to a gray color, may be red, pink, green, tan, brown, and cream. The sandstones are petrographically diverse. They may be micaceous, feldspathic, or calcareous; others are ferruginous, bituminous, or pyritiferous. Trough and planar crossbeds are common, and range up to 1.2 and 2.3 m in thickness, respectively. Coarse grained sandstones are thickly bedded and, together with conglomerates, have erosive, basal contacts. We observed straight-crested ripples and ripple cross-lamination in fine grained sandstones and a preserved megaripple. Parallel lamination is also present and is particularly abundant in medium grained, green, micaceous sandstone. Three types of nodules are present in sandstone: (1) ironstone (common, especially between Hinds Brook and Howley), (2) calcite (rare), and (3) pyrite (rare). The ironstone nodules range up to 75 cm in size, but are usually no larger than peas. Some of the ferruginous nodules appear to be a carbonate mineral (perhaps siderite). Iron-rich, fine grained sandstones occur near the tops of fining upward sequences north of Little Pond Brook. Plant debris, bark impressions and coalified wood chips are also common in the sandstones.

Siltstones and mudstones may be red, gray, and green, and some are micaceous. We noticed mudcracks, rootlets, and reduction spots in red siltstones and mudstones. Some beds of dark gray mudstone are extremely carbonaceous. Carbonate rocks occur only on the western side of Grand Lake as very thin beds of microcrystalline limestone.

At some outcrops, the strata are organized into fining upward sequences, but their vertical stratigraphic extent is unknown due to poor exposure. At other outcrops, there is no obvious organization to the beds.

In Unit 11b, however, the strata are arranged into well defined, fining upward sequences. Here, sharp-based, gray and red-gray, medium to coarse grained sandstone, pebbly sandstone, and conglomerate consistently grade upward into red, fine grained sandstone and siltstone. Conglomerates contain clasts up to 3 cm of quartz, mafic volcanic rocks, jasper, and intraclastic siltstone. The sandstones are massive, small to large scale, planar and trough cross- stratified, (sets up to 1 m thick), and parallel laminated. One distinctive type of sandstone is red and fine grained, and contains trough cross-laminations, outlined by concentrations of hematite. Plant and wood debris are not uncommon in the sandstones. Siltstones and mudstones are red, and contain reduction spots and calcrete nodules and layers.

Measurements of trough and planar crossbeds on the eastern side of Grand Lake both show consistent westerly paleoflow. Measurements of four trough axes on the western side of Grand Lake opposite Hinds Brook yielded paleoflow towards the northeast. A few measurements on strata of Unit 11b gave highly variable results, such that we are unable to determine the general sediment transport direction for these rocks.

Belt (1969) and Hyde (1979) had earlier interpreted the Howley Beds to be mainly fluvial in origin. The fining upward sequences in Unit 11b are clearly the result of meandering stream deposition. Less clear is the paleochannel configuration associated with the deposition of Unit 11a. There is too much mud for normal braided stream deposition, so that we favor a more meandering channel pattern, probably with coarse grained point bars. Cobble-boulder conglomerates near the contact with pre-Carboniferous rocks may reflect braided channel or alluvial fan deposition. The very carbonaceous mudstones and coals were most likely deposited within swampy floodplain areas.

STRUCTURAL GEOLOGY

FAULTING

Four major northeasterly trending faults occur in the map area. These are, from east to west : (1) the Grand Lake Fault, (2) the Cabot Fault, (3) the Glide Mountain Fault, and (4) the Deer Lake Fault.

The Grand Lake Fault forms the eastern margin of the Deer Lake Basin, and the fault is marked by a prominent break in slope. Outcrops of the Howley Beds adjacent to the Grand Lake Fault commonly display slickensided surfaces, fracturing, and recrystallization.

Outcrops are few close to the Cabot Fault in inland areas, but the fault probably passes very close to continuous exposures along the western shoreline of Grand Lake north of 35th Brook. Here, the effects of the fault are plainly visible in the arkose unit of the Anguille Group. Arkoses are recrystallized, cleaved, and veined with calcite. It is unclear where the Cabot Fault emerges from the north end of Grand Lake to connect with its extension near the north end of the map area.

Popper (1970) first mapped and described the effects of the Glide Mountain Fault (the southwestward extension of the Birchy Ridge Fault, Hyde, 1979; Hyde and Ware, 1980). In terms of its deformational and metamorphic effects on adjacent rocks, the little-known Glide Mountain Fault must rank alongside the well-known Cabot Fault. The effects of the Glide Mountain Fault (shearing, slickensided surfaces, and veining) are well displayed on Horseshoe Brook.

The Deer Lake Fault is poorly defined in the map area, and there is no evidence of its presence east of Deer Lake townsite. Either it simply terminates, or reactivation of the fault following burial by the Deer Lake Group did not extend to a point east of Deer Lake townsite. A splay off the Deer Lake Fault separates the North Brook Formation from quartz-mica schists of the Fleur de Lys Supergroup. Also, close to this fault along Lane's Brook there are small, westward dipping thrust faults contained within conglomerates of the North Brook Formation.

FOLDING

Two different fold styles are present in the map area. The first type is restricted to that portion of the Glide Mountain block flanked by the Cabot and Glide Mountain Faults and underlain by the Anguille Group. Here, parallel folds are oriented such that fold axes are oblique to fault traces. The folds can be small, with wavelengths less than 1 m, or be regional in scale. They tend to be tight, although one regional fold, termed the 39th Brook Syncline, is more open. Folds near the Grand Lake shoreline invariably plunge southward at moderate angles, whereas those on Johnson's Brook plunge northward. Fifty measurements on minor folds showed that 43 had axial planes dipping vertically or to the west.

In contrast, folds elsewhere in the map area are much more open, even in the Anguille Group. Also, these folds plunge northeastwards at shallow angles, and are folded about axes that are subparallel, rather than oblique, to fault traces. It is also noteworthy that the syncline cored by the Humber Falls Formation (Humber River Syncline) has its axial plane dipping southeastwards, whereas an inferred syncline passing up through the centre of Grand Lake has its axial plane dipping northwestwards.

It is difficult to interpret this diversity in fold orientation and style in terms of a single or multiple, *basinwide*, compressional event. For this reason, the folding is inferred to have been the result of fault movements (*see also* Belt, 1969; Popper, 1970; and Hyde, 1979). For reasons cited in Hyde (1979), we interpret the folds that are oblique to fault traces to be the result of strike-slip faulting along the Cabot and Glide Mountain Faults. The greater intensity of folding in the segment of the Glide Mountain block flanked by the above faults cannot easily be reconciled in terms of more intense folding at a lower crustal level because pre-Carboniferous basement rocks are exposed northwest of the Glide Mountain Fault where folds have an open style. Thus, we attribute the differences in intensity to contrasts in competency. Although there is little evidence of refolding of the relatively tight folds between the Cabot and Glide Mountain Faults, we interpret the more open, gently plunging folds as occurring at a later time, and as the result of dominantly vertical fault movements.

ECONOMIC GEOLOGY

URANIUM

Thirty-six radioactive anomalies (not all shown on map) were detected with a Scintrex BGS-1 scintillometer in the 1980 map-area. Of these, twenty-seven occur in the Rocky Brook Formation. These anomalies are presumed to be due to uranium, since previous assays of Rocky Brook Formation anomalies have shown them to be uraniferous (although in some cases there is apparent disequilibrium between uranium and its daughter products). Most of the anomalies in the Rocky Brook Formation are associated with gray and green siltstones and mudstones, but some are in limestones. These anomalies are all stratiform, and are ordinarily two to five times background and 20-50 cm thick. In terms of grade and thickness, the best anomaly is six times background over a distance of 1.2 m; it occurs south of Island Pond Brook along the western shoreline of Grand Lake. We detected six anomalies (again presumed to be due to uranium) near the unconformity between the Lower Paleozoic carbonates and karstic limestones, calcretes, and carbonate fanglomerates of the North Brook Formation. These anomalies are, in places, associated with solid bitumen in the rock. Two weak anomalies were encountered in limestones of the Howley Beds and one weak anomaly was detected in sandstone of the Anguille Group. Relatively high scintillometer readings (150-250 counts per second) were routinely found in the Silurian-Devonian felsic volcanic rocks.

BASE METALS

Numerous gossans occur in the Howley Beds along the western side of Grand Lake. One of these gossans contains a few grains of chalcopyrite associated with plant material in a sandstone at the base of a fining upward sequence. Approximately 100 m northeast of this occurrence, along the shoreline, we discovered a float block of red sandstone containing malachite, bornite, and scattered grains of chalcopyrite and pyrite. One of the gossans could be traced for about 70 m along structural strike. A gossan near the base of the Howley Beds contained two unidentified secondary minerals. One mineral was yellowish green and earthy; the other was clear and acicular.

BITUMEN

Solid bitumen occurs as veins and fracture fillings in Lower Paleozoic carbonates and in basal carbonates of the North Brook Formation. Solid bitumen also occurs as pore fillings in gray sandstones of the Howley Beds. Although locally quite rich, bituminous zones in the Howley Beds are less than 1 m thick with little apparent lateral extent.

OIL SHALE

Oil shales are most abundant in the gray unit of the Rocky Brook Formation, and are well exposed along Rocky Brook. The oil shale layers are usually less than 1 m thick but, at one locality, a 2 m thick section contained 1.6 m of oil shale.

COAL

Although coal seams are known to occur in the Howley Beds (Hayes, 1949), we observed no coal *in situ* within the Howley Beds. However, large fragments of coal occur along the bed of Alder Brook, and we also observed coal fragments along Coal Brook and an unnamed brook between Hinds and Alder Brooks. An old coal dump is present along a trail south of Coal Brook close to a trench like excavation. This dump and excavation are probably associated with coal mining early in this century (Hayes, 1949).

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REFERENCES

Baird, D.M.
1950: Oil shales of the Deer Lake region. Geological Survey of Newfoundland, Unpublished report, 23 pages.

1959: Geology, Sandy Lake (west half), Newfoundland. Geological Survey of Canada, Map 47-1959, Scale, 1:250,000.

Belt, E.S.
1965: Geologic map, Deer Lake Basin, Unpublished. Scale 1:250,000.

1969: Newfoundland Carboniferous stratigraphy and its relation to the Maritimes and Ireland. American Association of Petroleum Geologists, Memoir 12, pages 734-753.

Fleming, J.M.
1970: Petroleum exploration in Newfoundland and Labrador. Department of Mines and Energy, Mineral Development Division, Report 3, 118 pages.

Hacquebard, P.A., Barss, M.S., and Donaldson, J.R.
1960: Distribution and stratigraphic significance of small spore genera in the Upper Carboniferous of the Maritime Provinces of Canada.

Fourth International Carboniferous Stratigraphy and Geology Congress, Heerlen, 1958, Compte Rendus, volume 1, pages 237-245.

Hayes, A.O.
1949: Coal possibilities of Newfoundland. Geological Survey of Newfoundland, Information Circular 6, 15 pages.

Hyde, R.S.
1979: Geology of Carboniferous strata in portions of the Deer Lake Basin, western Newfoundland. Department of Mines and Energy, Mineral Development Division, Report 79-6, 43 pages, 5 geologic maps. Scale 1:50,000.

Hyde, R.S. and Ware M.J.
1980: Geologic map with marginal notes, Cormack-Silver Mountain area. Department of Mines and Energy, Mineral Development Division, Map 8011, Scale 1:50,000.

Lattman, L.H.
1973: Calcium carbonate cementation of alluvial fans in southern Nevada. Geological Society of America Bulletin, volume 84, pages 3013-3028.

Miall, A.D.
1978: Lithofacies types and vertical profile models in braided river deposits: a summary. Canadian Society of Petroleum Geologists, Memoir 5, pages 597-604.

Nijman, W. and Puigdefabregas, C.
1978: Coarse-grained point bar structure in a molasse type fluvial system, Eocene Castisent Sandstone Formation, South Pyrenean Basin. Canadian Society of Petroleum Geologists, Memoir 5, pages 487-510.

Popper, G.H.P.
1970: Paleobasin analysis and structure of the Anguille Group, west-central Newfoundland. Ph.D. thesis, Lehigh University, Bethlehem, Pennsylvania, 215 pages.

Taylor, R.P., Strong, D.F., and Kean, B.F.
1980: The Topsails igneous complex: Silurian-Devonian peralkaline magmatism in western Newfoundland. Canadian Journal of Earth Sciences, volume 17, pages 425-439.

Werner, H.J.
1955: The geology of Humber Valley, Newfoundland. Newkirk Mining Corporation, summary and final report, 116 pages.