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PALAEOMAGNETIC DATA FROM THE CANADIAN APPALACHIAN REGION AND THEIR SIGNIFICANCE RELATIVE TO NORTH AMERICAN POLAR WANDERING

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CANADA

Palaeomagnetic Data From the Canadian Appalachian and Their Significance Relative to North American Polar Wandering

Abstract

Data has been obtained from rocks of Cambrian to Triassic age from the Canadian Appalachian Region. While Carboniferous pole positions agreee well within the region and with others for North America, pole positions for Cambrian and Devonian rocks from the western part of the Island of Newfoundland are consistently different from those determined for rocks of similar age from the mainland of Eastern Canada. To effect coincidence of Devonian and Cambrian pole positions it is suggested that a 30 degree counterclockwise rotation of the Island of Newfoundland occurred between middle and upper Devonian time. This is the approximate angle that exists between the northern shore of the Gulf of St. Lawrence and the northwest shoreline of the Island of Newfoundland. The geology and tectonics can be interpreted to favour such a rotation as the divergence in the structural trends of belts of early to middle Palaeozoic rocks is reduced. The results of this study combined with other North America pole positions are used to suggest alternative polar wandering curves for North America.

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Introduction

Soon after the first few virtual geomagnetic pole positions had been derived from palaeomagnetic measurements, well over a decade ago, it was observed that the older the rocks dealt with, the farther away were their corresponding virtual poles from the present geomagnetic pole. Tentatively this observation was interpreted as the result of wandering of the pole with respect to the earth's crust throughout geological ages. As palaeomagnetic studies extended in the later years to most continental masses it became necessary to go one step further and to interpret the available palaeomagnetic data in terms of continental drift. To this date, considerably more data are required to confirm this hypothesis and the present study was initiated in order to add to the existing body of palaeomagnetic measurements on Precambrian to Mesozoic North American rocks. As a corollary to this task it was intended to investigate the possibility of a rotational movement in the past of the Island of Newfoundland with respect to the North American continent. This possibility had been suggested previously by Nairn et al. (1959) and disputed by DuBois (1959).

The data discussed in the present paper is based on the remanent magnetization measurements of rocks collected over four field seasons in Eastern Canada, as far east as the Avalon Peninsula in Newfoundland and as far west as the Gaspe Peninsula in Quebec. To date some of the data has been reported in the literature (DuBois, 1959; Black, 1964) in summary papers although an overall appraisal of these and additional data form the basis of the present paper.

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Geology

General

With one exception all sample localities in the present study lie within the Appalachian Mountain System which follows the east coast of North America for a distance of about 2,000 miles between Alabama, U.S.A. and the Island of Newfoundland. The exception being that part of the Bradore Formation which rests on Precambrian rocks on the southeast coast of Labrador in the Grenville geological province. The rocks in the Canadian part of the Appalachian System range in age from Precambrian to Triassic. They have been folded, faulted, and intruded in parts by lower and mid-Palaeozoic magmas varying from peridotite to granite in composition. Structures that generally trend northeasterly were developed during the Taconic and Acadian orogenies of the Ordovician and Devonian periods respectively. The Canadian part of the Appalachian System (see Fig. 1) was only locally affected by the great Appalachian revolution which occurred toward the close of the Palaeozoic era and yielded what is known today as the Appalachian Mountains. The effects of this period of folding and faulting are most conspicuous today in Newfoundland and eastern Nova Scotia.

A brief description of the geology of the formations or groups sampled in the present study will precede the discussion on the corresponding palaeomagnetic results.

Areas Sampled

Precambrian Rocks

The Precambrian rocks sampled are believed to be early to late Proterozoic sedimentary rocks (Rose, 1952; Hutchinson, 1953; McCartney, 1954) and they outcrop on the eastern part of the Avalon Peninsula of Newfoundland. They represent a sequence which is well in excess of 20,000 feet of unfossiliferous strata. They are overlain both unconformably and disconformably by fossiliferous Early Cambrian strata. These rocks have been folded and faulted to varying degrees and their present trend is in a north-northeasterly direction. The groups or formations sampled are, in order of decreasing age, the Harbour Main Group, the Conception Group, the Signal Hill and Blackhead Formations of the Cabot Group, the Whiteway and Snows Pond Formations of the Hodgewater Group. The Harbour Main Group underlies the Conception with local angular unconformity and with disconformity. The Conception Group in turn is conformably and/or disconformably overlain by the Hodgewater and Cabot Groups respectively.

Harbour Main Group

The oldest rocks that outcrop on the eastern part of the Avalon Peninsula belong to the Harbour Main Group. In the Holyrood map-area, where the samples were collected, the group has been divided on the basis of lithology into 3 map-units (McCartney, 1954). Red sandstones and conglomerates are interbedded with mainly rhyolitic and andesitic flows with associated pyroclastic and intrusive rocks. The Harbour Main rocks have been intricately folded and faulted, mainly in Precambrian time, with the development of north-northeasterly trending structures and have been submitted to slight metamorphism. The Harbour Main Group is overlain by the Conception Group with probable local angular unconformity in southeast Conception Bay and apparent disconformity elsewhere (McCartney, 1954, in press). The group is believed to be Proterozoic in age because at least 20,000 feet of unfossiliferous sedimentary rocks, considered to be mid- to late Proterozoic age,unconformably succeed the Harbour Main Group and underlie fossiliferous Early Cambrian beds. Volcanic rocks in the group in southeast Conception Bay are intruded by granite assigned an age of 1,033 million years (Fairbairn, W.H., personal communication).

Conception Group

Rocks of the Conception Group occupy large areas of the Avalon Peninsula. In the Torbay map-area they have been observed to unconformably overlie the Harbour Main Group and to disconformably underlie the Cabot Group (Rose, 1952). The group which has an estimated thickness of 6,000 feet has been folded and faulted in north-northeast trending structures similar to the Harbour Main Group.

The group is mainly comprised of a variety of sedimentary rocks with some metamorphic equivalents and intercalated red beds near the top of the sequence. In the Torbay map-area the group has been subdivided by Rose (1952) into the lower 'Conception slate' and the upper 'Torbay slate' on the basis of the predominance of red beds occurring near the top of the group. To the west and northwest of this area (McCartney, 1954; Hutchinson, 1953) the group is divided into a lower part which is dominantly greyish green siltstone, slate and minor red siltstone and an upper part, the Hibbs Hole Formation. The latter is mainly red slate and siltstone and serves as a useful marker horizon. The colour and lithology of some strata suggest that these sediments were deposited in alternating oxidizing and reducing environments. The colour of the beds is due chiefly to the presence of hematite in the cement and in the coating on the detrital grains. The Conception Group which lacks definite fossils and which is stratigraphically between the Proterozoic Harbour Main and Cabot Groups is possibly mid-Proterozoic in age (Rose, 1952).

Cabot Group

The Cabot Group, which rests disconformably on the Conception Group, has been divided by Rose (1952) into the St. John's, Signal Hill, and Blackhead Formations. The group occupies the eastern coast of the Avalon Peninsula from Red Head to Ferryland, a distance of some 50 miles. The Harbour Main and the Conception Groups were the source rocks for much of the detritus within the rocks of the Cabot Group. The group, which exceeds a combined 14,000 feet in thickness at the type localities and grades from fine black shales to coarse red conglomerate, has been folded in a north-northeasterly direction. Fossiliferous Cambrian beds, which are widespread elsewhere in southeast Newfoundland, are presumed to be younger than the Cabot Group but are not present in this district. As no undisputed fossils have been found in the Cabot Group it has been assigned a late Proterozoic age by Rose (1952).

Signal Hill Formation

The Signal Hill Formation conformably overlies the St. John's Formation and in turn is overlain conformably by the Blackhead Formation. In contrast to the St. John's Formation the Signal Hill Formation was deposited in a shallow-water oxidizing environment. Rose (1952, pp. 25-26) reports that the red sandstones are composed of quartz, feldspars, and acid volcanic rocks, as well as accessory minerals, which include magnetite with a cementing matrix of secondary quartz, sericite, epidote and hematite. Hematite and some of the component grains of volcanic rock and orthoclase account for the reddish colour of the formation. The formation, which is well bedded in the main, has an estimated thickness of 7,800 feet at Signal Hill where it has been broadly folded in north-northeasterly trending folds.

Blackhead Formation

According to Rose (1952) the Blackhead Formation, which conformably overlies the Signal Hill Formation, is best exposed in the core of a syncline near Blackhead south of St. John Bay. The formation, the top of which is not exposed, has an estimated thickness of more than 5,500 feet of strata comprised mainly of red and greenish arkosic sandstones with interbeds of slate, argillite and siltstone. These are well exposed in a syncline which plunges gently northward between Cape Spear and the city of St. John's. The lithology of the formation suggests that deposition occurred under relatively similar conditions to those for the Signal Hill Formation, although the finer grain size, lack of conglomerates, as well as colour variations, suggest a deeper more quiescent environment of deposition with prevailing alternating oxidizing-reducing conditions.

On the basis of its stratigraphic relation to the Signal Hill Formation and lack of fossils, the Blackhead Formation has been assigned a late Proterozoic age with a proviso that it may be very early Cambrian.

Hodgewater Group

The Hodgewater Group in the Harbour Grace map-area is composed of a sequence of four conformable sedimentary formations which are, in ascending order, the Carbonear, Halls Town, Whiteway and Snows Pond Formations (Hutchinson, 1953; McCartney, in press). The lower part of the Carbonear Formation is tentatively correlated with the St. John's Formation of the Cabot Group. The Hodgewater Group consists of grey to black slate, grey to green or red siltstone, and rare red and green conglomerates of an estimated thickness of at least 10,000 feet of strata. These rocks outcrop in open north-easterly trending, gently plunging folds cut by easterly and northeasterly trending faults.

No undisputed fossils have been found within the beds of the group, but because it forms the top of the Precambrian sequence in the area, except for the thin overlying Random Formation it has been assigned a late Proterozoic age (Hutchinson, 1953).

Cambrian Rocks

Strata of Lower Cambrian age were sampled from formations at widely separated localities throughout Eastern Canada. Samples were collected from the following Lower Cambrian sedimentary formations: red shales and limestones (unit 11, McCartney, 1954) on the Avalon Peninsula in eastern Newfoundland; brownish red sandstone of the Bradore Formation of the Labrador Series (Schuchert and Dunbar, 1934) from the Highlands of St. John's in northwest Newfoundland and along the south coast of Labrador near Forteau; red sandstone of the Ratcliffe Brook Formation, which outcrops in the vicinity of Saint John, New Brunswick (Hayes and Howell, 1937). Middle Cambrian strata of the March Poi... Formation, were sampled from red sandstones located along the south coast of Port au Port Peninsula.(Schuchert and Dunbar, 1934; Riley, 1962).

Lower Cambrian Rocks

Ratcliffe Brook Formation

The stratigraphically lowest rocks sampled in New Brunswick were collected from the Lower Cambrian Ratcliffe Brook Formation, which is found in and to the northwest of Saint John. The samples were taken from strata along Hanford Brook where they reach their greatest known thickness of about 2,000 feet.

These rocks were named and described by Howell (Hayes and Howell, 1937, pp. 58-63) as follows: "The beds of the Ratcliffe Brook Formation, are mostly dark purplish red, fine-grained, micaceous sandstones, or coarse-grained micaceous shales, the sandstones being so fine grained and thin-bedded that they resemble heavy-bedded, hard shales". The pebbles within the basal conglomerate according to Howell "have been derived principally, if not entirely from the Precambrian rocks immediately surrounding the Cambrian basins". Also according to Howell, no undoubted fossils, except worm trails, have ever been found in this probable non-marine formation. The Ratcliffe Brook Formation is overlain, with apparent conformity, by the Glen Falls Formation. The latter formation contains no fossils other than worm trails and grades conformably up into the Hanford Brook Formation, which contains a Protolenus fauna, that permits reliable correlations to be made with Lower Cambrian strata present elsewhere in the North Atlantic province (Alcock, 1938, p. 1?). The Ratcliffe Brook Formation unconformably overlies the volcanic rocks of the Coldbrook Group of Proterozoic age (Alcock, 1938, p. 13).

Lower Cambrian Rocks of the Conception Bay Area, Avalon Peninsula

Strata mapped as Lower Cambrian (Rose, 1952; McCartney, 1954) outcrop along parts of the south and east shores of Conception Bay and along inland river channels. They overlie with marked angular unconformity, the Precambrian Harbour Main and Conception Bay Groups and are in turn conformably overlain by Middle Cambrian strata with Paradoxides-bearing shales (Rose, 1952). The Lower Cambrian rocks, which contain a pre Paradoxides Callavia fauna, vary in thickness between 75 feet along Manuels River to about 450 feet in the vicinity of Colliers Bay. The strata are mainly greenish grey, olive green, and red shales, pink limestone and basal conglomerate. The upper, Protolenus-bearing beds of the Early Cambrian are markedly similar to the Hanford Brook Formation of the Saint John Group of New Brunswick[1] which has also been briefly discussed in this section (see page).

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[1] Geology and Economic Minerals of Canada; Geol. Surv. Can., Econ. Geol. Ser. No. 1, third edition, pp. 110-111 (1947).

Labrador Series

(Bradore Formation)

The Lower Cambrian strata of western Newfoundland and Labrador has been described in detail by Schuchert and Dunbar (1934). The lowest formation of the Labrador Series, the Bradore Formation which is an unfossiliferous continental deposit, was sampled at two principal localities. One near the northwest shore of Newfoundland where Lower Cambrian strata has been brought up in a great simple arch, by a fault east of St. John Bay to form the Highlands of St. John, although nearly 900 feet of Cambrian strata are visible on the west face of the scarp, the base of the Bradore Formation is not exposed. About 150 feet of red arkose and sandstone of the Bradore Formation is exposed and conformably underlies the fossiliferous Forteau Formation. The second occurs along the southeast coast of Labrador where a narrow strip of Lower Cambrian strata borders the Strait of Belle Isle. Here, the beds dip gently to the southeast and rest on folded Precambrian granitic gneisses of the Grenville Province (Schuchert and Dunbar, 1934; Christie, 1951; Leech et al, 1963). Only 470 feet of Cambrian strata remain, of which 285 feet is referred to the Bradore Formation, with the remaining 185 feet comprising the Forteau Formation.

Middle Cambrian Rocks

March Point Formation

On the west coast of Newfoundland Middle Cambrian strata of the March Point Formation outcrop along the southern coast of the Port au Port Peninsula between the villages of Petit Jardin and March's Point. The March Point Formation has been measured and described by Schuchert and Dunbar (1934, pp. 34-35), Lochman (1938, p. 461), and others. The formation has a minimum thickness of 850 feet, which outcrops in a broad arch plunging gently to the north, and where sampled dips up to 29 degrees to the northwest. Conformable contacts with the overlying Upper Cambrian Petit Jardin Formation and the underlying Lower Cambrian Kippens Formation, have been observed.(Riley, 1962).

Ordovician Rocks

Newfoundland

Sedimentary and igneous rocks of Ordovician age were collected from eastern, western and southern Newfoundland. On the east coast, samples of the hematitic iron ore beds of the Bell Island and Wabana Groups[1] (Van Ingen, 1914), of Lower Ordovician age were collected from surface and underground mine exposures located on Bell Island in Conception Bay. On the west coast, two rock types were sampled; gabbro of the Bay of Islands igneous complex and dolomitic strata of the St. George Group. The Bay of Islands igneous complex cuts strata of the Middle Ordovician Humber Arm Group, and is assigned a pre-Carboniferous age by Smith (1958). Riley (1962) suggests that it is Ordovician in age similar to the Humber Arm Group. The St. George Group is Lower Ordovician in age (Schuchert et al, 1934) and crops out on the Port au Port Peninsula. Along the southern coast of Newfoundland in the Fortune Bay area, samples were collected from strata of the Spoon Cove Formation the lowest of three formations forming the Cinq Isle series of Middle or low Upper Ordovician age.

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1 Originally introduced as Wabana Series by Van Ingen (1914), but referred to as Group by Rose (1952).

Lower Ordovician Rocks

Bell Island and Wabana Groups

The Bell Island and Wabana Groups of Lower Ordovician age outcrop mainly on Bell Island in the Conception Bay Basin. They comprise more than 8,000 feet of relatively unmetamorphosed fossiliferous shale and sandstone with intercalated beds of oolitic hematite iron ore (Rose, 1952). The strata strike northeasterly and generally dip gently between 9 and 14 degrees to the northwest similar to the underlying Upper Cambrian strata, which crop out approximately 6 miles to the south on the shores of Conception Bay. The Topsail fault along the east coast of Conception Bay has thrust up Proterozoic rocks, where the Lower Ordovician strata would normally outcrop.

Biostratigraphic studies indicate that the Bell Island Group is a product of shallow water marine deposition, while parts of the Wabana Group are of a somewhat deeper and reducing marine environment. Oxidizing conditions, however, existed during deposition of the lower part of the Wabana Group similar to the Bell Island Group, as indicated by the deposition of the hematitic iron ore beds. A minor disconformity exists between the Wabana Group and the underlying Bell Island Group as indicated by a thin intraformational conglomerate bed containing pebbles of oolitic iron ore derived from the uppermost iron ore zone of the Bell Island Group. Fossil content of the strata of both groups indicatesthey are of Lower Ordovician age. Observations by Hayes (1915), led him to conclude "that the iron ore occurs as a primary bedded deposit, and that the iron content was present in the sediments at the time that the series was laid down". Amongst his evidence is the presence of iron ore pebbles in the conglomerate at the base of the Wabana Group. Tests carried out by him show that siderite has replaced both chamosite and hematite as well as detrital quartz, while the sediments were still unconsolidated. The only observed secondarily introduced minerals are calcite and quartz. He concludes that "no important introduction of iron seems to have been made since the beds were deposited". For a full description of the origin of the iron ore the reader is referred to Hayes (1915).

St. George Group

(Port au Port Peninsula)

The most complete and a relatively undisturbed section of the St. George Group, lies along the southern shore of the Port au Port Peninsula, between the villages of March's Point and Port au Port, western Newfoundland. The strata here are approximately 2,000 feet in thickness and strike in an easterly direction with northwest dips up to 25 degrees. The St. George Group overlies, probably without a break, Upper Cambrian strata and are in turn disconformably overlain by the Table Head Group of Middle Ordovician age (Riley, 1962). Fauna collected from the St. George Group, by Schuchert and Dunbar (1934), Sullivan (1940) and others, indicate that it is of Lower Ordovician age. The strata comprise buff, pink, and red dolomite marble, grey and black limestone, shale as well as some chert (Schuchert and Dunbar, 1934; Riley, 1962).

Middle to Upper Ordovician Rocks

Cinq Isle Series, Spoon Cove Formation

The Cinq Isle Series, composed of red sandstones, shales, and some limestone beds, outcrops intermittently along the southern coast of Newfoundland between Great Bay de l'Eau and Bay d'Est in the Fortune Bay area. These rocks, indicated as Middle or low Upper

Ordovician age on structural and lithological correlation, unconformably cap a fossiliferous Cambro-Ordovician succession. A basal conglomerate of the series contains black Cambrian shale pebbles. The Cinq Isle Series in Great Bay de l'Eau near Wreck Cove, is unconformably capped by the fossiliferous late Devonian Great Bay de l'Eau conglomerate (Widmer, 1950). The Cinq Isle Series as described by Widmer is made up of three formations; the Spoon Cove, the Yankee Cove, and the Spyglass Cove Formations, which have a total thickness of about 1,250 feet.

Ordovician (?) Rocks

Bay of Islands Igneous Complex

The Bay of Islands igneous complex lies between Port au Port Peninsula and Bonne Bay on the west coast of Newfoundland. It is composed of a discontinuous belt of layered ultrabasic and gabbroic rocks, which trend north-northeasterly and extend over an area 60 miles long and up to 10 miles wide. Smith (1958) has studied the complex in great detail, devoting much time to the structure and petrology of the rocks in contact with the complex as well as the complex. Clastic sedimentary and basic volcanic rocks of the Humber Arm Group of Middle to late Ordovician age, which immediately underlie the intrusions have been folded and are cut by ultrabasic, gabbroic and dioritic intrusions which in turn have been broken by transverse and longitudinal faults of great magnitude. Riley (1962) suggests since no other field evidence is available "that the ubiquitous association of ultrabasic rocks with basic volcanic rocks suggests that they have a common origin and are thus of similar age - in this instance Ordovician age".

Of the four now separated igneous masses, only the most northerly Table Mountain mass was sampled. The Table Mountain mass, originally continuous with the North Arm Mountain mass, is offset to the northwest by the Trout River fault. Both these plutons contain thick zones of interbanded serpentinized peridotite and dunite overlain by a zone of genetically related banded gabbro, which grades into massive gabbro.

Silurian Rocks

North Central Newfoundland

Sedimentary and igneous rocks of Silurian age were collected from the Botwood Group, Springdale Group, and a large intermediate to basic intrusion, located in north central Newfoundland.

Botwood Group

Rocks of definite Silurian age occur in the vicinity of the town of Botwood and immediately south of the Bay of Exploits (Williams, 1962). The lower part of the Botwood Group is composed of purplish green flow and pyroclastic rocks, which conformably underlie the sedimentary rocks of the upper part. These sedimentary rocks are mainly red to grey sandstone, shale, and conglomerate, with some dark grey shale and argillite.

Intermediate to Basic Intrusion

The strata of the Botwood Group immediately south of the Bay of Exploits are intruded by a large body of medium to coarse-grained intermediate to basic rocks. The sedimentary rocks at the margins of the intrusion have been thermally metamorphed. A potassium argon age of 423 m.y. (Silurian) has been obtained from biotite collected from the thermally metamorphosed sediments (Leech, et al, 1963). This body as well as others in the area had previously been thought to have been implaced during the Acadian orogeny in Devonian tim .

Springdale Group

The Springdale Group previously assigned a Devonian age similar to the Botwood Group (Twenhofel, 1947) may now be referred as Silurian in age. No identifiable fossils have been found within the group but on its lithological similarities has been correlated with the Botwood Group (MacLean, 1947). Samples of both the sedimentary and volcanic rocks of the group (Kalliokoski, 1953), were collected southwest of the town of Springdale located about 45 miles northwest of the town of Botwood.

Springdale Group (?)

Rocks, provisionally assigned to the Springdale Group by MacLean (1947), occur about 7 miles northwest of Springdale, in the vicinity of King's Point near the southern end of Southwest Arm. These rocks occupy an area of approximately 4 square miles and are composed of weakly consolidated red beds (unit 11, Neale, 1960) which include maroon to reddish brown conglomerates, sandstone, and siltstones. They rest unconformably on rocks of Ordovician age and were interpreted by Neale (1960) to be post-granitic rocks, Devonian or later in age, on their strong resemblance to Mississippian rocks which outcrop about 30 miles to the west and southwest of King's Point.

Diabasic Rocks

Sill like masses of diabasic gabbro intrude the Ordovician rocks in the Gull Pond map-area(unit 17a, Kalliokoski, 1954) south of the Springdale map-area. These were mapped as the youngest known rocks in the area and were assigned a Devonian age similar to the Springdale Group.

Devonian Rocks

Clam Bank Group

The only occurrence of Devonian strata in western Newfoundland, the Clam Bank Group, outcrops as an open syncline along the west side of Port au Port Peninsula from Black Duck Brook to Salmon Cove. The group, which has a thickness between 1,700 feet (Schuchert and Dunbar, 1934, p. 104) and 1,879 feet (Sullivan, 1940), is composed of reddish brown, poorly sorted, crossbedded sandstone, buff and green siltstone, shale, conglomerate and fossiliferous limestone. The relation of the group to younger and older strata is obscure as the top lies beneath the sea and the bottom rests in fault contact with the Long Point Group of Ordovician age. Abundant fossil evidence in the limestone beds suggests that the fauna are best correlated with that of the Helderberg limestone of early Devonian age (Riley, 1962).

Perry Formation

The Perry Formation, composed of sedimentary and interbedded lava flows, covers an area of approximately 15 square miles in the vicinity of St. Andrews, New Brunswick. Similar beds, which were extensively studied by Smith and White (1905) occur over an area of similar size across the St. Croix River in eastern Maine in the United States.

The sedimentary rocks of the Perry Formation, are characterized by their generally red colour. The lowermost beds, which on St. Andrews Peninsula dip gently between 10 degrees and 18 degrees to the southeast, rest unconformably on Silurian rocks. The basal beds are often conglomeratic although near St. Andrews the thickest conglomerates occur near the middle of the formation. Studies by Smith and White (1905) in eastern Maine show that rapid lateral variation in rock facies occurs commonly. Smith and White have described the interbedded lava flows as purple basalts consisting of plagioclase in fine laths and augite in large ophitic plates. Dark reddish brown iddingsite is present and magnetite is abundant. With the exception of the alteration of what was probably olivine to iddingsite the basalt has a fresh appearance. There are also associated diabase dykes, which cut the sedimentary strata, and which may have been feeders for the lava. The Perry Formation has been assigned an Upper Devonian age on the basis of the plant remains described and discussed by Smith and White (1905).

Carboniferous Rocks

Carboniferous rocks cover an area of approximately 25,000 square miles in parts of Quebec, New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland. This represents about one-sixth of the total area of the basin in which Carboniferous sediments were deposited, as a large part of the basin lies under the Gulf of St. Lawrence (Gussow, 1953). Carboniferous rocks lie with pronounced angular unconformity on a basement of earlier Palaeozoic and Precambrian rocks. The Acadian revolution during Devonian time caused considerable metamorphism of the underlying Palaeozoic sediments. A great number of red bed sequences characterize the Carboniferous rocks, which are composed mainly of conglomerate, sandstone, siltstone, shale, and limestone with local occurrences of gypsum, anhydrite and rock salt as well as Pennsylvanian coal seams. These sediments, which were deposited in an arid environment on deltas or on flood plains of rivers, are mainly continental deposits; however, some marine sediments are present. An estimate of the total thickness of the Carboniferous sediments determined by combining formation thicknesses is in excess of 50,000 feet (Gussow, 1953).

Structurally the Mississippian rocks have suffered local folding and faulting. These movements were more severe towards the end of the Mississippian when there was a disturbance resulting in a marked angular difference between Mississippian and Pennsylvanian strata. This is readily seen on the Magdalen Islands where the folded Mississippian beds are overlain by flat lying red sandstone of probable Pennsylvanian age.

In New Brunswick the major part of the Carboniferous sediments are Pennsylvanian in age while the older strata, exposed at the southwest border of the basin which includes some volcanic rocks, are chiefly Mississippian in age. In places to distinguish Mississippian strata from Pennsylvanian strata is a difficult if not impossible task, due to an almost total lack of key horizon markers, or that lateral continuity in any particular bed or formation can be demonstrated only within some specific and stratigraphically cohesive area (Laughlin, 1960). For this reason strata in certain areas have been designated as Pennsylvanian and/or Mississippian. Similarly the age of the red bed sequences of Prince Edward Island is left as Permo-Carboniferous though fossils indicating both Pennsylvanian and Permian ages have been identified. This is more fully discussed below under the section concerned with Permo-Carboniferous rocks.

Mississippian Rocks

(New Brunswick, Newfoundland)

Kennebecasis Formation

The Kennebecasis Formation, a fluvial or partly fluvia-lacustrine deposit (Alcock, 1938), crops out northeast of Saint John, New Brunswick where it is well developed east of and along Kennebecasis Bay. The beds are composed of conglomerate, sandstone, and slate which are buff to red in colour. The beds which in most places strike northeast have moderate dips as a rule, though locally they stand at steep angles and in places are even overturned. They are strikingly fresh as compared to those preceding them.

Alcock (1938) has assigned the Kennebecasis Formation to the Mississippian, probably similar to the upper part of the Horton Series, on fossil evidence found within the beds. The beds have been observed by Alcock (1938) to overlie both Precambrian and Cambrian rocks and in turn are overlain by the Upham Formation of the Windsor Series.

Codroy Group

The Codroy Group of western Newfoundland accordantly overlies the Anguille Group and it is well exposed in cliff sections in two areas. One area lies between Ship Cove and Fischells Brook, where all of the samples but two were collected from west to northwesterly dipping strata; the other is the type section in the vicinity of Codroy village where strata dipping to the southeast reaches a thickness of 4,900 feet (Bell, 1948). Measurements of true thickness are subject to considerable error due to structural complications.

The lower beds of the Codroy Group are composed mainly of marine sediments made up of grey limestone, dolomitic siltstone, and thick gypsum zones with associated red mudstone and siltstone while the upper beds are mainly non-marine which include red and green shales, siltstones and sandstones as well as some limestone. Codroy strata are incompetent and are generally more deformed than the underlying strata of the Anguille Group. The lower beds of the Codroy Group have been correlated on fossil evidence with the Windsor Group of Nova Scotia while the upper beds may be equivalent to the lower part of the Canso Group of Nova Scotia since they contain plant fossils younger than those in the upper strata of the Windsor Group (Bell, 1948).

The Searston beds, which may exceed a thickness of 5,000 feet, overlie the Codroy Group and are very late Mississippian in age and are correlated in part with the Canso Group of Nova Scotia (Bell, 1948, p. 20). These beds consist of a succession of non-marine gritty and conglomeratic sandstones as well as highly micaceous sandstones and shales most of which are very soft and range in colour from grey to brown to red.

The Barachois Group, including the Searston beds (Riley, 1962), conformably overlies the Codroy Group and has similar structural trends as the other underlying Carboniferous rocks. The group consists of predominantly grey micaceous coarse-grained sandstone, siltstone and beds of conglomerate as well as non-marine micaceous silty limestone, coal beds and silty shale (Riley, 1962). Spores taken from the coal horizons suggest correlation of the Barachois Group with Middle Pictou (Pennsylvanian) strata of Nova Scotia (Riley, 1962).

Mississippian - Pennsylvanian Rocks

(Central New Brunswick, Gaspe Coast)

pre-Pictou Rocks

Sedimentary and volcanic rocks of pre-Pictou Carboniferous age, probably Late Mississippian to Early Pennsylvanian, occur in the Napadogan and Boiestown map-areas of central New Brunswick (Poole, 1958). Here the Carboniferous rocks directly overlie, unconformably, the highly cleaved Silurian sedimentary strata which are intensely deformed and regionally metamorphosed to slate grade. The Carboniferous rocks are generally composed of coarse-grained red to green undisturbed sediments which locally include basic volcanic rocks. The basic flows lie at and within the top 40 feet of the red beds as well as directly overlying the Silurian rocks.

Bonaventure Formation

The Bonaventure Formation, which in places unconformably overlies upper Devonian strata, forms an almost continuous border along the north shore of Chaleur Bay from Percé to Drapeau Quebec. It also occurs in patches along the south shore of Chaleur Bay in New Brunswick from Dalhousie Junction to near Bathurst.

The formation is composed mainly of flat-lying shales, sandstones, conglomerates, and some limestone, which are a deep red to salmon pink colour. The attitude of the formation is well displayed by the well defined bedding of the sandstone and shale interbeds. It is from these fine-grained red sandstones that samples were obtained along the north shore of Chaleur Bay. A lack of horizon markers and the great amount of lateral variations makes estimating the thickness of the formation difficult. A thickness, however, of 600 feet would probably be conservative. Alcock (1935) suggests that the Bonaventure Formation is the same age as the Cannes de Roche Formation which has the same general lithology and relation to the older formations. The Cannes de Roche Formation is dated as Late Mississippian or Pennsylvanian age by Bell who examined fossil material collected by himself and Alcock.

Pennsylvanian Rocks

(New Brunswick)

Bathurst Formation

Alcock (1935) has assigned the Bathurst Formation to the Pennsylvanian as it grades gradationally up into the plant bearing strata of the Clifton Formation which is dated as Upper Westphalian age (Pennsylvanian). He has separated these beds from the Bonaventure Formation, with which they were correlated by both Logan (1863) and Ells (1881) on their physical aspect as well as conformability, which is less conglomeratic and less brilliant in colour than the Bonaventure Formation which crops out to the north and west. The Bathurst Formation consists of dominantly reddish coloured shales, sandstones, and conglomerates. Many of the sandstones contain much calcite in the form of reddish grains and plate-like masses enclosing grains of sand. They crop out along the Nepisiguit River where the base, resting on Devonian granite, is well exposed south of Bathurst, New Brunswick and east to the Bass River. For the most part the beds which have a maximum thickness of 125 feet lie horizontal but dips up to 10 degrees, with no signs of faulting, have been observed.

Permo Carboniferous Rocks

(Prince Edward Island)

The discovery of Upper Carboniferous plants by Lyell in 1845 and by Gesner in 1847 on Governor Island led to the first definite age for the rocks of the Island. Dawson (1871) attempted to divide the strata into two periods the Upper Carboniferous and the Triassic, the latter based on the discovery of a fossil dinosaur Bathygnatus Borealis at New London near the north coast of the Island. Work since then has revealed that this discovery was not a Triassic dinosaur but a very early pelycosaur of Permian affinity. Prest (1962) reports that more recently, plant microfossils taken from a bore hole at a depth of 1,730 feet near Wellington indicate a Stephanian age for the red beds while similar studies on rocks from Governor Island near Charlottetown indicate a Middle or Upper Pictou (Westphalian) age. The lower part of the red bed sequence is therefore Pennsylvanian age (Prest, 1962). A Permian age was suggested by Holden (1913) based on plant remains and impressions from the south shore between Summerside and Charlottetown. Plant fossils, however, collected by Prest from the same areas and identified at the Geolgocial Survey of Canada did not yield a diagnostic Permian flora.

Langstrom of the National Museum of Canada collected vertebrate fossils from east of Malpeque Bay during 1960 and 1961, the aspect of which as now known has a distinctly lower Permian character (Prest, 1962). Prest (1962) suggests that on the basis of this evidence and the absence of any distinct lithological break, the red beds of Prince Edward Island be referred to as Permo-Carboniferous as originally suggested by Ells (1884).

There is little variation in the general appearance of the rocks forming the Island. In general they are composed of a number of soft bedded weakly cemented red to brown sandstones, siltstones, shales, an occasional horizon of conglomerate, and very minor horizons of grey to green strata. Upon close examination of the bedding planes in the cliff exposures it is evident that their continuity is sadly lacking and that large scale low angle crossbedding is generally common in the coarser sandstones. It is generally agreed (Frankel, 1960; Crowl, 1960a, 1960b) that the rocks forming the Island are of terrestrial origin and probably represent part of a complex of coalescing alluvial fans formed by slow moving streams over large deltas or alluvial fans.

Inadequate outcrops inland combined with the inability to measure reliable strikes and dips due to the lenticular nature of the strata in coastal exposures tend to obscure the true structure of the Island. Folding, if present, is very gentle as the more persistent beds lie close to the horizontal in most instances and the exact positioning of fold axes is quite difficult. The steepest dip measured was 17 degrees with an average dip of 6 degrees obtained from all the samples collected across the Island.

Triassic Rocks

In the Appalachian region the youngest consolidated rocks are of Triassic age and occur in the Bay of Fundy region. These postorogenic rocks are continuously distributed in Nova Scotia along the southeast shore of the Bay of Fundy and around the shore of Minas Basin. Their occurrence has been noted in New Brunswick scattered along the northwest shore of the Bay of Fundy and on Grand Manan Island., They are composed mainly of sedimentary rocks which are continental clastic deposits consisting of interbedded red conglomerate, sandstone, siltstone and claystone. Sedimentation was disrupted twice, locally by the intrusion of the McKay Head Basalt and completely by the North Mountain Basalt (Klien, 1962) which extends without interruption for about 130 miles along the southeast coast of the Bay of Fundy. These flows, probably fissure eruptions, occurred toward the close of the period of deposition.

North Mountain Basalt

The North Mountain Basalt is a thick sequence of basalt and dolerite underlying the North Mountain physiographic province. It conformably overlies the Late Triassic Blomindon Formation and in turn is overlain by the Late Triassic Scots Bay Formation (Klein, 1962). It has a thickness of 875 feet and is composed of 16 basalt and dolerite flows at the type section in Kings County, Nova Scotia. The basal flows consist of dolerite with macrogabbroic layers while the upper flows are chiefly amygdaloidal.

Petrographic study by Klein (1962) showed that these volcanic rocks are tholeiitic as olivine is almost totally absent. They are composed chiefly of plagioclase feldspar (labradorite), augite, pigeonite, and a small quantity of brown glass. Where alteration has occurred the plagioclase has been saussuritized while hornblende has formed at a late magmatic stage at the expense of pyroxene. The major accessory minerals are magnetite, chromite, and zeolite.

Field Work

Oriented samples were collected from rocks ranging from Precambrian to Mesozoic age from the Atlantic provinces as well as the Gaspé coast of Quebec (see Fig. 1). The program was first initiated in the summer of 1958 when the author accompanied Dr. P.M. DuBois to the Gaspé coast, New Brunswick and Nova Scotia. During 1960 the author, assisted by Mr. J. Kirwan, collected from many coastal and inland sites on Prince Edward Island. The 1961-62 field seasons were spent collecting from various localities in Newfoundland representing as many geological periods as were available or amenable to the palaeomagnetic method. Much assistance was given in the field by Mr. G.N. Freda of the Geological Survey of Canada who accompanied the author on both trips to Newfoundland.

Collection of Samples

The first step in the collecting of oriented samples consisted in marking on a flat surface an horizontal reference arrow with the aid of a straight edged pocket level and a china crayon. The flat surface was usually a smooth joint face on igneous rock samples or a smooth bedding plane in the case of sedimentary strata. However, where bedding planes were difficult to establish accurately a joint face was chosen as the reference surface and the approximate strike and dip in the near vicinity was recorded. The azimuth of the reference arrow was recorded in degrees east of true north with either a Brunton compass or a solar compass for sedimentary and igneous rocks respectively. The solar compass was generally used in the collection of igneous rocks in order to eliminate possible deflection of the compass needle as a result of bringing it close to a magnetically disturbed area. When these rocks were collected during cloudy weather or in the shade of trees or cliffs, the azimuth of the arrow was determined with a Brunton compass held several feet above the sample to minimize as much as possible the action of the rock on the compass needle. The reference arrow on the sample was then sighted. The inclination of the reference surface was determined with the clinometer of the Brunton compass. The orientation arrow and other identification marks on the sample were suitably protected by spraying the surface with a clear plastic coating. At each collection site it was standard practice to collect two samples at relatively close points on a stratigraphic horizon. This allowed a means of detecting gross experimental error in the collection or preparation of the samples and the degree of magnetic instability of the samples. Omissions to this practice were necessary when sedimentary rocks had thin and/or irregular bedding, and inhomogeneous texture.

As a study of the variation of the earth's geomagnetic field through part of geological history was the prime purpose of this investigation an attempt was made to collect a number of samples through the maximum thickness exposed. The results for the formation would then not be affected by short period variations or the non dipole components of the earth's magnetic field.

Laboratory Work

Sample Preparation

Only brief mention will be made here of the methods and equipment used in the preparation and measurement of the magnetization directions of oriented rock specimens as these methods have been fully described elsewhere in the literature.

A 1-inch slab, parallel to the reference arrow and at right angles to the reference surface, was sliced with a diamond blade from each sample. From this slab two 1-inch cubes were cut and a reference arrow in line with the arrow on the sample was drawn on the cube surface.

Magnetization Measurements

The magnetization of the sedimentary rocks and some of the least magnetized igneous rocks was determined with a sensitive Blackett type astatic magnetometer. This instrument was built by Mr. J, Roy (1963), and put at the disposal of the writer by the Dominion Observatories Branch. For measuring each of the three components of magnetization a given specimen was kept at a constant distance below the magnet system axis and made to assume 24 different positions successively. A description of the procedure followed was described by DuBois (1962). By repeated measurement the precision of the angular measurements determining the components of magnetization of a specimen is approximately 2 degrees. A number of the more intensely magnetized igneous rock specimens were measured in a motor drive spinner-type magnetometer. A description of this instrument and of the procedure followed in measuring magnetization vectors has been given by Larochelle (1962). Specimens with intensities of magnetization of 10^{-4} emu cm^{-3} can be measured with this magnetometer, while intensities as low as 10^{-6} emu cm^{-3} can be resolved with the astotic magnetometer. A test of the accuracy of these two instruments was carried out periodically by taking a number of comparative measurements using cubes that had intensities of magnetization in the measuring range of either instrument. No significant differences were observed in the measured directions.

Magnetic Cleaning

The natural remanent magnetization (NRM) directions obtained on some of the formations studied have been found to be rather dispersed and inconsistent. The inconsistency often reflects the presence of one or more secondary components of magnetization superimposed on an initial stable magnetization. These secondary components may or may not be parallel and their respective stability may differ. Secondary components may be acquired by lightening strokes in which case the rock becomes magnetized anhysteritically. Isothermal or viscous remanence may also be acquired as a result of the earth's field acting on the rock since its initial magnetization. As the direction of the NRM measured in a specimen is the vector sum of the components present it is imperative in palaeomagnetic work to detect and eliminate if possible these secondary components. If these secondary components can be successfully removed then the direction of the earth's magnetic field at the time the rocks were formed can be determined. When the secondary magnetization is the result of chemical alteration of part or all of the minerals forming the rock at a time when the earth's field was aligned significantly different from that when the rock was initially magnetized there is little or no chance to successfully remove it from the initial magnetization. Fortunately many rocks bear unstable secondary magnetizations which can be effectively destroyed by either of two methods, namely alternating field and thermal demagnetization.

Efforts to remove unstable components of magnetization were confined chiefly to the alternating field demagnetizing method with the exception being the thermal treatment given the Ordovician Wabana iron ore samples.

The apparatus used was built and described by Larochelle (1958). The specimen is placed at the centre of a coil capable of producing an alternating magnetic field of approximately 300 oersteds peak field. Cancellation of any steady magnetic field in the vicinity of the specimen is achieved by a system of two naturally perpendicular Helmholtz coils, the axis of one of the coils being horizontal and oriented in a N-S direction, through which appropriate currents are circulated to produce a restricted space free of any magnetic field. The amplitude of the alternating field is slowly reduced to zero by slow removal of the coil away from the specimen. To ensure uniform demagnetization throughout the specimen it is necessary to treat each specimen about at least three mutually perpendicular axes. This procedure is hereafter referred to as magnetic cleaning (As, Zigderveld, 1958).

In order to save time one cube from each sample was magnetically cleaned and its magnetization again determined. If its direction varied by more than 5 degrees then the secondcube was cleaned in the same demagnetizing field. The specimens were submitted to alternating fields of increasing maximum amplitude until no significant change occurred in the magnetization direction or until a maximum peak field of 300 oersteds had been applied.

Thermal treatment involved heating the specimens in a non magnetic oven in a null field to various temperatures up to 850°C and then allowed to cool to room temperature before measurement. The apparatus was built and described by Robertson (1964).

Processing of Data

The direction of magnetization for a specimen is defined by the letters D and I, D being the declination measured in degrees east of geographic north; I, the inclination, which is by convention positive in the downward direction and negative in the upward direction. An average direction of magnetization has been computed for each sample (sine-cosine method or graphical) from the results obtained from the two specimens cut from it and a mean direction of magnetization for each formation or group has been computed with the results of each sample given unit weight. The statistical parameters computed for the formations or groups sampled are the usual α, k, R, and N as defined by Fisher (1953); α is the radius of the circle of confidence calculated at the 95 per cent level of probability; k represents a measure of dispersion or precision with high values indicating a close grouping about the mean; R is the resultant vector for N samples. The circle of confidence about the mean vector is represented graphically as a solid line circle of the lower hemisphere or as a broken line circle on the upper hemisphere of the stereographic projection.

The mean direction of magnetization for a group of stably magnetized samples reflects the attitude of the earth's magnetic field at the collection locality at the time the rocks were magnetized; and if this stable magnetization is primary then the field at the time the rock was found is described. If the mean direction of magnetization is determined for a sufficient thickness of rock, the elapsed length of time is sufficient to remove secular variation, it then may be assumed that the magnetic field that produced this mean direction is the product of a dipole. By use of the dipole formula it is then possible to compute, from the mean direction of magnetization for a group or formation and its collecting site coordinates, the geographic coordinates or pole position of the geomagnetic pole produced by the assumed dipole. The quantities d ψ and d x are the semi-axes of the elliptical area of confidence around the pole at a probability of 95 per cent, d ψ is the colatitude direction and d x perpendicular to it. As the calculation of the pole position assumes only that the field directions are produced by a dipole and not necessarily as axial geocentric one the poles are referred to as virtual geomagnetic poles as described by Cox and Doell (1960).

The directions of magnetization for each sample have been corrected for the strike and dip of the sample so as to refer them to a common orientation. The choice of the reference plane is dependent on the structural and magnetic history of the formation samples. When the measurements indicate primary magnetization only, the direction of magnetization of a sample collected from titled sedimentary or volcanic rocks is corrected for the measured dip to restore the magnetic vectors to an assumed horizontal position at the time of formation. Hereafter this is referred to as <u>corrected for tilt of beds</u>. Samples collected from intrusion or dyke rocks have their magnetization corrected to a present day horizontal plane passing through the mass unless structural evidence is available from nearby strata which indicates that the body has been tilted. This reference plane is also used for tilted sedimentary and volcanic rocks that have been stably magnetized after deformation occurred and have not suffered subsequent deformation. Hereafter where this is applicable the magnetic vectors are described as before correction for tilt of the beds.

Presentation of Data

The palaeomagnetic results are presented in order of the oldest (Proterozoic) to the youngest (Mesozoic) rocks sampled and follow the same format used in outlining the geology of the areas samples. Table I is a summary of the basic palaeomagnetic data obtained for the various formations or groups sampled. Directions of magnetization for each sample as well as the mean coordinates of the collection locality are listed in the appendix by formations or groups. Stereographic projections have been used exclusively for illustrating the directions of magnetization and Fisher statistics obtained for each formation or group sampled.

Criteria for Rejecting Data

Samples with remanent magnetization moments that were too low to accurately measure have been included with the rejected samples. Also when the measured remanent magnetization directions obtained from two specimens from the same sample disagreed by more than 25 degrees the result for that sample was rejected and classed as internally inconsistent.

Palaeomagnetic Data

Precambrian Rocks

Harbour Main Group

Sixteen samples of fine to coarse-grained red sandstone were collected from deformed strata of the Harbour Main Group around the southern end of Conception Bay in the Holyrood map-area. The results for nine coarse-grained samples were rejected due to internal inconsistency in the measured directions, possibly as a result of the coarse nature of the detrital constituents. The remaining seven samples, whose natural remanent magnetization (NRM) directions are plotted in Figure 2, were collected from fine-grained dense red sandstone representing a stratigraphic interval of 35 feet near Ballyhack Point, have a specimen to specimen agreement of less than 5 degrees. The effect of magnetic cleaning on these samples in alternating fields up to 300 oersteds (peak value) was not significant with little or no change or improvement in the NRM directions of magnetization or Fisher statistics respectively. The NRM of these samples seems to be predeformational as indicated by the decrease in the k and α statistics when the results are corrected for tilt of the strata. These are given in Table II.

Table II

NRM Directions for the Harbour Main Group

Treatment	D	I	N	α	k	R
Corrected for tilt	308.1	+48.0	7	13.4	21.3	6.7186
Before Correction for tilt	110.5	+79.5	7	28.2	5.5	5.9142

Conception Group

A total of 12 samples of dense red to purple slaty siltstone were collected from two localities; one near Calvert on the east coast of the Avalon Peninsula, the other at the southwest end of Conception Bay between Bay Roberts and Holyrood. A well developed cleavage was present in the beds from which the samples were collected. Figures 3A and 3B are plots of the NRM and stable directions of magnetization for the two localities combined. The results are given in Table III.

Table III

NRM and Stable Directions of Magnetization for the Conception Group, Corrected and Before Correction for Tilt of the Beds

Treatment	D	I	N	α	k	R
NRM, Corr. for Tilt	173.0	+30.8	12	16.9	7.5	10.5419
Stable, Corr. for Tilt	172.9	+34.9	12	25.1	4.0	9.2185
NRM Before Corr. for Tilt	167.8	+38.1	12	19.8	5.8	10.0965
Stable " " " "	177.5	+46.9	12	26.6	3.6	8.9735

(Insert Figure 3A and B)

As seen in Table III the mean directions of magnetization were not significantly altered by magnetic cleaning in alternating fields of 300 oersteds (peak value). The precision parameter of the natural remanent magnetization grouping ($k = 7.5$, $\alpha = 16.9$) corrected for tilt of the beds was not improved with cleaning ($k = 4.0$, $\alpha = 25.1$). Regardless of whether or not correction is made for tilt of the beds the mean directions of magnetization are quite different than the present field directions. The development of the slaty cleavage during deformation may possibly have altered the NRM directions and produced the wide scatter of the vectors plotted on Figure 3A and B.

Cabot Group

Signal Hill Formation

Twenty samples were collected from the hard massive beds of medium to fine-grained red to reddish brown sandstone from the middle and upper members of the formation from the vicinity of Flat-rock, Signal Hill, and Petty Harbour. Magnetic cleaning in alternating fields up to 300 oersteds (peak value) had little significant effect on the directions of the majority of the magnetic vectors. The results for three samples from coarser sandstone were rejected from the analysis because of internal inconsistency. The stable directions of magnetization of the remaining 17 samples corrected and before correction for
and their mean directions listed in Table IV.
tilt of the beds are plotted on Figure 4. The mean directions of both presentations are significantly different than the present field direction. As seen in Table IV, by a comparison of k's, little improvement of the grouping of the magnetic vectors is achieved by not correcting for tilt of the beds. This suggests that the magnetization of the formation is not post deformational.

Table IV

Stable Mean Directions of Magnetization for the Signal Hill Formation, Corrected and Before Correction for Tilt of the Beds

Treatment	D	I	N	α	k	R
Corr. for tilt	149.5	+39.4	17	13.2	8.3	15.0695
Before Corr. for tilt	193.0	+56.8	17	13.8	7.7	14.9181

Blackhead Formation

Nine samples of unweathered fine-grained red arkosic sandstone were collected from the vicinity of Blackhead and Petty Harbour, about six miles south of the city of St. John's. Eight samples were taken through a stratigraphic interval of about 200 feet of the lower member of the formation and one sample from the upper member.

The NRM of these nine samples was not significantly altered by magnetic cleaning in alternating fields up to 300 oersteds (peak value). As seen in Figure 5, a sterographic projection of the results for the nine samples corrected and before correction for tilt of the beds, and from the results given in Table V, the scatter of the directions are much less when the bedding planes are used as the reference plane (k = 18.0, α = 12.5) as opposed to a horizontal plane through the tilted beds (k = 8.0, α = 19.4). This indicates that the magnetization of the Blackhead Formation is predeformational.

Table V

NRM Mean Directions of Magnetization for the Blackhead Formation, Corrected and Before Correction for Tilt of the Beds

Treatment	D	I	N	α	k	R
NRM Corr. for Tilt	61.7	+54.8	9	12.5	18.0	8.5550
NRM Before Corr. for Tilt	43.5	+79.9	9	19.4	8.0	8.0006

Hodgewater Group

Fifteen samples were collected from the Whiteway and Snows Pond Formations which are tentatively correlated on the basis of their similar lithologies with parts of the Signal Hill and Blackhead Formations of the Cabot Group. In the Harbour Grace map-area, 4 miles southwest of Clarkes Beach, nine samples of red siltstone and sandstone were collected through a stratigraphic interval of 100 feet of the Whiteway Formation which has a maximum and consistent thickness of 335 feet

(Hutchinson 1953). In thin section the detrital constituents, which are quite angular, but fairly well sorted, are mainly quartz with some feldspar, magnetite, and biotite with an argillaceous matrix stained red due to hematite and to which the rock owes its colour. In addition, six samples were taken from red siltstones, comprising Division 10, a lower part of the Snows Pond Formation and estimated by McCartney (1957) to be 1,100 feet thick, located near Greens Harbour on the eastern shore of Trinity Bay in the Dildo map-area. The samples from the Whiteway and Snows Pond Formations have been combined to describe the Hodgewater Group, rather than the individual units sampled, as only 9 of the 15 samples had measurable magnetization.

The NRM and stable directions of magnetization for the nine samples corrected and before correction for tilt of the beds are shown on Figure 6, A and B respectively with their mean directions and Fisher statistics given in Table VI. As seen from these the NRM grouping which was quite scattered ($k = 5.5$, $\alpha = 24.1$) was much improved ($k = 16.2$, $\alpha = 13.2$) by magnetic cleaning in alternating fields up to 300 oersteds (peak value) for the case where the results were calculated with respect to a horizontal plane through the tilted beds (before correction for tilt). The magnetization of the beds appears to be post-deformational as seen from a comparison of the precision parameters ($k = 16.2$, $\alpha = 13.2$) for a horizontal reference plane through the tilted beds as compared to the precision parameters ($k = 11.1$, $\alpha = 16.2$) for the strata restored to a horizontal position.

Table VI

NRM and Stable Mean Directions of Magnetization
for the Hodgewater Group, Before and
After Correction for Tilt of the Beds

Treatment	D	I	N	α	k	R
NRM before corr. for tilt	129.4	+22.6	9	24.1	5.5	7.5528
Stable before corr. for tilt	166.7	-28.2	9	13.2	16.2	8.5064
NRM corr. for tilt	156.7	+59.1	9	33.6	3.3	6.5807
Stable corr. for tilt	158.1	- 5.4	9	16.2	11.1	8.2780

Cambrian Rocks

Lower Cambrian Rocks

Ratcliffe Brook Formation

Fourteen samples of dark purplish red, fine-grained, micaeous sandstones were collected through a stratigraphical interval of 1,000 feet from the Ratcliffe Brook Formation northwest of St. John, New Brunswick. The samples were taken from a section, where the strata dip up to 50 degrees, exposed along Hanford Brook. The NRM and stable mean direction of magnetization after alternating field treatment at 300 oersteds (peak value) are given in Table VII and plotted on Figure 7. Two samples were rejected due to internal inconsistency. As seen in Figure 7 the mean direction after treatment is not significantly different from that of the NRM results and is nearly 180 degrees away from the present earth's field direction at the collection locality.

Table VII

NRM and Stable Mean Directions of Magnetization
for the Ratcliffe Brook Formation,
Corrected for Tilt of Beds

Treatment	D	I	N	S	R	α	k
NRM	175.6	+58.7	12	24	10.739	15.6	8.7
Stable	168.1	+53.2	12	24	10.843	14.9	9.5

Lower Cambrian of the Conception Bay
Area, Avalon Peninsula

Eight samples were collected from red shale and limestone, which dip gently to the northwest and outcrop along Kelligrews River and in the vicinity of Duffs, along the southeast coast of Conception Bay.

Figure 8 is a plot of the stable directions of magnetization of the eight samples, both before and after correction for tilt of the beds. Magnetic cleaning in alternating fields of 300 oersteds (peak value) had the effect of increasing the declination (D) and decreasing the inclination (I) by approximately 10 degrees respectively. A comparison of the statistics (k, α) listed in Table VIII indicates a decrease in the scatter of the vectors when it is assumed that their magnetization has occurred since the beds have undergone tilting. Further discussion as to the time of magnetization of these Lower Cambrian beds is given under the section 'Interpretation Data'.

Table VIII

Stable Mean Directions of Magnetization for Lower Cambrian Rocks of the Avalon Peninsula, Before and After Correction for Tilt of the Beds

Treatment	D	I	N	S	α	k	R
Before correction	29.2	+37.8	8	16	8.4	44.2	7.842
After correction	19.9	+32.1	8	16	9.7	33.0	7.788

Labrador Series, Bradore Formation

Highlands of St. John

Twelve samples of unweathered fine-grained red to brownish red sandstone were collected through a 50 foot section of the Bradore Formation exposed on the face of South Summit in the canyon of Frenchman's Brook on the northwest coast of Newfoundland. Figure 9A is a stereographic projection of the NRM and stable directions of magnetization of 11 and 10 samples respectively. One sample had a magnetization too weak to measure accurately while another became internally inconsistent after magnetic cleaning in an alternating field of 300 oersteds (peak value). Magnetic cleaning increased the scatter of the magnetic vectors; however, the mean direction of magnetization for the group was not appreciably altered. Statistics describing the NRM and stable directions of magnetization are given in Table IX.

<u>Southeast Coast of Labrador</u>

Thirty-four samples of medium to coarse-grained continental reddish arkose and sandstone were collected from the lower 150 feet of strata of the Bradore Formation exposed in sea cliffs between Blanc Sablon, Quebec, and Anse aux Morts, Labrador. Figure 10 is a plot of the stable directions of magnetization not corrected for tilt of the beds, that is computed with respect to a horizontal plane through the tilted strata as required when the magnetization is secondary and post deformational. Magnetic cleaning of the samples had little effect on the mean direction of magnetization for the group. Table IX lists the statistics for the NRM and stable directions of magnetization obtained for 31 and 28 samples respectively. Six samples were rejected due to internal inconsistency, three each after the NRM and stable results were obtained.

The mean direction of magnetization of the treated samples is significantly different from that obtained for the same formation sampled in the Highlands of St. John, and is close to the earth's present field direction (see Fig. 93). This suggests that the magnetization within this part of the Bradore Formation is secondary.

Thin sections of selected samples from the Highlands of St. John show abundant detrital iron oxide, quartz and feldspar grains surrounded by a siliceous matrix, whereas Labrador specimen show few detrital iron oxide grains, with quartz and feldspar grains enclosed by a hematite rich matrix. The section of the Bradore Formation sampled in Labrador is stratigraphically lower than that in the Highlands of St. John and is composed of much coarse-grained sandstone and pebble conglomerate. It, therefore, may have greater porosity than that part of the section sampled in the Highlands of St. John which would allow solutions freer mobility with the result that the detrital iron oxide minerals have been oxidized to hematite.

Table IX

Summary of the NRM and Stable Directions of Magnetization and Fisher Statistics for the Bradore Formation, Northwest Newfoundland and coast of Labrador

Location	Treatment	D	I	N	S	R	α	k	Remarks
Northwest	NRM	140.9	+55.5	11	22	10.8517	5.6	67.4	Corrected
Newfoundland	Stable	151.2	+44.5	10	20	9.6716	9.4	27.4	for tilt of beds
Coast of	NRM	17.3	+74.6	31	62	27.5253	9.3	8.6	Not cor-
Labrador	Stable	21.5	+72.3	28	56	25.5884	8.5	11.2	rected for tilt of beds.

Middle Cambrian Rocks

March Point Formation

Seventeen samples of fine-grained red to pink sandstone, some of which are variegated red and white due possibly to deoxidation, were collected from 350 feet of strata comprising the lower part of the March Point Formation exposed between DeGrau and March's Point, a distance of about 2 miles, on the Port au Port Peninsula, Newfoundland.

Figure 10 is a plot of the NRM results for 15 of the 17 samples with their directions of magnetization corrected and before correction for the existing tilt of the strata. The first infers that the magnetic vectors represent magnetization directions originating when the beds were in a horizontal position, while the second implies that the magnetization directions are post deformational. The directions of magnetization appears to be in two groups. Group one composed of nine samples plots near the present earth's field direction, while group two composed of six samples is about 180 degrees different. Samples of both groups have stable directions of magnetization in alternating fields up to 300 oersteds (peak value). Two samples were rejected as they had natural remanent magnetizations too weak to measure. Thin section study on samples from both groups reveals no significant difference in the composition of the detritus and cementing agents. Both groups are composed mainly of a quartzose sandstone with a hematite bearing siliceous cement.

Table X gives the mean NRM direction and Fisher statistics for each group before and after correction for tilt of the bedding. As seen in Figure 10 the magnetic vectors of Group 1, before correction for tilt of the strata, have a steeper inclination of magnetization and plot near the present earth's field direction. The precision parameter for the NRM of Group I ($k = 20.4$, $\alpha = 11.7$) did not alter appreciably when corrected for tilt of the beds ($k = 19.4$, $\alpha = 12.0$). Group II, however had a decrease in the precision parameter ($k = 18.7$, $\alpha = 15.9$ to $k = 10.6$, $\alpha = 21.5$) when correction for tilt of the beds was made which suggests that the magnetization has occurred since the beds were folded. The position of the magnetic vectors of Group I, near the present field direction indicates that they were magnetized considerably after those of Group II. Both groups appear to have a stable post deformational secondary magnetization but not of the same age. Further discussion as to the age of the magnetization is given under the section 'Interpretation of Data Results'.

Table X

Mean NRM Directions and Fisher Statistics of the March Point Formation, Before and After Correction for Tilt of the Beds

Group No.	D	I	N	S	α	k	R
I Before Correction	355.4	+73.6	9	18	11.7	20.4	8.6082
I After Correction	341.1	+54.3	9	18	12.0	19.4	8.5872
II Before Correction	185.5	+67.0	6	12	15.9	18.7	5.7329
II After Correction	183.3	+60.7	6	12	21.5	10.6	5.5301

Ordovician Rocks, Newfoundland

Lower Ordovician Rocks

Bell Island and Wabana Groups

A total of 47 samples was collected from the Lower, Middle, and Upper beds of the oolitic hematite located on the property of the Dominion Steel and Coal Corporation, Bell Island, Newfoundland. Thirty-three samples were taken from surface and underground exposures of the Lower bed while 4 and 10 samples were taken respectively from surface exposures of the Middle and Upper beds. The Lower bed, which is 10 to 30 feet thick and 240 feet below the Middle bed, occurs in the upper part of the Bell Island Group. The Middle and Upper beds which are separated by about 50 feet of strata, are 6 to 13 feet thick and occur in the Wabana Group.

Three samples collected from the Upper bed had magnetizations too weak to measure accurately. The directions of magnetization of the remaining 44 samples were not significantly affected by alternating fields up to 300 oersteds (peak value). The mean directions of magnetization for the three beds calculated from the NRM results as well as a combined mean direction of magnetization are given in Table XI.

Table XI

Mean NRM Directions and Fisher Statistics for Lower, Middle, and Upper Ore Beds of Bell Island and Wabana Groups, Corrected for Tilt of the Beds

Bed	D	I	N	S	R	α	k
Upper	5.9	+25.0	7	14	6.5465	17.2	13.2
Middle	8.2	+17.9	4	8	3.8162	23.4	16.3
Lower	9.8	+10.2	33	66	31.7502	5.0	25.6
Combined[1]	8.0	+17.7	-	-	-	11.6	113.5
Combined[2]	9.1	+13.2	44	88	41.9078	4.9	20.6

1) Each bed assigned unit weight.

2) Each sample assigned unit weight.

Figure 11A is a plot of the NRM directions of magnetization of the 44 samples from the three beds as well as a mean direction of magnetization for the three beds based on unit weight per sample.

The directions of magnetization obtained for the Wabana samples are not similar to those obtained for other Ordovician rocks from Newfoundland as shown in Figures 12 and 13. The virtual pole positions based on the mean directions of magnetization listed in Table XI have latitudes in the order of 30 degrees higher than those for the St. George Group and Spoon Cove Formation and approximate North American Permian poles (see Table XVII). This indicates that the natural remanent magnetization of the bed does not represent the earth's magnetic field direction during Ordovician time.

To be certain that the directions of magnetization obtained for the Wabana iron ore samples truly represents the direction at the time of magnetization of the ore beds and not that of a strong viscous component of magnetization, which was not removed by magnetic cleaning, further tests of stability were undertaken on 12 representative specimens. These specimens were progressively heated in a non magnetic oven in a space free of magnetic fields and the directions of magnetization determined after each heat treatment. Four of the samples had their NRM directions reproduced up to 605 degrees C, while the directions of magnetization of the remainder became randon at 405 degrees C. Seven of the specimens were then heated to about 850 degrees C, and cooled in a known magnetic field; three were placed with the magnetizing field normal to the bedding planes and four with the field parallel to the bedding planes. In all cases the applied field direction was reproduced within 4 degrees. The results of these tests indicate that the Wabana iron ore is magnetically isotropic and has a stable natural remanent magnetization.

As it is probable that the stable magnetization of the ore beds is post Ordovician, then two possible sets of magnetization directions can be given as the beds where samples have been tilted up to 14 degrees to the northwest. If it is assumed that the beds were magnetized before they were tilted, then the directions of magnetization are referred to the beds in an assumed horizontal position, as given in Table XI. However if the beds were tilted before magnetization, then the magnetic vectors must be referred to a horizontal plane through the tilted strata, as given in Table XII and plotted in Figure 11B.

Table XII

Mean NRM Directions and Fisher Statistics for Lower, Middle, and Upper Ore Beds of Bell Island and Wabana Groups, Before Correction for Tilt of the Beds

Bed	D	I	N	S	R	α	k
Upper	7.4	+ 30.9	7	14	6.4697	18.8	11.3
Middle	10.8	+ 29.1	4	8	3.7886	25.3	14.2
Lower	10.6	+ 15.9	33	66	31.6415	5.3	23.6
Combined[1]	9.6	+ 25.3	-	-	-	12.8	94.3
Combined[2]	10.1	+ 19.4	44	88	41.6502	5.2	18.3

1) Each bed assigned unit weight.

2) Each sample assigned unit weight.

The precision parameter of the natural remanent magnetization before correction for tilt of the beds ($k = 18.3$, $\alpha = 5.2$) is less than that for the beds corrected for tilt ($k = 20.6$, $\alpha = 4.9$) for the combined results from the three ore beds. This suggests that the ore beds obtained their stable NRM before they were tilted.

St. George Group

Ten samples of the buff to reddish dolomitic limestone were collected from a 30 foot section in Man-O-War Cove, situated on the south coast of the Port au Port Peninsula approximately 3 miles west of the village of Port au Port, Newfoundland.

Figure 12 is a plot of the NRM directions of 7 of the 10 samples corrected for tilt of the beds. Three were rejected as they had magnetizations too weak to measure accurately. Magnetic cleaning in alternating fields up to 300 oersteds (peak value) had no significant effect on the directions of magnetization of the measurable specimens. The mean direction of magnetization of these seven samples is 173.7 degrees inclined downwards at +42.2 degrees with a k value of 24.1 and α of 12.5 degrees.

Middle to Upper Ordovician Rocks

Cinq Isle Series, Spoon Cove Formation

Eighteen samples of fine-grained dark red to purple micaceous sandstone were collected from the Spoon Cove Formation where it outcrops along the southeast shore of Great Bay de l'Eau at Salmonier Cove, Newfoundland. The samples were taken through a stratigraphic interval of about 75 feet from strata dipping about 15 degrees southeast. The red sandstones are underlain by alternating beds of yellow and black banded sandstone and a dark grey to black basal conglomerate, all totalling a thickness of 300 feet (Widmer 1950).

Generally the NRM directions were not altered by magnetic cleaning in alternating fields up to 300 oersteds (peak value), however, the few that were apart from the general group were improved and brought into agreement with the stable ones. Figure 13 is a plot of the stable directions of magnetization of 15 of the 18 samples corrected for tilt of the beds. Three were rejected due to internal inconsistencies between cubes of the same sample which could not be improved with treatment. The group has a mean direction of magnetization of 197.1 degrees inclined downward at +38.7 degrees, with a k value of 15.5 and α of 7.7 degrees.

Ordovician(?) Rocks

Bay of Islands Igneous Complex

Sixteen samples of bytownite gabbro (unit 7, Smith 1958), capping the ultrabasic rocks, were collected from the Table Mountain mass approximately 3 miles east of the village of Trout River, Newfoundland. They are mainly grey to black fine- to medium-grained rocks, composed of plagioclase (bytownite), augite, olivine, and some hornblende as a result of secondary alteration. Anhedral crystals of magnetite are a common accessory mineral, and are late in the crystallization sequence. The NRM directions were consistently altered by the magnetic cleaning in alternating fields up to 200 oersteds (peak value). Considerable scatter of the directions resulted with further treatment in alternating fields of 300 oersteds (peak value). Four samples were rejected on the basis of internal inconsistency of the magnetic vectors, as the directions for two specimens from each sample did not improve at any step of the treatments. The directions of magnetization of the 12 remaining samples are plotted in Figure 14, as well as their mean direction, which was computed to be 149.6 degrees inclined at + 39.0 degrees with a k value of 21.8 and α of 9.5 degrees.

Silurian Rocks

North Central Newfoundland

Samples were collected from sedimentary and volcanic rocks of the Botwood Group and from a large intermediate to basic intrusion which cuts the Botwood Group. Samples were collected from the Springdale Group and from rocks provisionally mapped as belonging to the Springdale Group with the intention of correlating them on the basis of their palaeomagnetism as well as correlating the Springdale Group with the Botwood Group. A few samples were also collected from a sill like mass of diabasic gabbro in the Gull Pond map-area, which intrudes Ordovician rocks.

Botwood Group

Forty-two samples in all were collected from the Botwood Group from the west limbs of northeast trending folds; 16 from steeply dipping volcanic rocks located on the east side of the Bay of Exploits north of the village of Laurenceton, and 26 samples from medium to steeply dipping red sandstones near Bishops's Falls and in quarries located east of Peter's Pond about six miles northeast of Bishop's Falls.

Volcanic Rocks

Figure 15 is a plot of the stable directions of magnetization of 9 of 16 samples from the volcanic rocks of the Botwood Group. The NRM directions were quite scattered, however, with magnetic cleaning in alternating fields up to 300 oersteds (peak value), nine samples have had an unstable component of magnetization successfully removed as only minor changes occurred between final and second last step of the treatment. The directions of magnetization of seven samples continued to change significantly with cleaning and have therefore been rejected. The mean direction of magnetization of the stably magnetized samples is 22.3 degrees inclined at - 10.8 with a k value of 19.0 and α of 12.1 degrees.

Sedimentary Rocks

Figure 16 is a plot of the NRM results obtained for 24 of the 26 samples collected from the red sediments of the Botwood Group. Two samples with magnetizations too weak to measure were rejected. No significant change occurred in the directions of magnetization for the samples with magnetic cleaning in alternating fields up to 300 oersteds (peak value). Seventeen of the samples are negatively polarized while the remaining seven are positive with low inclinations. The mean direction of magnetization is 319.3 degrees inclined upwards at - 15.4 degrees with a k value of 110 and α of 9.4 when the samples are assumed to have a regional strike of 50 degrees E of N and dip 90 degrees NW.

Intermediate to Basic Intrusion

Sixteen samples of dark grey to black gabbro were collected along a 2 mile exposure of the intrusion in Rattling Brook south of the Bay of Exploits. All the samples are negatively polarized as are the sediments and volcanic rocks of the Botwood Group. Treatment in alternating fields up to 300 oersteds (peak value) had little effect on the directions of magnetization, other than to reduce the scatter of the NRM results. Figure 17 is a plot of the stable directions of magnetization for the 16 samples as well as the mean direction of magnetization of 69.3 degrees inclined upward to - 59.0 degrees with a k value of 49.7 and α of 5.3 degrees.

If it is assumed that the disagreement in the position of the mean magnetization vector for the intrusion as compared to that determined for the Botwood volcanic rocks and the Springdale Group (see pp) is a result of structural deformation of the intrusion in post Silurian time, then the amount of rotation the intrusion has undergone may be determined. A rotation about a horizontal axis of the intrusion through 65 degrees about an axis striking 78 degrees E of N is sufficient to bring the mean direction of magnetization into near coincidence with that of the Botwood Group volcanic rocks and the Springdale Group rocks. Immediately to the north of the intrusion the structural trend of the Botwood Group is approximately 50 degrees E of N with dips up to 60 degrees SE (Williams 1962), quite similar to the conditions required to effect coincidence of the Silurian mean directions of magnetization. This new position of the mean direction of magnetization for the intrusion is also shown on Figure 17. The statistics describing the group assuming the above correction for tilt about a horizontal axis has been given in Table I.

Springdale Group

Thirty-two samples were collected from gently dipping inter-bedded volcanic and sedimentary rocks, belonging to the Springdale Group. The samples were taken from an area located 5 to 10 miles southwest of the town of Springdale. Fourteen of the samples were collected from units 11 and 13, intermediate to basic fine-grained to amygdule lava flows; and of the 18 samples from unit 16, composed of red arkosic sandstones and conglomerates (Kalliokoski 1953).

Figure 18 is a plot of the final directions of magnetization of 12 of the 14 samples collected from the volcanic rocks. Two samples were rejected because of internal inconsistency. Magnetic cleaning in alternating fields of 250 oersteds (peak value) had little significant effect on the directions of magnetization of the majority of the samples; however, a decrease in scatter was obtained as the directions of a few anomalous vectors were brought into better agreement with those unaltered by the treatment. All samples have directions of magnetization that are negatively polarized. The mean direction of magnetization is 16.3 degrees inclined upwards at -13.3 degrees with a k value of 34.3 and α of 7.5 degrees.

On Figure 18 there is also plotted the stable directions of magnetization of 16 of the 18 samples collected from the red sediments. Again two samples were rejected due to internal inconsistency between specimens from the same sample, probably a result of the coarseness of the detritus forming these samples. The only effect observed after magnetic cleaning in alternating fields up to 300 oersteds (peak value) was an improvement in the group with four samples which initially were normally polarized as low inclinations became negative and similar to those that had stable and negative NRM's initially. The mean direction of magnetization for this group is 18.8 degrees inclined upwards at - 22.2 degrees with a k value of 21.9 and α of 8.1 degrees. As the volcanic and sedimentary rocks have mean directions of magnetization that are in very close agree-ment with each other, a better description of the geomagnetic field produc-ing these directions would be obtained by combining the results. The mean direction for the Springdale Group of 17.7 degrees inclined upwards at - 18.4 degrees with a k value of 24.7 and α of 5.6 is obtained by combining the results from 28 samples. This is shown in Figure 18.

Springdale Group (?)

Eighteen samples of red to reddish brown sandstones were collected from more than 1,000 feet of southwesterly dipping strata on the east and west shores of Southwest Arm near King's Point Newfoundland. Figure 20 is a plot of the NRM directions of 13 samples that have been used to determine the mean direction of magnetization for this formation. Five were rejected as three had magnetizations too weak to measure accurately and two were internally inconsistent due probably to the coarseness of the detritus forming the sandstone. All samples, but one, are positively polarized.

When subjected to magnetic cleaning the directions of magnetizations became badly scattered with both positive and negative poles occurring. The scatter could not be reduced by continued treatment in alternating fields up to 300 oersteds (peak value). It has been assumed for the purposes of this analysis that the NRM measurements represent stable magnetization vectors. This is suggested by the position of the magnetic vectors on Figure 19 which are quite different than the position of the earth's present field direction at the collection locality. The results for this group are diametrically opposite to those obtained from the stably magnetized Springdale Group located about 10 miles to the south.

The group has a mean direction of magnetization of 200.1 degrees inclined at +17.0 degrees with a k value of 19.7 and α of 9.6 degrees. It is suggested on the basis of the palaeomagnetic results that these rocks are comparable in age to those of the Springdale Group.

Diabasic Rocks

The results obtained from four of eight samples of diabasic gabbro collected from a sill-like mass (unit 17a, Kalliokoski 1954) located at the south end of Joes Lake, north of Badger, are shown in Figure 20. All of the NRM directions were altered by magnetic cleaning and only four samples had directions of magnetization that were stable after treatment in alternating fields of 300 oersteds (peak value). The other four samples were internally inconsistent as significant changes in the directions of magnetization occurred after each treatment. The four stably magnetized samples are negatively polarized with a mean direction of magnetization of 14.3 degrees inclined upwards at -19.3 degrees with a k value of 74.5 and α of 10.7 degrees, comparable to the results for the Springdale Group.

Devonian Rocks

Clam Bank Group

Eighteen samples of fine- to medium-grained red and reddish brown sandstone were collected through approximately 200 feet of strata from the southeast limb of a syncline exposed along the coast between Winterhouse and Clam Bank Cove, Newfoundland. The beds strike northeasterly and dip to the northwest at 40 degrees.

The NRM directions obtained for 18 of the 20 samples collected are plotted in Figure 21. Two samples were rejected as they contained large tabular chips and gave inconsistent results between cubes from the same sample. The magnetization directions were not affected by alternating fields up to 300 oersteds (peak value). The mean direction of magnetization for the group, composed of 14 negatively and four positively polarized samples, is 337.5 degrees inclined upwards at - 19.8 degrees, with a k value of 10.2 and α of 11.4.

Perry Formation

A total of 60 oriented samples was collected from the vicinity of St. Andrews Peninsula and Minister Island, New Brunswick; fifty-eight samples of sedimentary and volcanic rock from the Perry Formation, or diabase cutting the Perry Formation, and two samples of diabase from a dyke intruding the underlying Mascarene Group of Silurian age (Alcock 1946). Thirty-six of the 58 samples were collected from fine- to medium-grained red sandstone along the shoreline of the St. Croix River between Johnson Cove and the town of St. Andrews, a distance of approximately 4 miles, and from shore exposures on the northeast side of Minister Island. Sixteen samples of purple to greyish black volcanic rock interbedded with the red sediments, were collected in the vicinity of Brandy Cove and Bar Road. Four samples of diabase and two of red sediment, baked during the intrusion of the diabase, were collected from dykes at two localities.

The stable directions of magnetization for the 36 samples of sedimentary rock are plotted in Figure 22A. The directions were not significantly affected by alternating fields up to 300 oersteds (peak value). The mean direction for the group is 173.7 degrees inclined downwards at + 19.5 degrees with a k value of 8.9 and α of 8.5 degrees. Ten of the 36 samples have shallow negative polarities.

The results after magnetic cleaning in fields of 300 oersteds (peak value) for the 16 volcanic samples are more scattered than those of the sedimentary samples. These are plotted in Figure 22B. The mean direction of magnetization after treatment is 183.5 degrees inclined downwards at + 33.8 degrees, with a k value of 7.0 and α of 15.0 degrees and is somewhat different than that of the sediments, being 10 degrees greater in declination and 14 degrees steeper in inclination. The steeper inclination of the Perry Formation volcanic rocks may be due to the inability of the sedimentary rocks to preserve the ancient geomagnetic inclination or as is more probable, as was indicated by the changes in directions of the magnetic vectors for some samples, the volcanic rocks have acquired a secondary component of magnetization along the earth's magnetic field which has resulted in an increase in the inclination.

The six samples of diabase and baked sediment within the Perry Formation have directions of magnetization that are relatively stable in alternating fields up to 300 oersteds (peak value), but are significantly different from the directions of magnetization of the rocks they intrude. The mean direction of magnetization for the group is 10.2 degrees inclined at +46.5 degrees, with a k value of 40.9 and α of 10.6 degrees. The results for these six samples are also plotted in Figure 22B.

The two samples from the diabase dyke intruding the Silurian rocks of the Mascarene Group have a mean direction of magnetization different from either the Perry Formation volcanic rocks or the diabase dykes intruding the Perry Formation sediments. The mean direction for these two samples is 100.5 degrees inclined at +36.3 degrees. These are not plotted.

Carboniferous Rock

For the most part samples from the Pennsylvanian or units indicated as Pennsylvanian and/or Mississippian were collected from flat lying or gently dipping strata, whereas those from strata of Mississippian age were collected from moderate to steeply dipping strata.

In this study 244 samples have been used to determine the directions of magnetization for formations and groups of related rocks of Carboniferous to Permo-Carboniferous age deposited within the Carboniferous basin of Eastern Canada.

Mississippian

Kennebecasis Formation

Fourteen samples of red sandstone were collected from an area 10 miles square, from seven sites east of Kennebecasis Bay and

Kennebacis Lake, New Brunswick. The NRM directions were not significantly changed by alternating fields up to 300 oersteds (peak value). The results of the individual samples, with a mean direction of 161.3 degrees inclined at +33.3 degrees with a k value of 18.1 and α of 9.6 degrees, are shown in Figure 23.

Codroy Group

Forty-one oriented samples of red sandstone and siltstone were collected from sections F, G, and H of Bell (1948) in the vicinity of St. Davids and Robinson Head, western Newfoundland. Two samples were collected also from strata near the middle of section D (Bell 1948) south of Codroy village.

Magnetic cleaning in alternating fields up to 300 oersteds (peak value) did not significantly affect the directions of magnetization of the individual samples. Nine samples, however, four of which had magnetizations too weak to detect accurately, are rejected due to internal inconsistency which could not be improved with magnetic cleaning. These five samples are coarse-grained sandstones and exhibit pronounced cross-bedding. The results obtained from the remaining 32 samples have been divided into two groups.

Group I, is composed of 23 samples which have magnetic vectors that are relatively low in inclination and are both normal and reversed in polarity. Thirteen samples have had their direction of magnetization reversed for statistical and comparative purposes and are plotted with the remaining 10 samples in Figure 24. The mean direction of magnetization for this group is 173.2 degrees inclined downwards at +8.9 degrees with a k value of 16.4 and α of 7.7 degrees.

Group II is made up of 9 samples, all are positively polarized and have similar declinations but higher inclinations than those of Group I.

The mean direction of magnetization for this group is 181.3 degrees inclined at +61.7 degrees with a k value of 27.8 and α of 9.9 degrees. These are also plotted in Figure 24. The mean direction of magnetization for Groups I and II combined, obtained by assigning unit weight to each sample, is 174.5 degrees inclined at +23.4 degrees, with a k value of 7.3 and α of 10.1 degrees.

Searston Beds

Four oriented samples were collected from a 10 foot sequence of purplish grey highly micaceous sandstone and arenaceous shale (Bed No. 254 Section A Bell 1948) north of Stormy Point in the Codroy area. Alternating field demagnetization up to 300 oersteds (peak value) did not significantly alter the directions of magnetization of the individual samples. As illustrated in Figure 25 the directions of magnetization (NRM) of the samples have negative inclinations with declinations similar to those of the underlying Codroy. The mean direction of magnetization for the group is 174.3 degrees inclined upwards at -22.5 degrees with a k value of 90.7 and α of 9.7 degrees.

Mississippian - Pennsylvanian Rocks
Central New Brunswick, Gaspe Coast

pre-Pictou Rocks

Nine samples of flat-lying sandstone and 24 samples of volcanic rock were collected from a line of outcrops approximately 8 miles long by 2 miles wide a few miles southwest of Boiestown, New Brunswick.

The three flows present in the area (Poole 1958) were sampled. These flows are readily distinguished from one another in the field by megascopic examination. Flow type one, the upper flow, is a fine-grained non vesicular dark grey to reddish grey porphyritic basalt containing phenocrysts of feldspar. Flow type two, the lower flow, is a fine-grained grey slightly vesicular non porphyritic basalt. The red bed sequence sampled lies stratigraphically between flows two and one. Flow type three, which lies stratigraphically above and conformable with flow type two, is a black dense hard aphanitic non vesicular basalt containing sparse olivine phenocrysts. In thin section all three flows contain approximately 10 per cent magnetite which occurs as euhedral crystals in flow types two and three and as grains in flow type one. No severe alteration appears to have occurred in any of the flows except flow type three where some of the magnetite crystals are only skeletal remnants.

Most of the directions of magnetization for the volcanic samples were significantly altered by magnetic cleaning (see Fig. 26 and appendix). Little can be said with regard to the declinations obtained but a consistent pattern with regard to the inclination of the magnetic vectors is apparent after treatment. All nine samples collected from flow type one remained positively polarized after treatment whereas the 15 samples from flow types two and three became or remained negatively polarized after treatment in alternating fields up to 300 oersteds (peak value). The stable results of the individual directions of magnetization for each sample are shown in Figure 26.

In general it may be concluded that treatment of samples from flow type one yielded results more in line with those obtained for the sediments (see below) while the results for the samples from flow types two and three are somewhat diametrically opposite to those for the sediments. This is indicated by the few samples for which the directions of magnetization were not significantly altered by the treatment. The mean results for the three flow types are given in Table XIII. The extremely low values for k indicate the immense scatter of the results.

Table XIII

Mean Directions of Magnetization for the pre-Pictou Carboniferous Volcanic Rocks in the Napadogan and Boiestown Area, New Brunswick

Flow Type	D	I	N	S	R	α	k
1 (upper)	199.3	+51.8	9	18	7.3612	26.0	4.9
2 (lower)	321.8	-34.4	9	18	7.3394	26.2	4.8
3 (middle)	283.0	-67.7	6	12	3.6073	62.0	2.1

The directions of magnetization of all of the sandstone samples taken from strata which lie between the upper flow (type 1) and lower flow (type 2) were also significantly changed by alternating field cleaning as shown in Figure 27. The solid circles represent the NRM directions while the solid circles with crosses represent the stable directions for eight of the nine samples obtained after treatment in alternating fields of 300 oersteds (peak value). One sample was rejected due to internal inconsistency. The mean direction for the final results obtained is 161.5 degrees inclined at +30.5 degrees with a k value of 13.8 and α of 15.4 degrees. All of the samples are positively polarized.

Laughlin (1960) suggests that flow type three, mapped by Poole (1958) as above and probably continuous with flow type two and distinguished from it on the basis of petrography, is a dyke which may be much younger than the other irruptive rocks of the area. He infers from its elevation and location that the dyke may have intruded both the sediments and the volcanic flows as well as its fresher appearance when compared to the flow rocks near Boiestown. On the basis of the available palaeomagnetic evidence flow types two and three are similar in that they have reversed polarity to those of the normally polarized overlying sediments and volcanic flow. A more extensive collection as well as more exhaustive treatment may well statistically correlated these various units.

Bonaventure Formation

Twenty-four samples of fine-grained red sandstone were collected from exposures over an area 50 miles long on the north shore of Chaleur Bay. Alternating field demagnetization in fields up to 300 oersteds (peak value) did not significantly alter the directions of magnetization of 22 of the samples. Two samples were rejected as their magnetizations were too weak to measure. Figure 28 is a plot of the individual NRM directions with a mean direction of 166.1 degrees inclined at +13.1 degrees and a k value of 21.7 and α of 6.8 degrees.

Pennsylvanian Rocks
New Brunswick

Bathurst Formation

Ten samples of fine to medium-grained red sandstone were collected from four sites along 2 miles of Nepisiguit River just south of the city of Bathurst. The directions of magnetization were not significantly changed by alternating field treatment in fields up to 300 oersteds (peak value). The NRM directions are plotted, with respect to the bedding plane, in Figure 29 as well as the mean direction of magnetization for the group computed as 162.3 degrees inclined at +15.6 degrees with a k value of 28.1 and α of 9.3 degrees.

Permo Carboniferous Rocks
Prince Edward Island

An island wide collection of 245 oriented samples was made from coastal and some inland outcrops composed of red to brownish red coarse to fine-grained sandstone. Inland exposures are few as a result of glacial cover and deep weathering of surface bedrock and occur where road cuts or stream action was severe enough to expose the bedrock. Rock exposures are numerous and readily reached along most of the coast of the Island and for this reason sampling was confined mainly to the sea-cliffs. Five additional samples, which are combined with the results obtained for the Island samples, were collected from coastal exposures of red beds in the vicinity of Cape Tourmentine, New Brunswick. In addition 16 samples were collected from a 10 foot thick olivine dolerite dyke and two samples from baked sediments underlying the dyke. The dyke, ~~ix~~ the only known occurrence of igneous rock on the Island (Milligan 1949), is located on George Island in Malpeque Bay along the northern coast of Prince Edward Island.

Red Beds

One hundred and fifty-four samples, 62 per cent of the 250 samples collected from the red beds, had magnetizations that could be precisely determined. These samples proved to be magnetically stable in alternating fields of 300 oersteds (peak value). Thin section study of representative samples revealed their composition as fairly well sorted subangular to angular grains of fresh quartz, orthoclase and plagioclase, feldspars, occasional mica parallel to the bedding, and some altered grains of magnetite. The grains are held by a dark-brown-red ferruginous carbonate cement, mainly calcite with a little dolomite.

Figures 30 A, B, and C are plots of the individual directions of magnetization (NRM) for each sample corrected for tilt of the bedding. As palaeontological evidence suggests a decrease in age from west to east the data have been divided into three geographical areas for comparative purposes, namely; area 1, northwestern Prince Edward Island, which includes samples north of latitude 46°30' and west of longitude 63°30'; area 2, central Prince Edward Island, south of latitude 46°30' and east to longitude 63°00'; and area 3, eastern Prince Edward Island, east of longitude 63°00'. The mean directions of magnetization and Fisher statistics for each of the three areas are given in Table XIV.

Table XIV

Summary of the Mean Directions of Magnetization and Fisher Statistics of Permo-Carboniferous Rocks of Prince Edward Island

Area	Fig. No.	D	I	N	S	R	α	k
3. Eastern P.E.I.	30C	176.8	+5.5	59	118	54.358	5.5	12.5
2. Central	30B	170.9	+7.2	69	138	62.567	5.5	10.6
1. Northwestern	30A	170.0	+5.3	26	52	24.896	6.1	22.6

Olivine Dolerite Dyke

Microscopically the dyke rock is composed of a matrix of fine-grained laths of plagioclase feldspar with large phenocrysts of olivine which have been partially altered to serpentine. Disseminated through the groundmass is a large quantity of opaque iron oxides, ilmenite and magnetite.

Fourteen of the 18 samples collected from the George Island dyke are used to describe its palaeomagnetism. The NRM directions of most samples were significantly altered by magnetic cleaning in fields of 150 oersteds (peak value), but remained unaltered with further cleaning up to 300 oersteds. The four rejected samples were the exceptions as their directions of magnetization continued to change significantly with each treatment. Most samples whose NRM directions were positively polarized became negative after the initial treatment of 150 oersteds with one exception. The results indicate the successful removal of a viscous component of magnetization. Figure 31 is a plot of the stable directions of magnetization for the 14 samples which have a mean direction of magnetization of 180.6 degrees inclined upwards at -18.9 degrees with a k value of 11.3 and α of 12.4 degrees.

Triassic Rocks

North Mountain Basalt

Thirty-eight samples were collected from the North Mountain Basalt along the southeast coast of the Bay of Fundy from Cape Blomindon southwest of Margaretsville. Samples were collected from both coastal and inland exposures. Figure 32 is a plot of NRM directions of the 38 samples. Successive alternating field demagnetization in steps of 50 oersteds (peak value) up to a maximum of 300 oersteds did not alter appreciably ~~change~~ the directions of magnetization of the samples. A mean direction of magnetization of 357.6 degrees inclined at +51.5 degrees with a k value of 14.7 and α of 6.3 degrees was obtained for the group.

Interpretation of Data

Correlation

Correlation between different rock units using palaeomagnetic results can be achieved by either of two methods. One, when the rock units are from the same locality a direct comparison of the mean directions of magnetization can be made. The other can be used when the rock units are from widely separated locations and involves a comparison of the virtual geomagnetic pole positions calculated from the mean directions of magnetization or by a comparison of the field directions that would be produced at a specified location calculated from the mean directions of magnetization. The following correlations based on the above methods are suggested.

The olivine dolerite dyke which intruded the Permo-Carboniferous reds on George Island in western Prince Edward Island may be of early Triassic age. This is indicated by the proximity of its pole position (53N, 115E) to other Triassic poles determined from North American rocks and shown in Figure 36.

The pole position (71N, 84E) for the diabase dykes intruding the sediments of the Upper Devonian Perry Formation of southern New Brunswick is not at all in agreement with those calculated for either the volcanic (26N, 109E) or sedimentary (35N, 121E) rocks of the Percy Formation but agrees with some of the pole positions for the Triassic rocks that are listed in Table XVII and shown in Figure 36. The results suggest that the diabase dykes sampled are not feeders for the Devonian volcanic rocks as suggested by Alcock (1946) but are related to the more recent Triassic volcanic activity in the Bay of Fundy region.

The Springdale Group, located southwest of Notre Dame Bay in the vicinity of Springdale and Halls Bay Newfoundland, has been correlated by MacLean (1947) with the Silurian Bottwood Group (Williams 1962) on lithology only. Palaeomagnetic data obtained from two groups supports this correlation. Both the red beds and the volcanic rocks of the Springdale Group have mean directions (18.8, -22.2; and 16.3, -13.3 respectively) that are within 10 degrees of the mean direction for the Botwood Group volcanic rocks (22.3, -10.8). Both groups are reversely polarized and have pole positions that are within 3 degrees of latitude and 5.5 degrees of longitude of each other (see Table XV and Fig. 33). Similarly, positive correlation is achieved between the Springdale Group and the red beds located at the upper end of Southwest Arm near King's Point. The beds have been qualified by MacLean (1947) as belonging to the Springdale Group but as they markedly resemble Mississippian rocks, that outcrop 30 miles to the west and southwest, Neale (1960) suggested that they are of Devonian age or younger. The pole position for these red beds (29.0 N, 100.9E) is identical in latitude and two degrees west of that determined for the combined results for the Springdale Group (29.1N, 103.7E) which outcrops 10 miles to the south of King's Point. A minor difference in age exists, however, as the directions of magnetizations obtained for the samples near King's Point (200.1, +17.0, mean) are normally magnetized while those comprising the Springdale Group are reversely polarized and diametrically opposite to the King's Point results. As the Springdale Group contains rocks of sedimentary and volcanic origin with independent modes of magnetization, chemical and detrital remanent in the sediments and thermoremanent in the volcanic rocks, a total reversal of the earth's geomagnetic field is suggested for the time between the formation of the Springdale Group and the sediments described for the King's Point area. It is concluded that as a result of polarity difference only the permanent magnetization of these two groups of rocks cannot be simultaneous.

It is suggested that the diabase dyke which intrudes Ordovician strata at the south end of Joe Lake in the Gull Pond map-area, Newfoundland (Kalliokoski, 1954) is Silurian in age as it has a mean direction of magnetization (14.3 - 19.3) that lies within 3 degrees of that for the Springdale Group (17.7 - 18.4) and ten degrees of the volcanic rocks of the Botwood Group (22.3 - 10.8).

The Precambrian Hodgewater and Cabot Groups which have been suggested as being closely related in age in parts have not been correlated on the basis of their palaeomagnetism. This could not be achieved as the remanent magnetization of the Hodgewater Group appears to be post-deformational in origin while that of the Cabot Group is indicative of predeformational magnetization.

Polar Wandering

As seen from the section "Palaeomagnetic Data" or from an examination of the data listed in Table I it can be concluded that some of the formations dealt with in this study have remanent magnetizations that are stable and primary in origin while others have remanent magnetizations that appear to be secondary and possibly post-deformational in origin. The formations or groups that have primary magnetization and have reasonably well known ages are used to determine reference points for the polar wandering curve. The age of the time of magnetization of the formation or group which possesses a stable secondary magnetization is estimated from the determined curve.

Little significance is placed on the results obtained from the Precambrian rocks of Newfoundland in the location of a Precambrian polar wandering curve for the following reasons: a small number of samples (54) have been used to represent a considerable time span, some of the rocks have undergone rather severe structural deformation and metamorphism with some groups exhibiting well developed cleavage planes, only relative ages are known which have been estimated to be from early to late Proterozoic. More reliable Precambrian pole positions have been determined for less deformed and better dated rocks from the mainland of North America (DuBois 1962, Cox and Doell 1960, and others).

Figure 33 shows the pole positions listed in Table XV obtained for formations or groups from Eastern Canada which have a stable primary magnetization and which have been used to determine reference points on parts of the polar wandering curves for North America shown in Figure 36.

The following Palaeozoic formations or groups listed in Table I and described in the previous section are unsuitable for determining reference points on the polar wandering curve for North America.

The samples from the Mississippian Searston beds of western Newfoundland are not representative as only four were obtained from a thickness of 10 feet of a maximum thickness in excess of 5,000 feet.

The basic lower Silurian intrusion sampled south of the Bay of Exploits, Newfoundland, though stably magnetized requires a correction for tilt of the massive. A correction for tilt of approximately 65 degrees about an axis striking 78 degrees east of north, which is approximately the attitude of the intruded beds, northwest of the intrusion, will effect coincidence of the mean direction of magnetization with that for the Botwood Group volcanic rocks and the Springdale Group rocks for which depositional attitudes are reasonably well known. This suggests that both the Botwood Group and the intrusion have undergone a similar structural history.

The highly cleaved red sediments of the Botwood Group have a moan direction of magnetization that is significantly different from that obtained for the volcanic rocks which agrees in both direction and polarity with the results of the Springdale Group volcanic and sedimentary rocks.

The gabbro of the Bay of Islands igneous complex is rejected as both the age and structural history make the results suspect. The stability of the gabbro, however, indicates that palaeomagnetism could be applied to a study of the relative structure of the four masses forming the complex.

The lower Ordovician Wabana and Bell Island Groups have mean directions of magnetization that disagree significantly from those of more thoroughly represented Ordovician rocks. The magnetization of the hematite ore zones is post-Ordovician and probably Permo-Carboniferous age when the pole position (51N, 111E) is compared to the polar wandering curve in Figure 36.

The Middle Cambrian March Point Formation, the Lower Cambrian Bradore Formation of Labrador and the Lower Cambrian beds of the Avalon Peninsula have magnetization directions which suggest that they were either post-deformation or subsequently acquired in late or post-Palaeozoic times.

Data to Support Theory of Rotation of the Island of Newfoundland

A comparison of available palaeomagnetic data derived from Newfoundland and mainland North American formations of Carboniferous age has led Nairn et al (1959) and DuBois (1959) to differ in opinion regarding the possibility of post Carboniferous rotation of the Island relative to the mainland. This aspect of the Appalachian Geology was re-examined in the present study with the following results.

Evidence was found that suggests that the Island has not rotated relative to the mainland since Carboniferous times as there is a near coincidence of the Carboniferous poles derived from Newfoundland and mainland rocks (see Table XV and Fig. 33). However significant distances were found between the pole positions derived from the Devonian and Cambrian rocks of Newfoundland and of the mainland of southeastern Canada. The pole positions for the Lower Devonian Clam Bank Group (8N Fig. 33) and the Lower Cambrian Bradore Formation of western Newfoundland (2N, Fig. 33) plot about 30 degrees east of, and approximately at the same latitude as those determined for the Upper Devonian Perry Formation (9, 10 Fig. 33) and the Lower Cambrian Ratcliffe Brook Formation (1 Fig. 33) of southern New Brunswick.

If it is assumed that the Island of Newfoundland pivoted about a vertical axis by an angle of 30 degrees in a counterclockwise direction during Middle to Upper Devonian time, then the Devonian and Cambrian poles for both Newfoundland and the mainland almost coincide. By properly selecting the location of the pivot point, the western shoreline of Newfoundland could be made contiguous with the northern coastline of the Gulf of St. Lawrence. This is illustrated in Figure 34 where the pivot point has been positioned in the Strait of Belle Isle.

As previously outlined (Black 1964) the pre-Middle Devonian position of Newfoundland relative to the mainland cannot be determined uniquely on the basis of this palaeomagnetic data because the position of the pivot point is undefined. If the pivoting is assumed to be about a given axis it must be born in mind that the variation assumed by the latitude and longitude of a given point is dependent upon the position of the point relative to the axis. In the two cases where the pivot point is assumed to be at either extremity of the northwest shoreline of Newfoundland (points A and B, Fig. 34) the maximum change in the latitudes and longitudes of the collection localities are of the order of 2 to 3 degrees. Translation of the pole position calculated under the assumption of such a change in the coordinates of the collection locality would also be of the same order.

According to geological and tectonic studies of the Appalachian Region of Canada by Neale et al (1961) a counterclockwise rotation of the Island of Newfoundland during later Devonian time would seem plausible. Two broad belts of sediments interlayered with volcanic rocks of Cambro-Ordovician age and Siluro-Devonian age respectively occur on the mainland and on the Island. These belts appear to have been displaced relative to one another. A counterclockwise rotation of Newfoundland in the past would explain the divergence in structural trends. On the other hand a belt of deformed and relatively thick Carboniferous strata extends in a nearly straight line through the mainland and western Newfoundland. The postulated rotation would therefore have occurred in Middle to Late Devonian time.

The present palaeomagnetic data suggest the direction and approximate angle of rotation as well as the time of its occurrence. They suggest that from Lower Cambrian to Lower Devonian time Newfoundland remained fixed with respect to the present mainland and that the western part of Newfoundland has rotated in a counterclockwise direction by at least 30 degrees between Middle to Late Devonian time. This movement would then have taken place during the Acadian orogeny.

If the Island as a whole, as known today, underwent counterclockwise rotation then all formations in existence at the time of rotation have had their strike decreased by 30 degrees. This has been accounted for in the determination of the pole positions for rocks of pre-Middle Devonian age by the addition of 30 degrees to the declination of the mean magnetization direction. The coordinates of the collection localities have also been adjusted assuming rotation about point A located in the Strait of Belle Isle off the northern coast of Newfoundland (Fig. 34). Figure 35 shows the pole positions for the seven stably magnetized pre-Carboniferous Palaeozoic formations from Newfoundland determined for their present geographical location and for a pre-Carboniferous location assuming a 30 degree counterclockwise rotation about point A (see Table XV). All the pole positions obtained for each formation or group Lower Devonian or older from Newfoundland based on the postulated rotation are given in Table XVI.

Polar Wandering Curve

The 19 Cambrian to Triassic pole positions determined for stably magnetized rocks from the Canadian Appalachian Region assuming the present day land mass configuration given in Table XV and the seven recalculated poles assuming rotation of Newfoundland also given in Table XV and XVI have been combined with 29 other selected North American Cambrian to Triassic pole positions (Cox and Doell 1960, Irving 1962, and Roy 1963). These are used to plot a North American polar wandering curve shown in Figure 36 for this time span. Some observations regarding the distribution of these pole positions follows:

1. About 80 per cent of the poles plot between longitudes 160E and 90E.
2. Those determined for the older rocks lie at lower latitudes.
3. Variation in the longitudes of the pole positions, determined for formations of the same geological period, is greater for those from the Cambrian to Silurian rocks. This may be the result of errors introduced by non representative sampling, improper interpretation of the structural history, uncertain ages, and variation in the rate of movement of the earth's crust relative to the geomagnetic axis.
4. Devonian pole positions, which only those from the Canadian Appalachian Region appear reliable, differ in longitude only and flank the well grouped Carboniferous pole positions.

5. Permian pole though approximately at the same latitude as those for the Carboniferous rocks have greater variation in their longitude.
6. Triassic pole positions vary in latitude from 50 to 80 degrees with longitude variation occurring mainly for those poles that plot at latitudes of the order of 80 degrees.

The polar wandering curve from Early Carboniferous to late Triassic time can be plotted with some confidence as shown in Figure 36. The plotting of the early to middle Palaeozoic part is more speculative mainly because the longitudes of the pole positions are scattered.

Three interpretations based on specified assumptions are suggested for this part of the curve and are also shown in Figure 36. When it is assumed that the Island of Newfoundland has remained fixed relative to the rest of the North American continent since early Cambrian time, and with emphasis on the results from the Canadian Appalachian Region curve one is a reasonable choice for the polar wandering path. With emphasis again on the results from eastern Canada and assuming that Newfoundland underwent a 30 degree counterclockwise rotation during Middle to Late Devonian time, as required to bring Devonian and Cambrian poles from both land masses into coincidence, curve two is readily obtained. The change in the pole positions as a result of rotation effects a westerly shift of curve one with a minor decrease in latitude from Cambrian to Devonian time. Curves one and two suggest that the earth's crust has moved along an irregular course relative to its axis of rotation or conversely that the drift of the geomagnetic field has not always been in a westerly direction. Curve three is based on the assumption that the geomagnetic field has moved mainly westward and northward from Cambrian to Triassic time. In plotting this curve the poles derived from the continental Devonian and Cambrian rocks of New Brunswick are ignored as well as the Silurian and Ordovician results for rocks from Newfoundland.

Estimates of the rate of movement of the earth's crust in degrees per million years for each geological period from Cambrian to Triassic time are given in Table XVIII. These estimates were calculated assuming that the remanent magnetization of the various rock formations or groups was oriented along a coaxial dipole field. According to the three curves shown in Figure 36 the rate of movement from Cambrian to Triassic time was less than one degree per million years with the exception of that part of curve two for the Silurian period. The average rate of movement for curves 1, 2, and 3 for a time interval of about 420 million years is 0.4, 0.5, and 0.3 degrees per million years respectively.

Conclusions

Although the late Palaeozoic and early Mesozoic part of the polar wandering curve is reasonably well known the early and middle Palaeozoic part is not definitely established. Perhaps a more accurate position of this part of the curve could be obtained and the validity of the interpretations based on Canadian Appalachian results substantiated if Cambrian to Devonian pole positions were obtained for undisturbed rocks elsewhere on the North American continent. The difficulty of resolving the age of the magnetization within formations could be sharply reduced by sampling rock units which contain conformable sequences of igneous and sedimentary rocks.

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APPENDIX

DIRECTIONS OF MAGNETIZATION

HARBOUR MAIN GROUP

(NRM RESULTS)

Sample No.	Corrected for Tilt			Before Correction for Tilt		
	D	I		D	I	
2B	300.0	+28.0	α = 13.4	156.0	+84.5	α = 28.2
2G	308.5	+25.0	k = .3	192.0	+86.5	k = 5.5
3B	304.5	+60.0	N = 7	131.0	+51.0	N = 7
3G	302.0	+51.5		140.0	+64.5	
4B	326.5	+58.0		121.0	+63.5	
4G	289.5	+50.5		77.5	+58.0	
8B	335.5	+56.5		313.5	+23.5	

COLLECTION LOCALITY 47.4 N. 53.25 W.

CONCEPTION GROUP

(NRM RESULTS)

Sample No.	Corrected for Tilt			Before Correction for Tilt		
	D	I		D	I	
1B	165.0	+20.0	α = 16.9	159.5	-11.0	α = 19.8
1G	166.5	+42.0	k = 7.5	149.5	+ 4.5	k = 5.8
2B	169.0	+25.5		205.0	+26.0	
2G	183.0	+ 0.5		189.5	+10.5	
3B	185.0	+11.0		195.0	+14.0	
3G	129.0	-19.0		136.0	+40.5	
4B	148.0	+75.0		121.0	+62.5	
5B	182.0	+24.0		226.0	+57.0	
6B	175.5	+56.5		124.0	+60.5	
6G	176.0	+49.0		149.0	+53.0	
7B	199.0	+47.0		161.5	+54.5	
7G	183.5	+22.5		166.5	+38.0	

(STABLE RESULTS)

1B	184.5	+ 4.5	α = 25.1	190.5	+ 4.5	α = 26.6
1G	48.0	+37.5	k = 4.0	349.5	+45.0	k = 3.6
2B	162.0	-23.5	N = 12	158.0	+17.0	N = 12
2G	189.0	+10.0		201.5	+ 7.5	
3B	188.5	+ 8.0		199.0	+ 9.0	
3G	88.0	+63.5		294.5	+49.5	
4B	222.5	+60.5		191.0	+67.5	
5B	184.0	+22.5		178.5	+50.0	
6B	158.5	+45.0		127.5	+45.5	
6G	165.5	+46.5		141.0	+47.0	
7B	190.5	+43.5		159.0	+48.0	
7G	174.0	+23.5		157.0	+33.0	

COLLECTION LOCALITY SAMPLES 1-3, 47.0 N 53.0 W; SAMPLES 4-7, 47.5 N 53.3 W

CABOT GROUP

SIGNAL HILL FORMATION

(STABLE RESULTS)

Sample No.	Corrected for Tilt			Before Correction for Tilt		
	D	I		D	I	
1B	156.0	+32.5	α = 13.2	156.0	+22.0	α = 13.8
1G	198.5	+35.5	k = 8.3	198.0	+30.5	k = 7.7
2B	216.5	+45.0	N = 17	217.0	+36.5	N = 17
2G	180.5	+29.0		182.0	+22.0	
3G	162.0	+55.0		215.0	+48.0	
4B	134.5	+39.0		168.0	+33.0	
4G	168.5	+72.5		202.5	+37.5	
5B	190.0	+ 9.5		205.5	+20.0	
5G	134.5	+27.0		189.5	+74.0	

CABOT GROUP

SIGNAL HILL FORMATION

(STABLE RESULTS)

6B	159.0	+31.5	175.0	+40.0
6G	120.0	+31.0	156.0	+86.0
7G	137.0	+39.0	230.0	+74.0
8B	136.0	+41.5	250.5	+71.0
8G	136.0	+32.0	201.0	+74.0
9B	118.5	+23.5	37.0	+81.5
9G	96.0	+31.0	330.0	+84.5
10G	132.5	+27.0	176.5	+71.0

COLLECTION LOCALITY 47.5 N, 52.75 W.

CABOT GROUP

BLACKHEAD FORMATION

(NRM RESULTS)

Sample No.	Corrected for Tilt			Before Correction for Tilt		
	D	I		D	I	
1G	46.5	+34.5	α = 12.5	26.5	+45.5	α = 19.4
2B	78.0	+58.5	k = 18.0	192.0	+82.5	k = 8.0
2G	66.5	+59.5	N = 9	246.0	+86.0	N = 9
3B	55.0	+65.5		61.0	+30.5	
3G	63.0	+56.5		288.0	+88.0	
4B	26.0	+32.5		359.0	+54.0	
4G	47.5	+73.0		261.0	+70.0	
5B	89.0	+49.0		142.0	+74.5	
5G	90.0	+46.0		136.0	+73.0	

COLLECTION LOCALITY 47.5 N, 52.75 W.

HODGEWATER GROUP

(NRM RESULTS)

Sample No.	Corrected for Tilt D	Corrected for Tilt I		Before Correction for Tilt D	Before Correction for Tilt I	
1B	119.0	+39.0	α = 33.6	119.0	+11.0	α = 24.1
1G	104.0	-26.5	k = 3.3	108.0	-49.0	k = 5.5
3B	154.5	+12.5	N = 9	153.5	- 7.5	N = 9
4B	248.0	+51.0		134.0	+52.0	
5G	282.5	+60.0		134.5	+62.0	
6B	164.0	+73.0		121.0	+33.0	
7B	168.0	+63.5		131.0	+32.0	
8B	153.0	+51.0		136.0	+13.5	
8G	184.0	+77.0		122.0	+39.0	

(STABLE RESULTS)

Sample No.	D	I		D	I	
1B	150.5	-16.0	α = 16.2	160.0	-37.5	α = 13.2
1G	120.0	-41.0	k = 11.1	137.0	-59.5	k = 16.2
3B	149.0	-15.0	N = 9	158.0	-35.0	N = 9
4B	172.5	- 2.0		186.0	-18.0	
5G	185.0	+15.5		182.5	-10.0	
6B	152.0	+14.0		151.5	-14.5	
7B	159.0	- 7.5		171.0	-28.0	
8B	162.0	- 9.0		177.0	-32.5	
8G	162.0	+13.0		162.5	-13.5	

COLLECTION LOCALITY 47.5 N, 53.5 W.

RATCLIFFE BROOK FORMATION

(CORRECTED FOR TILT)

Sample No.	NRM RESULTS			STABLE RESULTS		
	D	I		D	I	
1B	177.0	+43.0	α = 15.6	192.0	+47.0	α = 14.9
1P	228.0	+68.0	k = 8.7	201.0	+58.5	k = 9.5
2B	65.0	+84.0	N = 12	135.0	+80.0	N = 12
2P	178.0	+45.0		182.0	+29.5	
3B	141.0	+35.5		156.0	+27.0	
3P	199.5	+53.5		183.0	+58.0	
5B	168.0	+70.0		133.0	+49.5	
5P	183.5	+45.5		153.0	+60.5	
6B	132.0	+79.0		144.0	+70.5	
6P	150.0	+65.5		153.0	+65.5	
7B	139.5	+29.0		134.0	+19.5	
7P	233.0	+27.0		217.0	+30.0	

COLLECTION LOCALITY 45.5 N, 66.0 W

LOWER CAMBRIAN RED BEDS, AVALON PENINSULA

(STABLE RESULTS)

Sample No.	Corrected for Tilt			Before Correction for Tilt		
	D	I		D	I	
4B	35.5	+21.0	α = 9.7	38.5	+25.0	α = 8.4
4G	23.0	+35.0	k = 33.0	32.5	+43.0	k = 44.2
5B	2.0	+42.0	N = 8	22.5	+47.0	N = 8
5G	9.0	+25.5		15.0	+31.5	
6B	16.5	+33.0		25.0	+38.5	
6G	31.0	+35.5		40.0	+37.0	
7B	38.0	+27.0		46.0	+33.5	
7G	1.0	+32.0		11.0	+42.0	

COLLECTION LOCALITY 47.5 N, 53.0 W

BRADORE FORMATION (NORTHWEST NFLD.)

(CORRECTED FOR TILT OF BEDS)

Sample No.	NRM Results			Stable Results		
	D	I		D	I	
1B	150.5	+55.0	α = 5.6	139.0	+28.0	α = 9.4
2B	134.0	+65.0	k = 67.4	174.5	+43.5	k = 27.4
2G	120.0	+51.5	N = 11	155.0	+31.0	N = 10
3B	123.0	+46.0		-	-	
3G	170.5	+59.5		166.5	+64.0	
4B	140.5	+54.5		158.5	+45.0	
4G	141.5	+48.0		126.5	+42.0	
5B	150.5	+56.5		172.0	+44.0	
5G	142.0	+52.5		157.0	+48.5	
6B	153.5	+54.5		139.5	+48.0	
6G	130.0	+58.0		133.0	+40.5	

COLLECTION LOCALITY 50.75 N, 57.10 W.

BRADORE FORMATION (LABRADOR)

(NOT CORRECTED FOR TILT OF BEDS)

Sample No.	NRM Results			Stable Results		
	D	I		D	I	
8G	334.0	+50.5	α = 9.3	332.5	+48.5	α = 8.5
9B	346.5	+68.0	k = 8.6	345.5	+63.5	k = 11.2
9G	125.0	+22.5	N = 31	-	-	N = 28
10B	93.0	+67.0		64.0	+42.5	
10G	132.5	+75.0		168.5	+67.0	
11B	99.5	+63.0		91.0	+67.5	
11G	129.5	+38.0		122.0	+25.0	
12B	9.0	+68.5		1.5	+58.0	
13B	328.0	+69.0		24.0	+66.0	
13G	355.5	+67.0		337.5	+68.0	
14G	302.5	+62.0		-	-	

BRADORE FORMATION (LABRADOR) (cont'd.)
(NOT CORRECTED FOR TILT OF BEDS)

15B	359.5	+60.0	358.5	+61.0
15G	13.5	-21.5	-	-
16B	2.5	+66.0	347.5	+67.5
16G	5.0	+64.5	3.0	+62.0
17B	17.5	+70.5	30.5	+66.0
17G	20.0	+62.5	20.5	+62.0
18B	359.5	+48.0	6.5	+44.5
18G	22.5	+71.0	356.5	+66.0
19B	9.5	+73.0	9.5	+73.0
19G	12.0	+69.0	1.0	+65.5
20B	304.5	+80.0	310.5	+80.0
20G	356.5	+74.0	357.0	+72.0
21B	343.0	+77.5	342.5	+77.0
21G	359.0	+75.5	354.5	+71.0
22B	347.0	+70.0	14.0	+72.5
22G	340.0	+75.5	43.5	+73.0
23B	108.0	+69.0	78.5	+57.5
23G	290.0	+80.0	331.0	+68.5
24B	110.5	+76.5	122.5	+38.5
24G	336.0	+79.5	312.0	+81.0

COLLECTION LOCALITY 51.3 N, 57.0 W

MARCH POINT FORMATION

(NRM RESULTS)

GROUP I

Sample No.	Corrected for Tilt			Before Correction for Tilt		
	D	I		D	I	
1B	335.5	+48.0	α = 12.0	331.0	+63.5	α = 11.7
1G	346.5	+49.5	k = 19.4	353.0	+77.0	k = 20.4
2B	336.5	+55.5	N = 9	351.0	+73.0	N = 9

MARCH POINT FORMATION (cont'd.)

(NRM RESULTS)

GROUP I

2G	340.5	+45.0		347.0	+62.0	
6G	326.5	+38.0		328.0	+62.0	
7B	303.0	+46.5		307.5	+68.0	
7G	55.0	+62.0		90.0	+56.0	
9B	2.0	+59.0		44.0	+68.0	
9G	346.0	+59.5		336.0	+79.5	

GROUP II

3G	163.5	+40.0	α = 21.5	180.5	+62.0	α = 15.9
5B	265.0	+64.0	k = 10.6	213.0	+64.5	k = 18.7
5G	161.5	+70.0	N = 6	58.0	+84.5	N = 6
6B	192.0	+54.0		203.5	+57.0	
8B	217.5	+58.0		200.0	+55.0	
8G	147.0	+43.0		139.0	+57.0	

COLLECTION LOCALITY 48.5 N, 59.1 W.

WABANA AND BELL ISLAND GROUPS

(NRM RESULTS)

Sample No.	Corrected for Tilt			Before Correction for Tilt		
	D	I		D	I	
		UPPER BED				
6G	10.5	+19.5	α = 17.2	10.5	+22.5	α = 18.8
7B	14.0	+36.0	k = 13.2	19.5	+41.0	k = 11.3
7G	322.5	+62.0	N = 7	307.5	+70.0	N = 7
10B	9.0	+ 8.5		9.5	+11.0	
11B	11.5	+ 7.0		12.0	+13.5	
11G	5.5	+20.0		8.5	+31.5	
12B	5.0	+20.5		4.5	+23.5	

WABANA AND BELL ISLAND GROUPS (cont'd.)

(NRM RESULTS)

MIDDLE BED

8B	23.0	+22.0	α = 23.4	26.5	+42.5	α = 25.3
8G	15.5	- 2.0	k = 16.3	15.5	+ 3.0	k = 14.2
9B	357.5	+35.5	N = 4	6.0	+42.5	N = 4
9G	355.5	+14.5		356.5	+26.0	

LOWER BED

1B M	354.0	+22.5	α = 5.0	348.0	+27.0	α = 5.3
1G M	35.5	+15.5	k = 25.6	37.5	+18.0	k = 23.6
2B M	26.0	+ 4.0	N = 33	26.0	+ 7.5	N = 33
2G M	355.0	+22.0		356.0	+27.5	
3B M	349.5	+15.5		349.5	+23.0	
3G M	347.5	+ 9.5		348.5	+16.5	
4B M	7.5	+ 9.0		13.0	+15.0	
4G M	357.0	- 5.0		356.5	+ 2.0	
5B M	359.5	+ 8.5		0.0	+16.5	
5G M	13.5	+ 9.0		14.5	+15.0	
6B M	17.0	+ 9.5		18.0	+15.0	
6G M	11.0	+11.0		12.0	+12.0	
7B M	20.5	+ 2.0		21.0	+ 6.5	
7G M	349.5	+ 0.5		339.0	+ 7.5	
8B M	28.0	+22.5		33.5	+26.0	
8G M	18.0	+22.5		20.5	+27.0	
9B M	359.5	+12.0		0.5	+18.0	
9G M	25.0	+10.0		26.0	+14.0	
10B M	30.5	+10.5		31.5	+14.0	
10G M	347.5	+ 8.5		347.5	+15.5	
11B M	3.5	+21.0		6.0	+23.5	
11G M	357.5	+15.0		358.0	+22.5	

WABANA AND BELL ISLAND GROUPS (cont'd.)

(NRM RESULTS)

LOWER BED

12B M	352.5	+ 8.0	353.0	+15.5
12G M	7.5	+ 4.5	8.0	+11.0
1B	18.5	+13.0	21.5	+18.5
1G	22.0	+15.5	24.5	+27.0
2B	26.0	+15.0	27.0	+17.5
2G	23.0	+ 4.0	23.0	+ 7.0
3B	11.5	+ 3.5	12.5	+ 9.0
3G	8.0	-11.0	7.5	- 3.0
4B	10.0	- 8.0	10.0	+ 1.0
4G	13.0	+24.5	17.0	+29.5
14B	19.0	+ 4.0	19.5	+ 6.0

COLLECTION LOCALITY 47.6 N, 52.9 W.

ST. GEORGE GROUP

(NRM RESULTS)

Sample No.	Corrected for Tilt D	I	
1B	171.0	+32.5	α = 12.5
1G	173.0	+45.0	k = 24.1
2B	170.0	+28.0	N = 7
2G	169.0	+72.0	
3B	182.0	+37.5	
3G	169.5	+27.5	
4G	181.5	+53.5	

COLLECTION LOCALITY 48.5 N, 58.75 W.

SPOON COVE FORMATION

(STABLE RESULTS)

Corrected for Tilt

Sample No.			
2B	204.0	+34.5	α = 7.7
2G	193.0	+28.0	k = 25.5
3G	195.0	+41.0	N = 15
4B	183.0	+42.0	
4G	180.5	+39.0	
5B	198.5	+25.5	
5G	206.5	+53.0	
6B	210.0	+40.0	
6G	189.0	+26.0	
7B	214.0	+50.0	
7G	166.5	+43.0	
8G	224.0	+17.5	
9B	207.5	+27.5	
9G	199.5	+52.0	
10B	179.5	+48.0	

COLLECTION LOCALITY 47.5 N, 55.0 W.

GABBRO BHY OF ISLANDS IGNEOUS COMPLEX

(STABLE RESULTS)

Corrected to Horizontal

Sample No.	D	I	α
11B	162.0	+50.0	α = 9.5
11G	131.0	+44.0	k = 21.8
12B	157.5	+49.0	N = 12
12G	149.0	+52.5	
13B	147.5	+49.5	

GABBRO BHY OF ISLANDS IGNEOUS COMPLEX (Cont'd.)

(STABLE RESULTS)

14B	151.0	+23.5
14G	165.5	+40.0
15B	131.0	+42.5
16B	133.5	+25.0
16G	148.0	+51.5
18B	168.0	+12.0
18G	149.0	+19.5

COLLECTION LOCALITY 49.5 N, 58.0 W.

POST-ORDOVICIAN DIABASE, JOES LAKE

(STABLE RESULTS)

Corrected to Horizontal

Sample No.	D	I	
1B	14.0	-10.5	α = 10.7
1G	11.5	-26.5	k = 74.5
5B	18.5	-27.5	N = 4
5G	13.5	-12.5	

COLLECTION LOCALITY 49.0 N, 56.0 W.

BOTWOOD GROUP, VOLCANIC ROCKS

(STABLE RESULTS)

Corrected for Tilt

Sample No.	D	I	
4BV	11.5	- 9.0	α = 12.1
5BV	6.0	- 8.5	k = 19.0
5GV	35.5	- 6.5	N = 9
6BV	31.0	-12.0	
6GV	15.0	+12.0	

BOTWOOD GROUP, VOLCANIC ROCKS (Cont'd.)

(STABLE RESULTS)

7BV	359.0	-28.5
7GV	31.0	-18.5
8BV	21.5	-15.0
8GV	48.0	- 7.5

COLLECTION LOCALITY 49.2 N, 55.35 W.

BOTWOOD GROUP, RED SEDIMENTS

(NRM RESULTS)

Corrected for Tilt of Beds (Strike 50°E of N, Dip 90°NW.)

Sample No.	D	I	
1B	343.0	-27.5	α = 9.4
1G	331.0	-42.0	k = 11.0
2B	324.0	-43.0	N = 24
2G	300.0	-13.0	
3B	326.0	-17.0	
3G	328.0	- 2.0	
4B	315.0	-23.0	
4G	309.5	-10.0	
5B	337.5	-12.0	
5G	336.5	-36.0	
6B	320.0	- 7.0	
6G	342.5	-35.0	
7G	301.0	-24.0	
8B	297.0	-38.0	
8G	311.0	-45.5	
22B	331.0	+ 5.0	
22G	326.5	+ 4.0	
23B	327.0	+23.0	

BOTWOOD GROUP, RED SEDIMENTS (Cont'd.)

(NRM RESULTS)

23G	321.0	+ 7.0
24B	312.5	-34.5
24G	311.0	-25.5
25B	309.0	+ 2.0
26B	294.0	+20.0
26G	312.0	+16.5

COLLECTION LOCALITY 49.1 N, 55.5 W.

SILURIAN INTRUSION

(STABLE RESULTS)

	Corrected to Horizontal			Corrected for Tilt of 65° about Axis Striking 78°E of N.		
Sample No.	D	I		D	I	
1B	75.0	-62.5	α = 5.3	17.5	-20.5	α = 5.3
1G	75.0	-66.0	k = 49.7	14.0	-21.5	k = 49.7
2B	32.0	-46.5	N = 16	17.0	+ 8.0	N = 16
2G	74.0	-60.0		20.0	-19.0	
3B	56.0	-61.0		15.0	-11.0	
3G	100.0	-55.5		27.0	-33.0	
4B	78.5	-51.0		30.0	-19.0	
4G	78.0	-52.5		28.5	-19.0	
5B	67.5	-47.5		30.5	-11.0	
5G	71.5	-62.0		17.5	-19.0	
6B	92.0	-71.0		9.5	-28.0	
6G	50.0	-52.5		20.5	- 4.0	
7B	72.0	-49.5		30.0	-15.0	
7G	82.5	-69.0		11.5	-24.5	
8B	60.0	-59.5		18.0	-12.5	
8G	66.0	-61.0		17.0	-16.5	

COLLECTION LOCALITY 49.0 N, 55.0 W.

SPRINGDALE GROUP

(STABLE RESULTS)

Corrected for Tilt

Volcanic Rocks

Sample No.	D	I	
1G	29.0	- 1.0	α = 7.5
1GA	9.0	- 5.0	k = 34.3
1B	11.0	- 9.5	N = 12
2G	12.0	- 9.0	
2B	22.0	-16.5	
3G	25.0	-14.0	
3B	24.0	-16.0	
4G	20.0	- 4.0	
5G	358.0	-28.0	
6W	359.0	-16.0	
NA 30831	34.0	-10.0	
NA 30832	10.0	-27.5	

COLLECTION LOCALITY 49.45 N, 56.2 W.

Red Sediments

Sample No.	D	I	
1B	21.5	-13.0	α = 8.1
1G	6.0	- 1.0	k = 21.9
2B	19.5	- 7.0	N = 16
2G	39.5	-37.0	
3B	22.0	-13.5	
3G	29.0	-14.5	
4B	17.0	-16.5	
4G	10.5	-18.0	
5B	9.0	-38.0	
5G	24.0	-37.0	

Red Sediments (Cont'd.)

6B	33.5	-35.0
6G	26.5	-33.0
7B	351.0	- 9.5
7G	25.0	-30.5
8B	6.5	-40.0
8G	24.0	- 6.0

COLLECTION LOCALITY 49.45 N, 56.2 W.

RED SEDIMENTS, KING'S POINT

(NRM RESULTS)

Corrected for Tilt

Sample No.	D	I	
16B	199.5	+ 10.0	α = 9.6
16G	181.0	+ 24.5	k = 19.7
17B	201.0	+ 9.0	N = 13
17G	204.0	+ 22.5	
18B	212.0	+ 34.5	
18G	221.0	+ 42.5	
19B	193.5	- 5.5	
19G	202.5	+ 3.0	
20G	210.5	+ 39.5	
21B	193.0	+ 13.0	
21G	215.5	+ 8.5	
NA 3069	190.0	+ 12.0	
NA 3071	186.5	+ 5.0	

COLLECTION LOCALITY 49.55 N, 56.2 W.

CLAM BANK GROUP

(NRM RESULTS)

Corrected for Tilt

Sample No.	D	I	
1B	318.0	+ 1.0	α = 11.4
1G	343.0	+20.0	k = 10.2
2B	328.0	-28.0	N = 18
2G	319.0	+ 4.5	
3B	330.0	-12.0	
3G	357.0	-18.0	
4B	310.0	+20.5	
5B	345.5	-14.0	
5G	348.5	-23.5	
6B	335.5	-25.0	
6G	350.5	-37.0	
7G	304.0	-49.5	
8B	343.5	- 1.0	
8G	353.5	-27.5	
9B	340.0	-41.0	
9G	338.5	-46.0	
10B	352.5	-43.0	
10G	354.0	-22.5	

COLLECTION LOCALITY 48.5 N, 59.0 W.

PERRY FORMATION, SEDIMENTS

(STABLE RESULTS)

Corrected for Tilt

Sample No.	D	I	
1B	184.5	+40.5	α = 8.5
1P	187.5	+24.0	k = 8.9
2B	187.0	+69.0	N = 36

PERRY FORMATION, SEDIMENTS (Cont'd.)

(STABLE RESULTS)

2P	155.0	+71.5
3B	160.5	+30.0
3P	164.5	+35.5
4B	141.5	+68.5
4P	193.0	+55.0
5B	160.0	- 3.5
5P	182.0	+18.0
6B	181.5	+25.5
6P	192.0	+26.5
7B	169.0	+ 2.5
7P	177.0	+16.0
8B	159.5	+13.0
8P	161.0	+16.0
9B	183.0	+22.0
9P	181.0	+16.5
10B	170.5	+11.0
10P	177.0	- 9.0
14B	131.5	+50.0
14P	175.5	+45.0
15B	169.5	- 4.5
15P	179.5	-13.0
24B	178.5	-16.5
24P	173.0	+15.5
25B	169.5	+22.5
25P	192.0	+53.0
26B	170.0	-15.0
26P	161.0	+ 4.5
27B	169.5	-10.0
27P	165.5	- 3.5
29B	192.5	+25.0

PERRY FORMATION, SEDIMENTS (Cont'd.)

(STABLE RESULTS)

29P	185.0	+25.5
30B	177.5	-17.5
30P	177.0	-10.0

COLLECTION LOCALITY 45.0 N, 67.0

PERRY FORMATION VOLCANIC ROCKS

(STABLE RESULTS)

Corrected for Tilt

Sample No.	D	I	
11B	180.0	+54.5	α = 15.1
11P	194.0	+46.5	k = 7.0
12B	179.5	+70.5	N = 16
12P	226.0	-12.5	
13B	185.5	-19.5	
13P	117.5	+75.0	
16B	162.0	+11.0	
16P	153.0	+12.0	
17B	145.0	+50.5	
17P	170.0	+29.5	
18B	208.5	+49.5	
18P	210.5	+34.5	
19B	178.5	+13.5	
19P	180.0	+15.0	
28B	188.0	+23.0	
28P	206.0	+25.0	

COLLECTION LOCALITY 45.0 N, 67.0 W

BAKED SEDIMENTS AND DIABASE CUTTING PERRY FORMATION

(STABLE RESULTS)

Corrected to Horizontal

Sample No.	D	I	
20B	8.0	+34.0	α = 10.6
20P	352.5	+45.5	k = 40.9
21B	14.5	+62.5	N = 6
21P	6.0	+52.0	
22B	14.5	+39.5	
22P	26.0	+43.0	

COLLECTION LOCALITY 45.0 N, 67.0 W.

KENNEBECASIS FORMATION

(NRM RESULTS)

Corrected for Tilt

Sample	D	I	
1B	139.0	+42.5	α = 9.6
1P	162.5	+41.5	k = 18.1
2B	170.5	+41.0	N = 14
2P	149.5	+48.5	
3B	147.0	+41.5	
3P	151.5	+30.5	
4B	147.5	+34.5	
4P	194.5	+11.0	
5B	141.0	+37.5	
5P	188.0	+ 8.0	
6B	166.5	+28.0	
6P	165.5	+25.0	
7B	149.0	+19.5	
7P	172.5	+41.0	

COLLECTION LOCALITY 45.5 N, 66.0 W.

CODROY GROUP

(NRM RESULTS)

GROUP I

Sample No.	Corrected for Tilt D	I		
1B	159.5	+24.0	α = 7.7	
3B	195.0	+11.5	k = 16.4	*
5G	185.5	- 9.0	N = 23	
7B	195.5	+15.0		*
7G	215.5	+36.0		
8B	176.0	+23.0		*
8G	188.0	+25.5		
10B	174.0	+15.5		
10G	159.0	+ 6.0		
11B	181.0	+22.0		
11G	176.0	+ 7.0		
12B	167.5	+ 5.0		*
13B	147.5	+16.5		*
14B	149.5	-13.5		*
17G	180.0	- 9.0		*
18B	159.0	- 3.0		*
18G	161.5	-11.0		*
19B	181.0	+12.0		*
19G	164.5	+ 9.5		*
20B	155.0	+ 9.5		*
20G	167.0	- 1.0		*
21B	178.0	+ 8.0		
21G	179.5	- 1.5		

* DECLINATION ADJUSTED BY 180°, INCLINATION SIGN REVERSED

CODROY GROUP (Cont'd.)

(NRM RESULTS)

GROUP II

1G	172.5	+66.5	α = 9.9
2B	167.5	+82.5	k = 27.8
2G	184.5	+62.5	N = 9
3G	144.0	+52.5	
4B	177.0	+57.0	
5B	168.5	+43.5	
6B	198.5	+56.5	
6G	199.5	+59.0	
17B	219.0	+59.5	

COLLECTION LOCALITY 48.0 N, 59.0 W.

SEARSTON BEDS

(NRM RESULTS)

Corrected for Tilt

Sample No.	D	I	
1B	176.5	-24.0	α = 9.7
2B	173.5	-14.0	k = 90.7
2G	174.5	-18.5	N = 4
3G	172.5	-33.5	

COLLECTION LOCALITY 48.0 N, 59.5 W.

PRE-PICTOU CARBONIFEROUS ROCKS OF NEW BRUNSWICK

(REFERENCE - HORIZONTAL BEDDING)

VOLCANIC ROCKS

FLOW TYPE 1

	NRM RESULTS			STABLE RESULTS		
Sample No.	D	I	α	D	I	
2A	326.0	+77.0	-	283.0	+52.0	α = 26.0
2B	27.0	+84.0		169.5	+39.0	k = 4.9
2C	109.0	+65.0		120.0	+50.5	N = 9
5A	354.0	+70.5		280.0	+37.5	
5B	329.0	+65.0		228.5	+61.0	
5C	8.5	+67.5		178.0	+34.0	
7A	198.5	+52.5		191.5	+13.5	
7B	326.0	+63.5		210.0	+50.0	
7C	268.0	+84.0		178.0	+34.0	

FLOW TYPE 2

3A	326.0	+26.0	-	325.5	-16.5	α = 26.2
3B	332.5	-11.5		330.5	-40.5	k = 4.8
3C	313.0	-13.5		210.0	-20.0	N = 9
9A	227.0	+56.5		228.0	-11.0	
9B	249.5	+37.5		299.0	-11.5	
9C	265.0	+66.0		355.5	-32.5	
10A	346.5	-48.5		348.5	-53.0	
10B	15.0	-51.0		12.0	-48.0	
10C	11.0	+57.5		329.0	-24.0	

FLOW TYPE 3

12A	66.5	+43.0	-	25.0	-55.5	α = 62.0
12B	18.0	+11.0		46.0	-44.0	k = 2.1
12C	320.0	+64.0		275.0	- 8.0	N = 6
15H	188.0	-79.5		218.0	-27.0	
15C	288.0	+56.5		224.0	-24.0	
15E	18.0	-22.5		8.0	-55.0	

SEDIMENTARY ROCKS

1A	126.0	+59.0	-	149.5	+48.0	α = 15.4
1B	128.5	+59.0		154.5	+47.0	k = 13.8
1C	146.5	+65.0		162.5	+46.5	N = 8
4A	153.0	+30.5		156.0	+14.0	
4B	188.0	+20.5		197.0	+ 8.0	
4C	149.5	+31.0		157.0	+11.0	
11A	101.0	+63.0		160.5	+36.0	
11B	171.0	+64.0		150.0	+26.5	

COLLECTION LOCALITY 46.5 N, 66.5 W.

BONAVENTURE FORMATION

(NRM RESULTS)

Corrected for Tilt

Sample No.	D	I	
1P	161.5	+14.0	α = 6.8
2P	179.0	+38.0	k = 21.7
2B	152.0	+21.0	N = 22
3P	132.5	- 3.0	
4P	167.0	+ 9.5	
4B	196.5	- 2.5	
5P	164.0	+16.0	
5B	166.0	+22.0	
6P	166.0	+15.5	
6B	167.0	+ 6.0	
7P	169.0	+ 8.5	
7B	155.5	+41.5	
8P	172.0	+42.0	
8B	171.0	+23.0	
9P	163.0	+ 6.0	
9B	165.0	+ 6.0	

BONAVENTURE FORMATION (Cont'd.)

(NRM RESULTS)

10P	168.0	+ 2.0
10B	166.0	+ 5.5
11P	167.5	+ 4.0
11B	164.5	+ 0.5
12P	180.0	+ 4.5
12B	160.5	+ 5.5

COLLECTION LOCALITY 48.0 N 65.5 W

BATHURST FORMATION

(NRM RESULTS)

Corrected for Tilt

Sample No.	D	I	
S1	141.5	+30.5	α = 9.3
S2	169.0	+28.5	k = 28.1
S3	153.5	+32.5	N = 10
S4	170.5	+ 3.5	
S5	166.5	+25.5	
S6	159.0	+17.0	
S7	169.0	+ 3.5	
S8	163.0	+ 9.0	
S9	169.0	+ 2.5	
S10	158.5	+ 2.0	

COLLECTION LOCALITY 47.6 N, 65.6 W.

RED BEDS NORTHWEST PRINCE EDWARD ISLAND

(NRM RESULTS)

Corrected for Tilt

Sample No.	D	I	
46K	149.5	+16.5	α = 6.1
47B	167.5	+ 6.0	k = 22.6
50B	156.0	+24.5	N = 26

RED BEDS NORTHWEST PRINCE EDWARD ISLAND (Cont'd.)

51B	163.5	+46.0
52B	167.0	- 1.5
52K	171.5	- 1.5
53B	173.5	- 4.5
53K	170.5	- 6.0
54B	160.5	-14.0
55B	168.0	- 4.5
55K	164.0	+ 3.5
56B	177.0	+ 3.0
56K	175.0	+ 6.5
57K	166.0	- 3.0
59B	174.0	+ 6.0
59K	172.5	+ 5.0
60B	176.5	+15.5
62B	163.0	- 8.5
63B	187.0	+ 7.0
63K	173.0	+ 0.5
64K	172.0	- 7.0
66B	167.0	+41.5
66K	170.0	+20.5
78B	177.5	+ 7.0
81B	161.0	-10.0
81K	194.0	- 7.0

COLLECTION LOCALITY 46.8 N, 64.0 W.

RED BEDS CENTRAL PRINCE EDWARD ISLAND

Corrected for Tilt

Sample No.	D	I	
17B	165.0	+ 2.5	α = 5.5
17K	155.5	- 1.0	k = 10.6
18B	133.0	+19.5	N = 69
18K	160.0	- 5.5	
19B	168.0	+ 1.5	
21B	178.5	+14.0	
22B	173.5	+ 2.5	
24K	132.5	-43.5	
25B	168.0	- 9.0	
25K	174.5	+ 3.0	
26B	203.0	+34.5	
27B	185.0	+ 8.5	
29B	194.0	+46.0	
30B	134.0	+29.5	
31B	171.0	+13.0	
32B	176.0	+11.0	
32K	177.5	- 3.5	
33B	178.5	+ 1.0	
33K	192.5	+ 4.0	
35B	164.5	- 1.5	
35K	164.0	- 2.5	
36B	166.5	+ 9.0	
36K	161.0	- 1.5	
37B	229.0	+28.0	
37K	170.5	-17.5	
38K	167.5	+ 3.0	
39K	169.5	+47.5	

RED BEDS CENTRAL PRINCE EDWARD ISLAND (Cont'd.)

67B	159.5	+ 1.5
67K	165.5	+ 3.5
69B	199.0	+21.5
69K	157.5	- 3.5
70B	156.5	- 9.5
70K	166.5	- 4.0
71B	189.0	+ 3.0
72B	164.0	- 5.0
72K	175.0	- 1.5
73B	179.5	- 1.5
73K	168.0	+ 7.0
74B	171.0	+16.5
74K	172.5	+ 1.0
75B	175.0	- 6.0
75K	95.0	- 8.0
83K	171.5	- 8.0
84B	180.5	- 8.0
84K	162.5	-10.0
85B	142.0	- 8.5
85K	188.0	+ 3.0
86K	158.0	+ 3.5
87B	173.5	+19.0
87K	172.0	- 6.0
89B	167.5	+ 8.0
89K	163.0	+ 7.5
90B	154.5	+ 2.5
90K	210.5	+ 4.0
91B	191.5	+11.5
91K	186.5	+ 6.5

RED BEDS CENTRAL PRINCE EDWARD ISLAND (Cont'd.)

92B	187.0	+31.5
92K	193.5	+39.0
122B	159.0	+32.5
122K	158.0	+16.0
123B	195.0	+28.0
123K	160.0	+32.5
124B	138.5	+25.5
124K	232.0	- 6.5
125B	153.5	- 4.0
125K	160.5	+12.0
126B	195.5	+23.0
127B	169.0	+ 3.5
127K	169.0	+ 6.5

COLLECTION LOCALITY 46.3N, 62.5 W.

RED BEDS EASTERN PRINCE EDWARD ISLAND

(NRM RESULTS)

	Corrected for Tilt		
Sample No.	D	I	
1B	181.0	+ 3.5	α = 5.5
1K	175.5	+ 6.0	k = 12.5
2B	146.5	+48.5	N = 59
3B	176.0	+ 2.0	
3K	159.5	+ 2.5	
4B	180.0	- 3.5	
4K	173.5	+ 1.5	
6B	177.5	+22.0	
6K	182.0	+37.5	

RED BEDS EASTERN PRINCE EDWARD ISLAND (Cont'd.)

7K	190.5	-11.5
8K	181.5	+27.0
9B	179.0	+12.0
11K	185.5	+29.5
12B	161.0	+ 4.0
12K	166.5	+ 3.5
13B	175.5	- 3.5
13K	167.5	-11.0
15K	163.5	+ 6.5
16K	179.5	+ 1.0
40K	147.0	+23.5
41B	177.0	+17.5
41KK	168.0	+ 8.0
94B	184.0	-11.5
94K	177.0	+ 6.5
95B	174.5	+ 9.5
95K	175.0	+ 6.5
96B	170.0	+21.0
96K	158.5	+32.0
97B	214.0	+23.5
97K	194.5	+17.5
98K	167.5	+30.5
99B	214.0	+11.0
99K	191.5	+16.0
104B	189.0	+ 4.5
104K	198.0	+ 8.5
106B	216.0	- 9.5
106K	176.5	+12.5

RED BEDS EASTERN PRINCE EDWARD ISLAND (Cont'd.)

107K	179.0	+22.0
108B	205.0	-22.0
108K	189.0	- 2.0
109B	184.0	-19.0
109K	161.0	- 6.5
110K	200.0	+ 2.5
112B	180.0	- 6.0
113B	181.0	+ 7.0
113K	184.0	- 0.5
114B	162.5	-18.5
114K	171.0	-43.5
115B	151.0	+ 3.0
115K	161.0	+ 7.5
116K	166.0	-27.0
117B	152.0	-16.5
117K	210.5	- 2.5
118B	163.5	+20.0
119B	166.5	- 1.5
119K	137.5	- 3.5
120B	180.0	- 4.5
120K	177.0	-12.5
121B	169.5	+29.0

COLLECTION LOCALITY 46.3 N, 62.5 W.

OLIVINE DOLERITE DYKE

GEORGE ISLAND, PRINCE EDWARD ISLAND

(STABLE RESULTS)

Reference Horizontal Plane

Sample No.	D	I	
1B	195.5	-14.5	α = 12.4
1K	172.5	-16.5	k = 11.3
2B	191.0	- 3.0	N = 14
2K	176.5	-13.5	
4B	181.5	-19.0	
4K	182.0	-19.5	
6B	183.0	-33.5	
6K	229.0	-42.0	
7B	174.0	-18.0	
7K	184.0	-29.5	
8B	135.0	-50.5	
8K	175.5	+25.5	
9B	172.0	-14.0	
9K	173.5	- 4.0	

COLLECTION LOCALITY 46.6 N, 63.8 W.

NORTH MOUNTAIN BASALT

(NRM RESULTS)

Corrected for Tilt

Sample No.	D	I	
1B	18.0	+57.5	α = 6.3
1P	45.0	+49.5	k = 14.7
2B	6.5	+32.5	N = 38
2P	11.0	+42.5	
3B	9.5	+63.5	
3P	8.5	+60.0	

NORTH MOUNTAIN BASALT (Cont'd.)

(NRM RESULTS)

4B	335.0	+43.0
4P	3.5	+67.0
5B	13.0	+76.5
5P	321.5	+34.0
6B	23.0	+41.0
6P	13.5	+53.0
7B	13.0	+36.5
7P	19.5	+35.0
8B	348.0	+45.5
8P	20.5	+32.5
9B	346.5	+61.0
9P	291.0	+23.0
10B	10.5	+54.0
10P	22.5	+51.0
11B	327.5	+60.0
11P	286.5	+40.0
12B	25.5	+44.0
12P	0.5	+34.0
13B	0.5	+46.5
13P	332.0	+53.5
14B	351.5	+40.5
14P	7.5	+71.5
15B	331.5	+35.5
15P	331.5	+42.5
16B	337.0	+38.0
16P	339.0	+49.0
17B	349.5	+49.0
17P	34.0	+47.5

NORTH MOUNTAIN BASALT (Cont'd.)

(NRM RESULTS)

18B	3.0	+47.5
18P	4.0	+54.0
19B	33.0	+61.5
19P	16.0	+63.0

COLLECTION LOCALITY 45.0 N, 64.5 W.