FOSSIL PLANTS APPLIED TO DATING OF THE HAZELTON GROUP

by

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ABSTRACT

Fossil plant remains from the "upper sedimentary unit" of the Hazelton Group were investigated in order to attempt the assignment of a precise age to the strata. Collections of leaves and specimens for plant microfossil analysis were collected in the Hazelton area, and were supplemented by leaf collections loaned by the Geological Survey of Canada. Intensive maceration of rock specimens failed to yield sufficient microfossils for dating or correlation, and subsequent work was limited to the analysis of megafossils. Identification of leaves and other remains resulted in the discovery of one new species and the recognition of 7 species previously unreported in the Hazelton flora. Statistical analyses and correlations with other floras have led to the conclusion that the flora from the "upper sedimentary unit" of the Hazelton Group is late Jurassic to early Cretaceous in age, encompassing the stages Portlandian to Neocomian inclusive.

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INTRODUCTION

Purpose:

The purpose of this thesis is to attempt an assignment of geological age to the "upper sedimentary unit" of the Hazelton Group on the basis of fossil plants. Discussion is limited to fossil plants which were collected in the Hazelton and, to a lesser extent, the Smithers map-areas of central British Columbia.

Previous Work:

The only previous work on dating of the "upper sedimentary unit" by fossil plants was done by W.A. Bell of the Geological Survey of Canada (1956). From collections made in the Hazelton area Bell assigned an early Cretaceous Neocomian-Barremian age to florules from 13 localities and a probable Aptian age to florules from 6 localities. An Aptian age was also assigned by Bell to florules from 7 localities in the Smithers area.

Both Armstrong (1944, 1953) and Bell (1956) have indicated that there is a discrepancy in the ages indicated by invertebrate evidence on the one hand and by fossil plants on the other. This discrepancy has arisen from the discovery of upper Jurassic or earliest Cretaceous marine shells 300 feet stratigraphically above beds containing a flora of Blairmore

(Aptian) age. In addition the Hazelton flora was assigned to the Cretaceous by correlation to the Kootenay, lower Blairmore and Bullhead floras of Alberta and eastern British Columbia (Bell, 1956, p.23), the ages of which are still in dispute (Rouse, 1959; Gussow, 1960; Pocock, 1960). These conflictions have led to a general uncertainty as to the age of the "upper sedimentary unit" of the Hazelton Group. The present study was undertaken to attempt to shed new evidence concerning the age, particularly by the investigation of plant microfossil assemblages.

For this purpose the writer, accompanied by Dr. G.E. Rouse, spent 8 days in mid-September of 1960 collecting fossil plants and samples to be macerated for plant microfossils in the Hazelton-Smithers area of central British Columbia. These collections, together with most of Bell's original collections loaned by the Geological Survey of Canada, form the basis for most of the work done in the present study.

Geology:

The Hazelton Group, as presently defined, is known most completely from mapping conducted in the Hazelton, Smithers, and Terrace map-areas. In the Smithers map-area (Armstrong, 1944) the group consists of the following five map units:

(1) volcanic division (Lower Jurassic).

(2) marine sedimentary division (Middle Jurassic).

(3) volcanic division (Middle or Upper Jurassic).

(4) continental and marine sedimentary division (Upper Jurassic and Lower Cretaceous). This is referred to in subsequent pages as the "upper sedimentary unit."

(5) volcanic division (Lower Cretaceous or later).

According to Armstrong, the Hazelton Group in this area has a possible thickness of 10,000 feet.

In the Hazelton map-area the two lower members of the Hazelton Group (1) and (2), are either missing or have not been recognized (Armstrong, 1953). The lowermost member of the Hazelton Group in this area is the volcanic division of Middle Jurassic age (3). Overlying these volcanics is the "Upper Jurassic and Lower Cretaceous sedimentary division" (4) which consists of at least 5000 feet of interbedded continental and marine strata. Overlying the sedimentary division is a volcanic division of Lower Cretaceous age or younger, corresponding to division 5 of the Smithers map-area. A comprehensive discussion of the Hazelton Group from other areas has been given by Tipper (1959).

PART I - METHODS

(1) Microfossils

Samples to be macerated for plant microfossils were collected from 31 localities in the Hazelton-Smithers area.

All samples were taken from carbonaceous shales, shaly coals or coaly shales. Many of the shales contained leaf impressions. Care was taken during the sampling to ensure that only fresh material was collected, and that no highly weathered surface material was included in the samples.

Laboratory analyses were performed on the samples for microfossils using modifications of the procedure outlined by Rouse (1959). Generally, the basic procedure for the treatment of samples is as follows:

(1) The sample is broken to 1 mm. fragments;

(2) The rock fragments are immersed in hydrochloric acid (HCl) until all visible effervescence ceases;

(3) The residue is washed two or three times;

(4) Concentrated hydrofluoric acid (HF) is applied for 12 hours with 3 stirrings;

(5) The residue is washed three times;

(6) Portions of the sample are spot checked under the microscope for indications of plant microfossils;

(7) The sample is immersed in Schultze's solution (nitric acid plus potassium chlorate), or nitric acid alone, depending on the degree of preservation of the microfossils. The sample is periodically checked under the microscope during this step;

(8) The oxidized residue is washed two or three times;

(9) A 10% solution of potassium carbonate (K_2CO_3) is added for 1 - 12 hours. This residue is checked frequently under the microscope during this step;

(10) The residue is centrifuged and mounted in corn syrup or a plastic medium.

Treatment of the first few samples yielded no microfossils, and it was decided to modify the procedure for subsequent samples. The modifications in the treatment involved the following:

(1) The time in hydrofluoric and hydrochloric acidwas increased (up to 75 hours). In some instances, the acid solutions were replaced with fresh acid, and the number of stirrings increased.

(2) The time in Schultze's solution was increased, in one case up to 141 hours. Increases in the amount of potassium chlorate in the Schultze's solution were made. In several instances, where oxidation of carbonized particles was slow or incomplete, fresh Schultze's was added to the sample.

(3) The time in 10% potassium carbonate solution was decreased because some of the fragments appeared to dissolve in the strong solution.

(4) Prior to centrifuging (step 10), separation techniques involving the "vibraflute" and zinc chloride solution (sp. gr. 2.0) were employed.

The first modification of adding fresh HF was intended to dissolve as much rock material as possible from around the plant microfossils. The second modification was considered necessary because of the black carbonaceous film remaining on the "microfossils" following normal treatment.

It was hoped that by increasing the time in Schultze's solution, the coaly film would be removed. The first two modifications were only partially successful. The third modification was made in order to discount any possibility of microfossils having been completely dissolved by excessive immersion in the potassium carbonate solution. This modification gave negative results. The fourth modification in the treatment procedure was made in order to dispose of excess rock material and hence facilitate a better concentration of microfossils in the sample. The "vibraflute" and zinc chloride treatments were successful in disposing of excess fine rock material in some samples, but did not increase the yield of microfossils.

Treatment of all 31 samples yielded only a very few poorly preserved plant microfossils. In order to ensure that the treatment procedures were effective, 3 of the more "promising" samples were retreated. Two samples were retreated once, and the other sample was retreated twice, with negative results.

At this stage, work on the microfossil samples was discontinued. It is considered that although the writer's work gave negative results, further sampling in the Hazelton area followed by exhaustive studies in the laboratory would probably yield a limited microflora.

(2) Macrofossils

Plant macrofossils were collected from 16 localities in the Hazelton-Smithers area (see sample locality map, fig. 5).

Of this number, 14 are in the Hazelton map area and two are in the Smithers map area. Altogether, over 300 specimens were collected. Most of these are compressions of leaves although a few stem fragments were included.

In addition to the previously mentioned macrofossils, collections of the Geological Survey of Canada from an additional 14 localities in the Hazelton area were made available to the writer. Some of these collections were made prior to publication of W.A. Bell's memoir in 1956; others were made since that time by personnel of the Geological Survey, and serve to increase the areal distribution of Hazelton species.

TABLE I

Geological Survey of Canada
Fossil Plant Localities

(These are the localities as given by the Geological Survey of Canada)

Locality No.	
2386	Hazelton area, from ridge L at elevation 6220 feet,
2388	Hazelton area, from head of Salmon River.
2393	Hazelton area, Canyon Creek, Skeena River Valley.
2394	Hazelton area, Canyon Creek, Skeena River Valley.
2408	Suskwa River, 1/2 mile above 20 mile Creek.
2413	Creek flowing into Skeena River opposite Hazelton.
2419	2 miles up Campbell Creek from Kispiox River.
4993	2 miles along road leading to Silver Standard Mine, short distance east of Hazelton.
4996	Old road cut, approach to Skeena River bridge north of Hazelton.

4998 Road cut on #16 just east of bridge over Kitsequela, east of Skeena Crossing.

4999 Road cut on road north of Kispiox (15.2 miles from where road leaves #16).

5000 West end of 17 mile bridge on Kispiox River (= loc. H-26).

5054 Rocher de Boule Range.

5055 Rocher de Boule Range.

The most noteworthy feature of the field collections is the apparent segregation of the plant species in strata from different localities. For example, of 29 localities 7 contain only one species, 6 contain 2 species, 3 contain 3 species, 2 contain 4 species, 2 contain 5 species, 4 contain 6 species, 5 contain 7 species and 1 locality contains 10 species. In 16 of 29 localities (55.1%) 3 species or less are present. It is observed also (fig. 1) that in the case of localities containing several species, generally 1 and sometimes 2 species comprise the bulk of the florule at these localities.

The distribution of species among the 29 localities can be shown also by the following data which are derived from fig. 1:

11 species occur in 1 locality.
10 species occur in 2 localities.
4 species occur in 3 localities.
3 species occur in 4 localities.
4 species occur in 5 localities.
1 specie occurs in 6 localities.
1 specie occurs in 8 localities.
1 specie occurs in 12 localities.
1 specie occurs in 15 localities.

From the above table it is observed that 32 of 36 species (88.8%) identified occur in 5 localities or less, and that 11 of 36 species (30.5%) occur in 1 locality.

The distribution of the species according to localities is shown in figure 1, and the frequency of species distribution is shown in fig. 2. It is apparent that there are no significant discrepancies in the distribution which would suggest that there are plants of different ages represented. This is further substantiated by the relatively close geographic proximity of many of the collecting sites, and the general lithologic similarities of the rocks containing the plants. Thus it appears most reasonable to consider the plants from all of the localities collected in the "upper sedimentary unit" of the Hazelton Group as belonging to a single contemporaneous and syngenetic flora. This is in marked contrast to the suggestions of Bell (in Armstrong, 1944; Bell, 1956, p.23) that some florules are of probable Aptian age, others of Cretaceous age (Neocomian-Barremian), while still others were admitted as possibly Jurassic age.

Identifications

All specimens collected by the writer were numbered (B-3084 to B-3432) and are housed in the permanent collection of the Department of Biology and Botany at the University of British Columbia.

No type specimens were available and all identifications were made by comparison of the specimens on hand with photographs, illustrations, and written descriptions of previously described forms. Examination of the specimens involved use of a 10 power hand lens and, to a lesser extent, a binocular microscope. In general, the binocular microscope was not satisfactory for this type of work because high magnification enlarged the mineral grains in the rock to such an extent that details of the plants were obscured rather than improved.

From the two collections studied (i.e., the writer's collection and that of the Geological Survey of Canada), a total of 560 specimens representing 36 species, were identified. Seventeen of the 36 species were identified as previously described species, some were compared to species, and still others were identified only to genus.

The summary list of species that follows is a compilation from 3 sources:

(1) All species identified from the writer's collection:

(2) Species identified from the Geological Survey of Canada collections that were made available to the writer;

(3) Species identified by W.A. Bell (1956) but which are not reported in either (1) or (2) above.

In this summary list the source collection for each plant species is designated as follows: W for species from the writer's collection, G.S.C. for species from the Geological Survey collections available to the writer, and B for species not found in either of the foregoing but reported by W.A.Bell in his memoir. Forms marked with an asterisk have not been previously reported in the Hazelton flora.

Source of Collection		
		Division ARTHROPHYTA
		Order EQUISETALES
W		*Equisetites lyelli* (Mantell) Unger
W		*Equisetites* sp. cf. *lyelli* (Mantell) Unger
		Division PTEROPHYTA
		Order FILICALES
W		*Cladophlebis* sp.
W	?	*Cladophlebis* sp.
G.S.C.	*	*Cladophlebis heterophylla* Fontaine
W		*Cladophlebia impressa* Bell
B		*Cladophlebis parva* Fontaine
W	* ?	*Cladophlebis* (*Gleichenites*) *porsildi* Seward
W		*Cladophlebis virginiensis* Fontaine emend Berry
W		*Cladophlebis* sp. cf. *virginiensis* Fontaine emend Berry
W		*Coniopteris* sp.
W		*Coniopteris brevifolia* (Fontaine) Bell
G.S.C.	*	*Coniopteris* (*Sphenopteris*) *hymenophylloides* (Brongniart) Seward
B		*Dictyophyllum fuchsiforme* (Bell) Seward
W		*Gleichenites* sp.

W		*Gleichenites nordenskiöldi* (Heer) emend Seward
B		*Klukia canadensis* Bell
B		*Phlebopteris* ? *elongata* Bell
B		*Sphenopteris acrodentata* Fontaine
G.S.C.		*Sphenopteris dentata* (Velonovsky) Seward
B		*Sphenopteris* (*Ruffordia*) *göpperti* (Dunker) Seward

Division PTERIDOSPERMOPHYTA

Order CAYTONIALES

G.S.C.		*Sagenopteris* sp.
B		*Sagenopteris williamsi* (Newberry) Bell

Division CYCADOPHYTA

Orders BENNETTITALES and CYCADALES

B		*Ctenopteris insignis* Fontaine
B		*Nilssonia brongniarti* (Mantell) Dunker
W		*Nilssonia canadensis* Bell
W		*Nilssonia parvula* (Heer) Fontaine
W	*	*Nilssonia pterophylloides* Nathorst
B		*Nilssonia schaumburgensis* (Dunker) Nathorst
B		*Pseudoctenis hazeltonensis* Bell
B		*Pseudocycas dunkeriana* (Göppert) Florin
W	*	*Pterophyllum tennuipinnatus* n. sp.
B		*Pterophyllum rectangulare* Bell
G.S.C.	*	*Ptilophyllum arcticum* (Göppert) Seward

B	Ptilophyllum columbianum Bell
B	Ptilophyllum hirtum Bell
B	Ptilophyllum (Anomozamites) montanense (Fontaine) Bell

Division GINKGOPHYTA

Order GINKGOALES

W	Baiera sp. cf. furcata (Lindley and Hutton) Braun
G.S.C.	Baiera sp. cf. gracilus (Bean) Bunberry
W	Ginkgoites arcticus (Heer) Florin
W	Ginkgoites sp. cf. arcticus (Heer) Florin
W	Ginkgoites sibirica Heer
W	Ginkgo sp. cf. sibirica Heer

Division CONIFEROPHYTA

Order CONIFERALES

B	Athrotaxites berryi Bell
W	? Elatides sp.
W	Elatides curvifolia (Dunker) Nathorst
B	Elatides splendida Bell
W	? Elatocladus sp.
W	Pityophyllum sp.
B	Pityophyllum cf. nordenskiöldi (Heer) Krystofovich

INCERTAE SEDIS

W	Czekanowskia sp.
W	Czekanowskia sp. cf. rigida Heer

B		Phoenicopsis arctica (Heer)
W	?	Podozamites sp.
W		Podozamites sp.
W		Podozamites lanceolatus (Lindley and Hutton(Schimper

The discussion in the following pages is limited to those plants about which the writer has new information, or which have not been treated adequately in former investigations.

The photographs (plates 1 and 2) are presented to supplement the discussion of species in the text, and to illustrate the significant features of species reported here for the first time.

Generally, two problems were encountered in the identification of the plants. The first problem was that of having to deal with many imperfectly preserved specimens. The second and most frustrating problem, was the variation shown in photographs and descriptions of some previously reported species. These variations allowed for considerable overlapping of species in some cases, and most certainly point out the need for revision of some of the plant groups encountered in this study. The latter problem, that of variation among species, is exemplified strongly by Cladophlebis virginiensis and Coniopteris brevifolia. In considering the problem of plant speciation, and in particular leaves from one plant (eg. Ginkgo), unless measurable variations exist, species cannot be separated adequately.

Equisetites: Although the specimens of Equisetites lyelli (Mantell) Unger (plate 1, fig. 12) are incomplete, the excellent preservation allows for identification to be made with considerable confidence. This species is relatively rare in the Hazelton flora.

Cladophlebis: In the many specimens of Cladophlebis virginiensis Fontaine which were studied by the writer, it is considered virtually impossible to establish any distinct boundaries between the many variants, as they grade imperceptibly into each other. Bell (1956, p. 51-52) recognized three main variants of Cladophlebis virginiensis. However, the present writer was unable to do this because of the fact that imperfect preservation of the specimens made it impossible to observe details of venation. It is considered that among the specimens of Cladophlebis virginiensis studied by the writer there are forms which could be referred just as easily to Cladophlebis denticulata, since some forms of this latter species with entire margins do not differ in any easily observable or measurable character from forms of Cladophlebis virginiensis in the Hazelton flora. The writer has had available for study a specimen of Cladophlebis denticulata from the Jurassic of Yorkshire, England, in which imperfect preservation does not allow venation details to be noted. However, the general shape of the pinnules, their angle and manner of attachment to the rachis, and their apparently entire margins suggest strongly that the specimen is typical of some forms of Cladophlebis virginiensis in the Hazelton flora.

Coniopteris: Coniopteris brevifolia (plate 2, fig. 14) is the most common leaf in the Hazelton flora next to Cladophlebis virginiensis. Once again, because of the great variability of this species, it overlaps certain forms referred by other authors, notably by Seward (1900, p. 99) to Coniopteris hymenophylloides. The writer has identified several specimens of Coniopteris hymenophylloides, which are identical in morphology to the English Jurassic species (see plate 1, fig. 10w). At the same time, however, some of the leaf remains are identical with Coniopteris brevifolia from the Potomac flora. However, there do not appear to be any satisfactory criteria for distinguishing between the many variants of the two species, and there is a good possibility that the 2 fossil species represent one natural species.

Sphenopteris: Leaves named Sphenopteris latiloba Fontaine (in Bell, 1956, p. 69-70) had been synonymized previously by Seward in 1926 under Sphenopteris dentata Velonovsky (Plate 1, fig. 5), and hence should bear the latter name.

Nilssonia: Nilssonia parvula, an abundant form at locality H-8, is considered by the writer to be synonymous with Nilssonia nigracollensis Wieland, (in Ward, 1905, p. 320) and Bell (1956, p.103). Bell in reference to Nilssonia nigracollensis writes:

> "*Nilssonia parvula*, Fontaine (non Heer)... obviously belongs to this species."

Fontaine (in Ward, 1905, p. 320) writes as follows:

> "This plant (*N. nigracollensis*) is strikingly like *Nilssonia parvula* (Heer) Fontaine of the Jurassic of Oregon. As however it is constantly larger and more robust than the predominant forms of that fossil, it is probably distinct."

Nilssonia parvula was first described as *Taeniopteris parvula* by Heer in 1876, and since it is obviously con-specific with and takes precedence over *N. nigracollensis*, the writer has seen fit to reinstitute this species.

Pterophyllum (*Ctenophyllum*): In the writer's collection of Hazelton plants are 5 specimens which are strikingly similar to forms from the Oregon Jurassic flora which Fontaine (in Ward, 1905, p. 105, pl. XXII) has referred to *Ctenophyllum angustifolium*. *Ctenophyllum*, however, as originally defined by Schimper (Fontaine, 1883, p. 67) has the pinnae attached to the upper surface on the rachis and, according to Seward, (1917, p. 528) differs in no significant respects from forms of *Ptilophyllum* or fronds of *Dioonites*. Consequently, as Seward (1917, p. 528) has pointed out, there would seem to be no adequate reason for the retention of *Ctenophyllum* as a generic designation.

A transfer preparation of one of the writer's specimens shows that the pinnae are attached laterally as in species of the bennettitalean genus *Pterophyllum*. Consequently, it was planned originally to establish a new combination for this plant under *Pterophyllum angustifolium*. However, since this name has already been used for another species of _Pterophyllum_ (Seward, 1900, p. 228), the only alternative is the circumscription of a new species of _Pterophyllum_. This is given below.

Seward (1917, p. 549), in reference to _Pterophyllum nathorsti_, writes:

> "The Jurassic fronds from Oregon described by Fontaine as _Ctenophyllum angustifolium_ are similar forms."

Although these two species are indeed somewhat similar, the differences between them are sufficient to preclude any attempt to combine the forms referred to _Ctenophyllum angustifolium_ under _Pterophyllum nathorsti_. Probably the most striking difference between these two species is that _Pterophyllum nathorsti_ has up to 16 veins per pinnule, whereas the Oregon and Hazelton forms are characterized by 3 to 5 veins per pinnule. The Hazelton specimens have a constant number of veins (4).

Pterophyllum tennuipinnatus n. sp.

1896 - _Ctenophyllum angustifolium_ Fontaine: Am. Journ. Sci. 4th ser., Vol. II, p. 274 (nomen).

1900 - _Ctenophyllum angustifolium_ Fontaine: Twentieth Ann. Rep. U.S. Geol. Surv., 1898-99, Pt. II, p. 360, pl. LXIII, figs. 2, 3.

1905 - _Ctenophyllum angustifolium_ Fontaine: U.S. Geol. Surv., Mon. 48, p. 105, pl. XXII.

1916 - _Ctenophyllum angustifolium_ ? Fontaine: U.S. Nat. Mus., Proc., vol. 51, p. 458, pl. 80, f.2.

Type Specimen B-3407, and counterpart B-3399, University of British Columbia Paleobotanical Collection.

Description:

Frond: fragments 8 cm. long are available, but the original length must have approached 15 cm.

oblong-elliptical in outline, narrowing toward base and apex.

fragments 7 cm. wide.

Leaflets: - in the basal regions, leaflets are perpendicular to the axis; in the distal region becoming more and more inclined, or somewhat falcate (more so in the distal parts of leaflets).

leaflets are generally slightly expanded at base and some appear to coalesce with adjacent pinnules; others have width unchanged to middle of pinnule and then narrow gradually to the tip.

width of leaflets varies from 2 to 3 mm., and decreases towards leaf apex.

the tips of leaflets are obtusely rounded.

the longest leaflet observed is 6 cm. long.

the spacing between adjacent leaflets varies from .5 to 1.5 mm.

Attachment to rachis:- alternate to opposite, but mostly sub-opposite.

the leaflets are attached laterally on the rachis. This was suspected in the hand specimen and confirmed by the transfer preparation.

Rachis:- whole width of rachis is exposed and uncovered by leaflet bases.

rachis varies from 2 to 3.5 mm. in width, decreases towards apex of frond generally.

Venation:- the veins are non-branching, are 3 to 5 in number and are parallel all the way out to the distal ends of the leaflets.

Baiera: The problem of species variation together with that of imperfect preservation did not permit specific identification of specimens of Baiera. None of the specimens showed enough of the leaf lamina or sufficient venation to be certain of a species affinity. Consequently, these specimens could be identified with confidence only as "sp. cf. gracilus" (plate 2, fig. 16) or "sp. cf. furcata" (plate 2, fig. 15). Similar reservations were noted by Bell (1956).

Ginkgo: Two species of Ginkgo were distinguished by the writer as Ginkgoites sibirica (plate 2, fig. 6) and Ginkgoites arcticus (plate 2, fig. 3). Florin (1936, p. 34). Some specimens were relatively easy to identify, whereas others were most difficult to assign to one species or the other.

It should be mentioned here that Ginkgoites arcticus has been called Ginkgo pluripartita by Bell (1956, p. 85) and other authors, but represents a previously omitted synonymy. In referring several "Ginkgos" to Ginkgoites sibirica, I have been influenced by A.C.Seward (1919, p. 24) who wrote:

> "For the present the most convenient course would seem to be the retention of Ginkgoites sibirica for leaves similar to some of the more deeply divided forms of G. digitata and to G. pluripartita, but normally characterized by a lamina divided almost or quite to the base into oblong, obtuse or more or less acute segments."

The writer considers Ginkgo nana Dawson (in Bell, 1956, p. 86) synonymous with the earlier Ginkgoites sibirica. Bell (1956, p. 86) states in reference to Ginkgo nana and two similar species that:

> "In form and venation all three of these species are much like Ginkgoites sibirica, (Heer) Seward, ... Although they are of smaller size than normal with that species."

Bell (1956, p. 86) gives in his list of synonymies for Ginkgo nana the species Salisburia (Ginkgo) sibirica Dawson, 1886. However, Ginkgoites sibirica (Heer, 1876) Seward, by rules of botanical nomenclature, takes priority over Dawson's species.

On the problem of identification of Ginkgo leaves in general, Seward (1919, p. 14) writes:

> "It is impossible to define precisely the several species of Ginkgoites founded on leaves; in the account of the recent species attention is called to the range in leaf form and its bearing on the determination of fossils. All that can be done is to adopt certain specific names as a matter of convenience, recognizing that the differences on which the classification is based are not either sufficiently sharply defined or morphologically important to be regarded as criteria of true specific distinction."

F.H. Knowlton (1914, p. 55) writes as follows on this topic:

> "In dealing with such an abundance of specimens and multiplicity of forms, one must needs make either many 'species' to accommodate this diversity, or only one or two, and in view of the known variation exhibited by the single living species, the latter plan seems preferable."

These last two quotations serve to illustrate the many variations in ginkgoalean leaves; these result in immeasurable difficulties in specific identification and indicate that leaves of Ginkgo have little use in correlation or dating.

PART II - COMPARISON OF THE HAZELTON FLORA WITH OTHER FLORAS IN NORTH AMERICA

In attempting to date the Hazelton flora by comparisons and correlations with other floras, it is apparent that there are very few floras of comparable age in North America. With a few exceptions of relatively small floras, the only ones considered suitable for correlation with the Hazelton flora are those listed in the following paragraphs (see also fig. 3 and fig. 4). Rather than attempting long distance inter-continental correlations, it is considered that, by limiting the correlations to relatively short (intra-continental) distances, the validity of the correlations will be increased.

Simpson (1960) discusses several methods for the measurement of faunal resemblance under the following two groups; (1) measurement based on numbers of taxa; (2) measures involving abundance of taxa. The application of the latter measurements cannot be undertaken in the present study, as numbers of species are only partially known for the Hazelton flora, and are unknown for other floras with which the Hazelton flora can be compared.

According to Simpson, the most obvious and acceptable measurement of faunal resemblance is expressed as follows:

$$\frac{C}{N_t} \times 100 \qquad (1)$$

where C = number of taxa common to both faunas;

N_t = total taxa in both.

If both faunas are almost completely represented and if they are of at least approximately equal size, the above index (1) is useful.

Samples, however, are frequently of unequal size and the following index eliminates this disadvantage:

$$\frac{C}{N_1} \times 100 \qquad (2)$$

where C = number of taxa common to both faunas;

N_1 = total taxa in the smaller of the two faunas compared.

As an estimate of a population index from samples, the second index minimizes the effects of differences in size between two faunas. When samples are small, both (1) and (2) have considerable sampling error; but (2) is also preferable in this respect, and the larger the discrepancy between N_1 and N_2 (total taxa in the larger of the two faunas compared), the better N_2 but not N_1 is sampled, the lower the bias resulting from the sampling error. When the sample (and population) sizes are equal, index (2) is still at least as good as (1).

The % correlations for the 4 largest floras (Oregon, Patuxent, Grundel and Patapsco) have been calculated using index (2), with the Hazelton flora as N_1. Three floras, viz., Kootenay, lower Blairmore and upper Blairmore, are of slightly smaller size than the Hazelton, and in these cases N_1 represents the smaller flora. Both the Kennecott and Cape Lisburne floras are much smaller than the Hazelton and again N_1 is the smaller figure. The resultant measurements are presented in figure 3, and are given again under the detailed discussion of each flora.

In the following section, all correlations have been made on the basis of number of species identified specifically plus the number of different species identified as "sp. cf." This latter group includes species in brackets.

In the section on "Interpretation of Results," correlations made on the basis of species only are discussed. These correlations do not include bracketed species, in the following section, unless such species represent established synonymies.

It is observed in the summary list (pages 11 to 14) and figure 4, that the Hazelton flora has 35 species identified specifically and 4 species identified as "sp. cf."

For the other floras discussed in subsequent pages, the following table summarizes the number of species identified specifically etc., for each flora which is used as N_1 in index (2).

TABLE II

	Total Species	Number of species identified specifically.	Number of species identified specifically plus number identified as sp. cf.
Cape Lisburne	17	16	17
Kennecott	16	8	11
Kootenay	33	21	26
Lower Blairmore	37	33	36
Upper Blairmore	35	18	20

In figure 4, where presence of a species is another flora is indicated by quotation marks, that species is a "cf." species.

The list of species in figures 1 and 2 is a compilation from the writer's collection of plants, and the Geological Survey of Canada collections loaned to the writer. Some of the species listed by Bell (1956) and also given in the floral lists in succeeding pages, are not included in figures 1 and 2. This is because the writer has no information on the frequency of occurrence; or on the numbers of individuals of these species.

Although a record of the occurrence of species said to be "characteristic of the Jurassic period" etc., is useful information for dating a flora, the method is subject to personal opinion. If, however, a statistical method, as outlined can be used in conjunction with the "characteristic species" method, the results should prove to be much more meaningful and objective.

Jurassic Flora of Cape Lisburne, Alaska

F.H. Knowlton (1914) has identified seventeen species of plants from the Cape Lisburne region of northwestern Alaska. 16 of the plants are identified specifically. These plants are contained in the Corwin formation.

The flora of the Cape Lisburne region includes the following species which are also present in the Hazelton flora. Where a Cape Lisburne species differs in name from the Hazelton equivalent, the Hazelton species is given in brackets.

Coniopteris hymenophylloides.

Podozamites lanceolatus.

Elatides curvifolia.

Pityophyllum nordenskiöldi.

Ginkgo digitata (*Ginkgoites arcticus*).

These five species result in a 29.4% correlation with the Hazelton flora. The last species named above (i.e. *Ginkgo digitata*, in Knowlton, plate VII, fig. 5) appears strikingly similar to species in the Hazelton flora that the writer has referred to *Ginkgoites arcticus*, and consequently has been included in a list of species common to both floras.

Flora of the Kennecott Formation (Albian)
Chitina Valley, Alaska

The flora of the Kennecott formation (Knowlton, in Martin, 1926, p. 344-346) includes 16 species of which only 8 are identified specifically.

The following species are also present in the Hazelton flora. Where a Kennecott species differs in name from the Hazelton equivalent, the Hazelton species is given in brackets.

Elatides curvifolia.

Pinus nordenskiöldi (*Pityophyllum nordenskiöldi*).

Ginkgo schmidtiana (*Ginkgoites sibirica*).

Podozamites sp. (*Podozamites lanceolatus*).

Taeniopteris parvula? (*Nilssonia parvula*).

Cladophlebis cf. *C. moissenti* (*Cladophlebis heterophylla*).

These 6 species result in a 54.5% correlation with the Hazelton flora.

Pinus nordenskiöldi has been synonymized with *Pityophyllum nordenskiöldi* (in Bell, 1956, p. 112). It is also probable that some of the specimens in the Hazelton flora, referred by the writer to *Pityophyllum* sp., are referable to this species although such an assignment cannot be made with confidence.

Ginkgo schmidtiana is referable to *Gingoites sibirica* of the Hazelton flora (Seward, 1919, p.24).

Knowlton (in Martin, 1926, p.344) states, "The *Podozamites* is of the type *P. lanceolatus*..," hence it appears that this form is also common to the Hazelton flora.

In reference to the forms of *Cladophlebis* present, Knowlton (in Martin, 1926, p. 344) writes:

> "One form may be compared with *C. moissenti* from the French Jurassic, or with *C. heterophylla* as known from the Kootenai."

Consequently, this form has been included, though possibly somewhat doubtfully, in the list of species common to both the Kennecott and Hazelton floras.

Flora of the Riddle Formation, Douglas County, Oregon (Portlandian, Middle to Late Tithonian)

F.H. Knowlton (1910) lists 79 plant species plus 2 indeterminate leaves from the plant beds of Douglas County, Oregon. Sixty-five of the 79 plants are identified specifically.

The following species are also present in the Hazelton flora. Where an Oregon species differs in name from the Hazelton equivalent, the Hazelton species is given in brackets.

Coniopteris hymenophylloides.

Thyrsopteris murrayana (*Coniopteris hymenophylloides*).

Polypodium oregonense (*Cladophlebis parva*).

Cladophlebis vaccensis (*Cladophlebis virginiensis*, pars.).

Ruffordia göpperti.

Nilssonia parvula.

Nilssonia pterophylloides.

Pinus nordenskiöldi (Pityophyllum nordenskiöldi).

Ctenophyllum angustifolium (Pterophyllum tennuipinnatus).

Podozamites lanceolatus.

Ginkgo digitata (Ginkgoites arcticus).

Ginkgo sibirica.

Sagenopteris grandifolia (Sagenopteris williamsi).

Pterophyllum contiguum (Ptilophyllum arcticum).

Pterophyllum aequale (Ptilophyllum columbianum).

Cladophlebis denticulata (Cladophlebis virginiensis, pars.).

Taeniopteris orovillensis (Nilssonia canadensis).

Ginkgo lepida (Ginkgoites sibirica).

The foregoing list results in a 46.1% correlation with the Hazelton flora.

Thysopteris murrayana has been synomymized under Coniopteris hymenophylloides by Seward (1900, p. 100), however, Fontaine (in Ward, 1905, p. 61) maintains they are separate species.

W.A.Bell (1956, p.57) in reference to Polypodium oregonense Fontaine (in Ward, 1905, Pl. X, fig. 1 - 7) states in part:

> "Cladophlebis parva as defined in this report is apparently very close specifically to Polypodium oregonense."

Fontaine's species Cladophlebis vaccensis (in Ward, 1905, p. 66-68, plate X, fig. 8-12) appears identical to forms in the Hazelton flora which the writer has referred to Cladophlebis virginiensis, and for this reason is included in the list of plants common to both floras.

Some of the forms referred by Fontaine to Ginkgo digitata (in Ward, 1905, pl. 30, fig. 1-7) are seemingly identical to Ginkgoites arcticus in the writer's collection of Hazelton plants: this is especially true of Fontaine's fig. 5 which shows the lobes dissected to the same degree as the Hazelton specimens.

Other similarities noted in species of ginkgos are as follows:

(1) Ginkgo huttoni magnifolia (in Ward, 1905, pl. 31, fig. 4-8) is, in the opinion of the writer, identical with specimens of Ginkgoites arcticus in the Hazelton flora.

(2) Some forms that Fontaine (in Ward, 1905, plate 32, fig. 3-8) has referred to Ginkgo lepida, are very close to Ginkgoites sibirica, (especially fig. 6 of Fontaine's) except that Fontaine's material has a greater number of lobes, a feature of doubtful specific significance.

The strong resemblance of Sagenopteris grandifolia Fontaine (in Ward, 1905, pl. 15, fig. 4, 5) to Sagenopteris williamsi of the Hazelton flora has already been cited by W.A.Bell (1956, p. 80).

Specimens referred by Fontaine to *Pterophyllum contiguum* (in Ward, 1905, p. 99, pl. 19, fig. 7-11) are according to Bell (1956, p. 95) possibly conspecific with *Ptilophyllum arcticum* in the Hazelton flora.

Bell (1956, p. 96) cites *Ptilophyllum columbianum* of the Hazelton flora as bearing a close resemblance to *Pterophyllum aequale* Fontaine (in Ward, 1905, pl. 20).

Fontaine's example of *Cladophlebis denticulata* (in Ward, 1905, plate 11, fig. 7) with entire margins is not unlike forms of *Cladophlebis virginiensis* in the writer's collection of Hazelton plants.

Nilssonia canadensis of the Hazelton flora (in Bell, 1956, p. 104) is comparable with forms referred by Fontaine to *Taeniopteris orovillensis* (in Ward, 1905, p. 78, 79, plate 12, fig. 12-17), the only difference being that in the Oregon form the veins are somewhat curved.

From the foregoing list, it can be noted that 9 species from the Riddle Formation are considered specifically identical with counterparts from the Hazelton. This has been done carefully and cautiously because of the inferences this has in dating, but the writer is confident of the accuracy of the identifications and comparisons.

Comparison with Potomac Flora

The Potomac Group of Maryland and Virginia contains an extensive flora totalling 174 species (Dorf, 1952, p. 2165,2166). This flora is contained in three formations comprising the

Potomac Group, namely, the Patuxent of Neocomian age, the Arundel of Neocomian age and the Patapsco of Albian age.

This flora contains the following species that are also found in the Hazelton flora. Where a Potomac species differs in name from the Hazelton equivalent, the Hazelton species is given in brackets.

Ruffordia göepperti.

Onychiopsis brevifolia (Coniopteris brevifolia).

Equisetum lyelli (Equisetites lyelli).

Gleichenites nordenskiöldi.

Podozamites lanceolatus.

Cladophlebis virginiensis.

Cladophlebis parva.

Sphenopteris dentata.

The first four species in the above list occur only in the Patuxent formation, whereas the fifth species above (Podozamites lanceolatus) occurs in the Patuxent and Patapsco formations. The last three species range from the Patuxent through the Patapsco Formation.

If this flora is considered as a whole, it has a 20.5% correlation with the Hazelton flora. The % correlation is much less for the Arundel and Patapsco floras if each flora is considered separately; viz, Patuxent, 20.5%, Arundel, 7.6%, Patapsco 10.2%.

Comparison with the Flora of the Kootenay Formation

W.A.Bell (1956, fig. 1) lists a total of 33 plant species in the Kootenay flora, of which 21 are identified specifically.

The following species from the Kootenay also occur in the Hazelton flora. Where a Kootenay species differs in name from the Hazelton equivalent, the Hazelton species is given in brackets.

Coniopteris brevifolia.
Cladophlebis virginiensis.
Cladophlebis heterophylla.
Sphenopteris latiloba (*Sphenopteris dentata*).
Equisetites lyelli.
Baiera cf. *furcata*.
Baiera cf. *gracilus*.
Ginkgo pluripartita (*Ginkgoites arcticus*).
Ginkgo cf. *lepida* (*Ginkgoites sibirica*).
Czekanowskia cf. *rigida*.
Ptilophyllum (*Anomozamites*) *montanense*.
Ptilophyllum arcticum.
Nilssonia schaumburgensis.
Nilssonia nigracollensis (*Nilssonia parvula*).
Nilssonia canadensis.
Pseudoctenis hazeltonensis.
Pityophyllum cf. *nordenskiöldi*.
Podozamites lanceolatus.

These 19 species provide a 73.0% correlation with the

Hazelton flora.

As pointed out previously in the section on identifications, the following synonymies occur in the foregoing list: Sphenopteris latiloba for Sphenopteris dentata, Ginkgo pluripartita for Ginkgoites arcticus, Ginkgo nana for Ginkgoites sibirica, and Nilssonia nigracollensis for Nilssonia parvula.

The Kootenay species Ginkgo cf. lepida (in Bell, 1956, p. 87, pl. 37, fig. 5) differs in no significant respects from forms referable to Ginkgoites sibirica. As pointed out by Seward (1919, p. 11) an increase in the number of lobes is not considered to be a feature for specific distinction.

Comparison with the Flora of the Blairmore Group

Lower Flora: The Blairmore "lower flora" comprises 37 plant species (Bell, 1956, fig. 1). 33 of the species are identified specifically.

The following species also occur in the Hazelton flora. Where a lower Blairmore species differ in name from the Hazelton equivalent, the Hazelton species is given in brackets.

Coniopteris brevifolia.

Cladophlebis virginiensis.

Cladophlebis parva.

Klukia canadensis.

Sphenopteris (Ruffordia) göpperti.

Sphenopteris latiloba (Sphenopteris dentata).

Equisetites lyelli.

Sagenopteris williamsi.

Ginkgo pluripartita (*Ginkgoites arcticus*).

Ginkgo nana (*Gingoites sibirica*).

Phoenicopsis arctica.

Ptilophyllum (*Anomozamites*) *montanense*.

Ptilophyllum arcticum.

Pseudocycas dunkeriana.

Nilssonia canadensis.

Elatides curvifolia.

Pityophyllum cf. *nordenskiöldi*.

Podozamites lanceolatus.

These 18 species result in a 50.0% correlation with the Hazelton flora. The synonymies for those names in the above list that differ from names in the Hazelton flora, have been pointed out in the previous section and elsewhere in this paper, and need not be repeated here.

The most noteworthy feature of the Blairmore "lower flora" is the presence of one dicotyledon, *Sapindopsis angusta* (Bell, 1956, p. 11). This species also occurs in the Blairmore "upper flora" which will be compared with the Hazelton flora in the next section.

Upper Flora: The "upper flora" of the Blairmore group contains a total of 35 plant species (Bell, 1956, fig. 1) of which 18 are specifically identified.

The following species also occur in the Hazelton flora:

Cladophlebis virginiensis.

Equisetites lyelli.

These two plants constitute a 10.0% correlation with the Hazelton flora.

The most significant feature of the Blairmore "upper flora" is the presence of 9 dicotyledons, whereas none is reported from the Hazelton flora.

PART III - INTERPRETATION OF RESULTS

The floras of the Riddle and Kennecott formations are the only floras, in the previous section, which have the floral datings substantiated by faunal datings.

In the case of the flora of the Kennecott Formation, at least three molluscan assemblages are present (Imlay et al, 1954) which can be correlated with certainty with beds of the Albian of the latest early Cretaceous in California, in the Queen Charlotte Islands, and in Europe.

In sharp contrast to the foregoing evidence of the age of the Kennecott formation, Knowlton (in Martin, 1926, p. 344-346) was quite definite that the age of the Kennecott Formation is either late Jurassic or earliest Cretaceous. However, the overwhelming faunal evidence together with the generally acknowledged fact that faunas take precedence over floras for dating, makes it apparent that Knowlton, although his identifications of the plants are undoubtedly correct, has dated the flora slightly too old.

The Jurassic flora of Douglas County, Oregon, has since 1905 (Fontaine, in Ward) been accepted as a Jurassic flora. However, the exact relationships of the plant-bearing beds to the overlying and underlying strata have been in doubt until recently. Recent work by R.W. Imlay et al (1959) has shown that the plants are contained in the Riddle Formation (redefined), and that this unit also contains fossils of late Jurassic (Portlandian-middle to late Tithonian) age. The Riddle Formation rests with angular unconformity on the older Jurassic Galice, Rogue, and Dothan formations. The Days Creek Formation rests concordantly on the Riddle Formation and locally overlaps onto older Jurassic rocks. The contact between the Riddle and overlying Days Creek Formation is considered to be a disconformity involving the Berriasian and part of the Valanginian stages.

Imlay (1959, p. 2780) in reference to the plants says:

> "The evidence based on mollusks shows that the paleobotanists were correct in their Jurassic age assignments of certain plants, but that the particular beds in Douglas County, Oregon, in which the plants occur are latest Jurassic rather than Middle Jurassic."

Knowlton (1910, p. 145) thought that the plants were as old as the Lower Oölite (Bajocian) of Europe.

The Corwin Formation of northwestern Alaska contains, in addition to the Jurassic flora of Cape Lisburne (Knowlton, 1914), a younger flora at inland exposures that has been dated from Early to Late Cretaceous by several authors (in Chapman and Sable, 1960, p. 125). Attempts to correlate the inland exposures with the coastal ones, on the basis of similar lithologies and structural continuity, do not appear to be entirely conclusive. In view of the discrepancy in the ages of the inland and coastal exposures, which are based entirely on fossil plants, the writer does not propose to discuss further the Cape Lisburne or inland floras.

At the present time, the location of the Jurassic-Cretaceous boundary in western Canada and in particular the age of the Kootenay and Blairmore formations are problems about which there is considerable controversy (Pocock, 1960, p. 9, 10; Gussow, 1960). Inspection of figure 3 and of the comparisons of the Hazelton flora with other floras made in the previous section, indicate that the Hazelton flora has its strongest correlations with the flora of the Riddle Formation, the Kootenay flora, and the lower Blairmore flora. Consequently any assignment of an age to the Hazelton flora depends to a considerable extent on the ages of these three floras, particularly the ages of the Kootenay and lower Blairmore floras. The ages of these last 2 floras are not established conclusively.

It is observed in figure 4 and a previous section of this thesis that the Hazelton flora has few similarities of importance with the Cape Lisburne, Kennecott, and Upper Blairmore floras. In so far as the Cape Lisburne and Kennecott floras are concerned this is undoubtedly due in part to the small number of plants that comprise these floras.

It is observed in figure 4 that only 2 species in the Hazelton flora occur also in the upper Blairmore flora resulting in a 10.0% correlation. This very low correlation, together with the presence of 9 dicotyledons in the upper Blairmore flora (whereas no dicotyledons occur in the Hazelton flora) makes it apparent that these two floras are definitely not correlative.

Eighteen species in the Hazelton flora also occur in the lower Blairmore flora, as pointed out earlier, resulting in a 50.0% correlation. Probably the most significant aspect of a flora to be considered when assigning an age, is the introduction of new species. Therefore, the presence of a dicotyledon, _Sapindopsis angusta_ in the lower Blairmore flora assumes prime importance. The presence of this dicotyledon in the lower Blairmore flora (and the complete absence of dicotyledons in the Hazelton flora), together with the absence of such characteristic Jurassic species as _Coniopteris hymenophylloides_, _Baiera_ cf. _furcata_, _Baiera_ cf. _gracilus_, etc., (which are present in the Hazelton flora) is considered sufficient evidence to preclude a close correlation of these two floras for purposes of assigning an age. However, the relatively high % correlation indicates a general syngenetic relationship of the 2 floras.

The flora of the Riddle Formation and the flora of the Potomac Group are the only two major Jurassic-Cretaceous floras in North America that are well dated; the Kennecott has been accurately dated but contains a relatively small flora. Although the Potomac flora is an "accepted" Lower Cretaceous flora, there is apparently some doubt as to the ages of the three floras comprising the overall Potomac flora, and hence of the three formations (Patuxent, Arundel, and Patapsco) comprising the Potomac Group. Some discussion on this problem is given by Bell (1956, p.12), who in discussing the age of the lower Blairmore flora and the presence of 15 lower Blairmore species in the Potomac flora says:

> "If the Patuxent and Arundel were deposited within the Neocomian-Barremian time unit as thought by Berry (1911, p. 172) an explanation for the occurrence of the Aptian lower Blairmore species, *Gleichenites nordenskiöldi*, *Elatocladus brevifolia* and *Elatocladus acifolia*, in the supposedly Neocomian Patuxent formation might be attributed to the distance between the occurrences. On the other hand, there is a possibility that the Patuxent and Arundel florules may be as young as Aptian. Dorf (1952, p. 2176) has recorded E.H. Colbert's summary of the age significance of Arundel dinosaurs as possibly pointing to 'a high stage in the Lower Cretaceous'."

Eight species in the Hazelton flora also occur in the flora of the Potomac Group, resulting in a 20.5% correlation, as has been pointed out in the previous section. This % correlation figure includes species and "cf" forms. If, however, only well defined species are considered, the Hazelton flora has a 22.8% correlation with the Potomac flora.

If the Potomac flora is divided into three sub floras with respect to the three formations (Patuxent, Arundel, and Patapsco) comprising the Potomac Group then the % correlation with any one sub flora becomes much less. Of the eight Hazelton species occurring in the Potomac Group four of them (Ruffordia göepperti, Onychiopsis brevifolia, Equisetum lyelli and Gleichenites nordenskiöldi) occur only in the Patuxent Formation of supposed Neocomian age. One species (Podozamites lanceolatus) occurs in both the Patuxent and Patapsco formations, and three species (Cladophlebis virginiensis, Cladophlebis parva, and Sphenopteris dentata) occur only in the Arundel Formation of presumed Neocomian age.

Considering species only then, the Hazelton flora has the following % correlations with the three sub floras of the Potomac Group:

Patapsco	8.7%
Arundel	8.5%
Patuxent	22.8%

These very low % correlations, together with the following data, serve to point out that a close correlation of these floras with the Hazelton flora is not possible with any confidence:

(a) The absence in the Potomac flora of the Jurassic element present in the Hazelton flora, i.e., Coniopteris hymenophylloides, Czeckanowskia cf. rigida, species of Baiera, etc.);

(b) The presence of 6 (out of 111) angiosperm species in the Patuxent flora, 5 (out of 37) in the Arundel flora, and 25 (out of 91) in the Patapsco flora, whereas the Hazelton flora is characterized by the complete absence of angiosperms.

The flora of the Riddle Formation in Douglas County, Oregon, contains 9 species that occur also in the Hazelton flora. These 9 species result in a 25.6% correlation between the two floras. If species and "cf" forms are considered in the comparison, however, the % correlation is increased sharply to 46.1%.

This strong statistical correlation with a well-dated flora of late Jurassic age, together with the complete absence of dicotyledons in these floras and the presence in the Hazelton flora of such characteristic Jurassic species as Coniopteris hymenophylloides, Nilssonia pterophylloides, Pterophyllum tennuipinnatus, Baiera cf. furcata, Baiera cf. gracilus, Nilssonia parvula and Czeckanowskia cf. rigida point strongly to the acceptance of a late Jurassic age, in part at least, for the Hazelton flora.

In comparing floras the words of A.C. Seward (1900, p. 302) are worthy of note:

> "In the comparison of floras more or less widely separated geographically, the recognition of specific identity is naturally desirable, but the object of a comparative study of fossil floras is primarily to determine the resemblances and differences as regards the general facies of the vegetation rather than the absolute specific identity of individual plants."

Fourteen species of plants are common to both the Hazelton and Kootenay floras resulting in a 66.6% correlation. If "cf" forms are included, then the % correlation is increased to 73.0%. The list of species common to both floras has been given in the previous section and will not be repeated here.

The age of the Kootenay flora is to some extent dependent on the ages of the lower Blairmore and upper Blairmore floras, the ages of which depend to a considerable extent on the age of the Potomac floras. Hence it is observed that the ages of the 3 Potomac floras, though apparently not established conclusively, have considerable significance in the present discussion.

The following six species in the Kootenay flora occur also in the Potomac flora (Bell, 1956, p.7):

Cladophlebis virginiensis.
Sphenopteris latiloba.
Onychiopsis psilotoides.
Coniopteris brevifolia.
Equisetites lyelli.
Podozamites lanceolatus.

It is observed that all the foregoing species occur also in the Hazelton flora. These 6 species give the Kootenay flora a 28.5% correlation with the Potomac flora. As pointed out earlier, the Hazelton flora has 8 species common to the Potomac flora for a 22.8% correlation. If however, "cf" forms are included for a % correlation figure, the % correlation is reduced to 23.5% for the Kootenay and 20.5% for the Hazelton flora.

The following 8 species of the Kootenay flora occur also in the flora of the Riddle Formation. Where an Oregon species differs in name from the Kootenay equivalent, the Kootenay species is given in brackets.

<u>Nilssonia parvula</u> (<u>Nilssonia nigracollensis</u>).

<u>Taeniopteris orovillensis</u> (<u>Nilssonia canadensis</u>).

<u>Cladophlebis vaccensis</u> (<u>Cladophlebis virginiensis</u> pars.).

<u>Ginkgo digitata</u> (<u>Ginkgoites arcticus</u>).

<u>Ginkgo sibirica</u> (<u>Ginkgo nana</u>, <u>Ginkgo</u> cf. <u>lepida</u>).

<u>Pterophyllum contiguum</u> (<u>Ptilophyllum arcticum</u>).

<u>Podozamites lanceolatus</u>.

<u>Pityophyllum</u> cf. <u>nordenskiöldi</u>.

These 8 species result in a 32.5% correlation of the Kootenay with the Oregon flora (46.1% for the Hazelton flora). If, however, species only are considered, then the % correlation of the Kootenay with the Oregon flora is reduced to 14.3% (25.7% for the Hazelton flora).

Bell (1956, p.7) cites 6 species in the Kootenay flora which are characteristic Jurassic species. At the bottom of the same page Bell states:

> "The occurrence of such characteristic Wealden species as <u>Sphenopteris cordai</u>, <u>Onychiopsis psilotoides</u> and <u>Nilssonia schaumburgensis</u> is considered to be sufficient evidence to date the Kootenay flora as early Cretaceous and falling within the time unit for Infravalanginian to Barremian inclusive."

The writer most certainly agrees that these are characteristic Wealden species. Using this same method of reasoning, however, one could argue just as strongly for an Upper Jurassic age for the Kootenay flora based on the Jurassic element in this flora, e.g., _Czeckanowskia_ cf. _rigida_, _Baiera_ cf. _Furcata_, _Nilssonia_ _parvula_, _Podozamites_ _lanceolatus_ and some forms of _Cladophlebis_ _virginiensis_ pars (=_C_._denticulata_). Presumably, the hypothesis behind the argument presented by Bell is that new species are characteristically superimposed on species carrying over from older floras. If this is so, then it indeed enhances an argument for a lowermost Cretacous age.

CONCLUSIONS

A lower limit for the age of the "upper sedimentary unit," in the Smithers area at least, has been established by F.H.McLearn (1926, p. 89) who identified a fauna from the underlying sedimentary unit as being of Late Sonninian to Early Steppheoceratan or Middle Bajocian age. As a result, the Hazelton flora may be as old as Oxfordian or Callovian.

At this point it is pertinent to comment on the apparent conflicts between fossil faunas and plants in both the Hazelton and Smithers map area.

Armstrong (1953) in the descriptive notes on the Hazelton map states:

> "Fossil fauna were collected from at least twenty localities, but only two of the collections contained diagnostic specimens. These are of late Upper Jurassic age. They were collected from beds that apparently lie stratigraphically above beds containing fossil plants of Kootenay age."

Dr. Armstrong (personal communication) stated that the identification of this fauna was done by F.H.McLearn. It would appear then that in this instance the plants were dated too young, since there is no evidence to indicate that the strata in question are overturned.

In the descriptive notes on the Smithers map-area, Armstrong (1944) states:

> "In Glacier Gulch, however, fossil shells of Upper Jurassic or very early Lower Cretaceous age were collected from a bed 300 feet stratigraphically above a bed containing fossil plants of Blairmore age."

This fauna was identified by F.H.McLearn (J. E. Armstrong, personal communication). Since some controversey (see Bell, 1956, p.24) prevails about the stratigraphy in this area, the writer does not propose to discuss the problem any further.

In an attempt to determine how many Hazelton species occur in Jurassic areas and how many in Lower Cretaceous (Wealden) areas the following table was compiled. The Hazelton flora was compared with the Potomac, Oregon Jurassic, Kennecott, Yorkshire Jurassic, and English Wealden floras. To supplement data from these comparisons, use was made of Seward's 4 volumes on fossil plants.

TABLE III

Hazelton Species	Jurassic	Lower Cretaceous (Wealden)
Equisetites lyelli		X
Cladophlebis heterophylla		X
C. impressa		
C. parva		X
C. virginiensis	X	X
Coniopteris brevifolia		X
C. hymenophylloides	X	
Dictyophyllum fuchsiforme		
Gleichenites nordenskiöldi		X
Klukia canadensis		
Sphenopteris acrodentata		
S. dentata		X
S. (Ruffordia) göpperti	X	X
Sagenopteris williamsi	X	
Ctenopteris insignis		
Nilssonia brongniarti		
N. canadensis	X	
N. parvula	X	X
N. pterophylloides	X	
N. schaumburgensis		X
Pseudoctenis hazeltonensis		
Pseudocycas dunkeriana		
Pterophyllum tennuipinnatus	X	
P. rectangulare		

Hazelton Species	Jurassic	Lower Cretaceous (Wealden)
Ptilophyllum arcticum	X	
P. columbianum	X	
P. Hirtum		
P. (*Anomazamites*) *montanense*		
Baiera sp. cf. *furcata*	X	
Baiera sp. cf. *gracilus*	X	
Ginkgoites arcticus	X	
G. sibirica	X	X
Athrotaxites berryi		
Elatides curvifolia	X	X
Elatides splendida		
Pityophyllum cf. *nordenskiöldi*	X	X
Czekanowskia sp. cf. *rigida*	X	
Phoenicopsis arctica		
Podozamites lanceolatus	X	X

From the foregoing table it is observed that 18 species occur in Jurassic areas and 14 occur in Lower Cretaceous areas. Seven species occur in both Jurassic and Lower Cretaceous areas. This data is sufficient to indicate that the Hazelton flora is undoubtedly a transitional flora between the Jurassic and Cretaceous.

It is considered that the Hazelton flora, and the "upper sedimentary unit" in which it is contained, can be dated with confidence as late Jurassic to early Cretaceous, that is, Portlandian to Neocomian inclusive because of the following:

(1) A strong statistical correlation (46.1%) with the flora of the Riddle Formation in Douglas County, Oregon.

(2) The presence of an undoubted Jurassic element in the Hazelton flora.

(3) The presence of 6 angiosperms out of 111 species in the Patuxent Formation (Neocomian), whereas none occurs in the Hazelton flora. This would suggest an age assignment of younger than Purbeckian (Uppermost Jurrasic) cannot be made for the Hazelton flora. However, according to Axelrod (1959) angiosperms initially invaded lowland basins at generally lower latitudes, and appeared in the record at higher latitudes only in the later part of the Early Cretaceous. If this is indeed the case, then the Hazelton flora may be Neocomian when compared to the lower Blairmore (Aptian) flora with its one dicotyledon.

(4) The wide ranging nature of some of the fossil plants under consideration suggests the possibility of the assignment of an Early Cretaceous age to the Hazelton flora, e.g., Ginkgoites sibirica, Elatides curvifolia, Pityophyllum nordenskiöldi, Nilssonia parvula, Podozamites lanceolatus.

(5) The presence of shells of Upper Jurassic age in the Hazelton area at two localities.

(6) The presence in the Hazelton flora of characteristic Lower Cretaceous species such as Nilssonia schaumburgensis, (Ruffordia) göpperti, and Coniopteris brevifolia.

It is considered probable that the Hazelton flora does not range through the entire Neocomian, but rather that it may be restricted to the lower half of the Neocomian epoch. Evidence for this consists of the following:

(1) Presence of a strong Jurassic element in the Hazelton flora;

(2) Absence of angiosperms in the Hazelton flora and the presence of them in the Patuxent and Arundel floras which apparently represent part of the Neocomian, and presumably the later part;

(3) Absence in the Patuxent and Arundel floras of many of the characteristic Jurassic species which are present in the Hazelton flora.

Future Work:

Suggestions for further work on the age of the "upper sedimentary unit" and the Hazelton Group in general, include the following:

(1) Additional collecting of fossil plants and faunas to aid in the study of the stratigraphy and also in assigning conclusive ages to the units comprising the Hazelton Group. In this regard the possibility of having Jurassic floras of more than one age should be considered. Another feature with regard to the plant fossils is the unlikelihood of cuticle work being of any use due to the metamorphism of the rocks and the contained leaves.

(2) Fossil plant collections should, if possible, be taken to Europe and the United States and compared directly with type specimens.

(3) Further collections of samples for plant microfossil analysis should be made, as discussed earlier.

(4) Consideration should be given to the possibility of using other methods for dating; eg. potassium-argon.

PLATE I

(Photographs are natural size;
scale divisions are in mm.)

Figure 12	Equisetites lyelli (Mantell) Unger.
Figure 9.W	Cladophlebis heterophylla Fontaine.
Figure 11	? Cladophlebis (Gleichenites) porsildi Seward.
Figure 10.W	Coniopteris (Sphenopteris) hymenophylloides (Brongniart) Seward.
Figure 5	Sphenopteris dentata (Velonovsky) Seward.
Figure 4	Nilssonia parvula (Heer) Fontaine.
Figure 7	Nilssonia pterophylloides Nathorst.
Figure 1	Pterophyllum tennuipinnatus n.sp. (type specimen B-3407).
Figure 2	Pterophyllum tennuipinnatus n.sp. (counterpart B-3399).
Figure 8	Ptilophyllum arcticum (Goppert) Seward.

PLATE II

(Photographs are natural size unless otherwise indicated, scale divisions are in mm.)

Figure 15 *Baiera* sp. cf. *furcata* (Lindley and Hutton) Braun.

Figure 3 *Ginkgoites arcticus* (Heer) Florin.

Figure 13 *Elatides curvifolia* (Dunker) Nathorst.

Figure 6 *Ginkgoites sibirica* Heer

Figure 16 *Baiera* sp. cf. *gracilus* (Bean) Bunberry.

Figure 17 *Czekanowskia* sp. cf. rigida Heer (X½)

Figure 14 *Coniopteris brevifolia* (Fontaine) Bell (X 4).

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PLATE I

PLATE 2