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MID-NINETEENTH CENTURY CRETACEOUS STUDIES IN THE CANADIAN INTERIOR PLAINS

W.O. Kupsch* and W.G.E. Caldwell*

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BACKGROUND TO THE BRITISH AND CANADIAN EXPEDITIONS

Mid-nineteenth century geological exploration of the Western Interior Plains of North America, and particularly of the widespread, underlying Cretaceous rocks, has had a profound influence on developing notions of the geological evolution of the region. Fielding Bradford Meek and Ferdinand Vandiveer Hayden, a famous team of geological observers, said as much more than a century ago when they reviewed the contributions made by their predecessors to knowledge of the Nebraska Territory and adjacent terrain: 'justice to former explorers requires that we should at least give a brief statement of the results of such expeditions as have contributed to the development of the geology of this region.'[1] When the scope and significance of the older contributions are considered, particularly those by Meek and Hayden themselves, their statement is even more valid today, not only in the interest of according a just measure of credit to previous investigators but also of providing the necessary information for a true understanding of the classification and correlation of the Cretaceous rocks of the Interior Plains.[2] An analysis of early work thus serves both history and science.

Meek and Hayden thought that the oldest record of Cretaceous rocks dated to the Lewis and Clark Expedition of 1804-06, when these noted explorers 'established the fact of the occurrence of Cretaceous rocks at the Great Bend of the Missouri below Fort Pierre,'[3] which leaves the impression that the occurrence of Cretaceous rocks in the Western Interior has been firmly established for about 175 years. Such an impression is misleading, however. As Waage[4] correctly pointed out, the publication in 1834 of Samuel George Morton's 'Synopsis of the organic remains of the Cretaceous Group of the United States,' is the first time the term *Cretaceous* was used in print in North America. Morton established the presence of rocks of that age beyond question in the Western Interior.

In the northern part of the Interior Plains, Sir John Richardson, a member of the first Franklin expedition to the Arctic Ocean, may have suspected the presence of Cretaceous rocks in what is now Saskatchewan when he travelled to Fort Carlton in the spring of 1820. At the top of the generalized geological section given in his *Geognostical Observations*[5]

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Richardson mentioned 'green sand,' and, being prone to identifying the rocks and minerals he encountered in terms of their known occurrences in his native land, may have considered this 'green sand' a likely correlative of one or other of the formations today designated the Lower or Upper Greensand in Britain.[6] He did not, however, use the term *Cretaceous* at that time.

As early as 1839, Joseph Nicolas Nicollet, an eminent geographer trained in France, collected Cretaceous fossils for the US Corps of Topographical Engineers from localities in what is now North Dakota, where he travelled as far north as Devil's Lake. He ascended the Missouri River to Fort Pierre and collected Cretaceous fossils at the Great Bend, these fossils subsequently being investigated and reported on by Morton in 1841. Further collections from the Great Bend were made in 1849 by John Evans. He was an assistant to David Dale Owen, who was then engaged in a geological survey of Wisconsin, Iowa and Minnesota, but whose party ranged well beyond the limits of these states as they are today.

James Hall, the autocratic New York State paleontologist destined to become a leading, if controversial, figure in American geology and palaeontology, likely became familiar with the work of Evans as soon as it was published, particularly that on the White River Mauvaises Terres or badlands in present-day South Dakota. Similarly, Hall probably knew of Joseph Leidy's description of fossil vertebrates from the same localities. Being himself concerned with the preparation of a map of the trans-Mississippi West, Hall employed Meek and Hayden as his assistants and sent them by way of St. Louis to the Western Interior to collect fossils. Although his excursion of 1853 was Meek's only one to the Upper Missouri country, it was the first of many for Hayden.[7] Among other accomplishments, Meek and Hayden obtained 'Cretaceous fossils from Sage Creek, as well as from Great Bend and other localities along the Missouri below Fort Pierre'[8] in what is now South Dakota and Nebraska. Evans too collected more Cretaceous fossils in that busy year of 1853.

When the railroad era came to the Interior Plains of North America, a systematic appraisal of resources had to be made.[9] Large-scale geological mapping began in 1853, when Isaac Stevens, Governor of Washington Territory, explored the country from Lake Superior to the Pacific Ocean between the 47th and 49th parallels. Across the 49th parallel, which by then had been designated as the boundary between the United States of America and British North America but had not been surveyed, Stevens made three side journeys -- to Roche Percée, to the Cypress Hills and to an area just north of Chief Mountain -- all three of which now lie within southern Saskatchewan and southern Alberta.

The Stevens Expedition was followed by other surveys in search of suitable routes for the Pacific Railroad. Some of these involved further field studies by Hayden and fossil determinations by Meek, which together with their other

investigations led to a stratigraphical classification of the Cretaceous rocks in the Nebraska Territory. That classification became a standard with publication in preliminary form by Meek and Hayden and by Hall and Meek in 1856;[10] it remained a standard for many years through amplifications and revisions by Meek and Hayden, which began in 1856[11] and continued through 1861. The exploratory expeditions into western British North America appear to have made greatest use of Hayden's (1857) revision.[12]

The importance of the stratigraphical classification of the Cretaceous System, both to Meek and Hayden and to their successors who sought to build upon and to refine it, cannot be overemphasized. Even the modest and unassuming Meek, the workshop and museum-based counterpart to the field-based Hayden in the fruitful ante-bellum partnership, was perspicacious enough to see this. In a letter to Hayden, written from Albany and dated 26 February 1856, Meek said:

> It should be understood that it is not merely the introduction to the scientific world of about one hundred species, we propose, but that *we possess the means, and the right, to give the classification and nomenclature to the formations of the great Cretaceous* & Tertiary Systems so grandly developed over an area of country more extensive than all that of Great Britain.[13] (Our italics)

Whereas it has been recognized that Meek became disillusioned with the voracious Hall, his tyrannical mentor for almost exactly five years (Meek ultimately "escaping" from Albany to the Smithsonian Institution, Washington, in 1858), it was long assumed by many that the initial superpositional sequence of Cretaceous rocks should be credited to Hall, and Meek.[14] Meek and Hayden[15] almost implied as much. Recently, however, Nelson and Fryxell[16] have shown that the Meek and Hayden classification, described by them, was available in pre-print form in 1856 between four and thirty-nine days prior to publication of essentially the same information by Hall and Meek.

Geological knowledge was also summarized on maps in the 1850s, the one by Henry Darwin Rogers (1855)[17] deserving of particular mention because it extended Cretaceous rocks from North Dakota into adjacent British North America and because it is known to have been a source of information to geologists exploring the northern part of the Western Interior.

North of the 49th parallel, response to the industrial challenge of railroad building lagged some years behind that in the United States. The response also took a different form in that two governments, the British and Canadian, sent scientific exploratory expeditions to the west between 1857 and 1860 and in that, compared to the American efforts, both were only modestly funded and staffed. The British undertaking was the well-known Palliser Expedition of 1857 to 1860, the Canadian the less well-known Red River Exploring Expedition

of 1857 and the Assiniboine and Saskatchewan Exploring Expedition of 1858.

Although the Geological Survey of Canada was founded in 1842, it was not until after Confederation in 1867 and the transfer of Rupert's Land from the Hudson's Bay Company to the new country of Canada in 1870 that the Survey's operations could be extended from Upper and Lower Canada (which in 1867 had become Ontario and Quebec) to the Western Interior. In the 1880s, some field work on the Cretaceous rocks of the Western Interior was begun under the auspices of the Geological Survey of Canada, although George Mercer Dawson, later to become Director of that Survey, published his comprehensive report for the British North American Boundary Commission in 1875 and already then dealt with the problem of separating the youngest Cretaceous from the oldest Tertiary rocks.[18]

THE BRITISH EXPEDITION

Late in 1856, the Royal Geographical Society received from John Palliser, who had been elected a Fellow only two weeks before, a plan for the exploration of a large part of North America.[19] The plan was considered by the Expedition Committee, under the chairmanship of Sir Roderick Impey Murchison, then President of the Royal Geographical Society and Director-General of the Geological Survey and of the Royal School of Mines. What had at first been conceived as an individual adventure, patterned on the buffalo and grizzly bear hunt in which Palliser had been engaged in September 1847 on the prairies of the Upper Missouri and the Yellowstone, became transformed into a scientific enterprise in the course of evaluation of Palliser's proposal by the Expedition Committee.

Irene Spry[20] has described and interpreted John Palliser's character and actions, and shows how these shaped his life. Palliser was the wealthy heir of a socially eminent family of Irish landowners, the family pillars of the Protestant church and leading conservationists. Although Palliser never obtained a degree, he attended Trinity College, Dublin, where his wide-ranging interests in the sciences, the arts and the letters were cultivated. He became a fine pianist and singer, and he developed his natural ability in modern languages, becoming fluent in French, German and Italian. The central preoccupations of his life, however, were travel and sport, particularly hunting.

In 1847-48 John Palliser travelled extensively through the central United States.[21] By steamer he ascended the Missouri River from St. Louis for 3200 km. On his way he passed Fort Vermillion, the Big Bend and Fort Pierre, all important outcrop localities of Cretaceous rocks. He wintered at Fort Union, the American Fur Trading Company's post at the confluence of the Yellowstone and Missouri Rivers. From his winter quarters he ranged as far as Turtle Mountain, on the boundary of present-day Manitoba and North Dakota. His account of this adventure made no reference to any scientific matters but contained much useful information on the then-abundant wildlife.

When John Palliser presented to the Royal Geographical Society his plan for an excursion into western British North America, the Expedition Committee endorsed the plan and extended the duration of the journey from one to two years.[22] The Secretary of State for the Colonies was requested to appropriate £5000 of public funds in support of the expedition. The question of when and why Palliser's preoccupation with big game hunting chanted into one with geographical exploration still requires a decisive answer. Some critics maintained that Palliser's first priority was still to lead a hunting party, but the substantial scientific record of his expedition belies this. He may have been persuaded to take a serious scientific line by another Irishman and a close friend, John Ball, who as an Under-Secretary of State in the Colonial Office exerted strong perssure on the government to fund the expedition. Ball, who had a substantial knowledge of botany and glaciology himself, worked out the details of the expedition. He dealt with not only the budget but also the scientific investigations to be undertaken and the personnel to be hired. Ball sought the advice of several leading scientists of the day, most, if not all, of whom were Fellows of the Royal Society.

Thus the Royal Society in addition to the Royal Geographical Society became involved and, when the expedition was over, the British Treasury with great reluctance took care of the £13,000 total cost. In United States currency of the time, this came to about $25,000. Originally the Royal Geographical Society had wanted to

> ... emulate the American Pacific Railroad Surveys of 1853-55. The appropriation for these surveys, which were carried out by the Corps of Topographical Engineers, was $150,000, divided into $40,000 for each of three of the exploring groups and $30,000 for the fourth, while a further sum of $500,000 was spent on assembling printing the twelve massive volumes of the *Pacific Railroad Reports*. One hundred and six scientifically-trained men, assisted by a small army of "chain-bearers," "rodmen" and part-time soldier-naturalists, took part in this mammoth reconnaissance south of the border.[23]

Palliser was accompanied by only four others who were trained to some extent in science, mathematics or engineering. This band was assisted by a few Indian or Métis guides, hunters and horse wranglers.

James Hector (1834-1907), only twenty-three years old in the first field season of the Palliser Expedition in 1857, served as surgeon and geologist to the British party. His education had culminated in an MD degree awarded by the University of Edinburgh in 1856. Like many a young medical student at Edinburgh in those years, Hector had taken a great interest in natural history; he had attended extra-curricular lectures in geology, mineralogy and paleontology by Professors Stevenson Macadam, Alexander Rose, David Page and possibly

Robert Jameson. As a result, Hector combined a thorough academic training in natural science with perhaps the most demanding and respected training in medicine available at the time. No less important in terms of accomplishing what lay before him, he was wise for his age, had a cheerful disposition based on a deep sense of humour and was naturally kind. As Spry puts it, 'he possessed steady good sense and a warm heart.'[24] Before leaving British shores, Hector received instructions from Murchison himself, who had called Hector's attention, among other material, to Rogers' map.[25] Most likely Murchison also appraised Hector of the findings of Meek and Hayden. By late 1856, Hayden had interested Joseph Henry, Secretary to the Smithsonian Institution, in the possibility of publishing a monograph of the fossils Meek and Hayden were describing. Earlier, Meek had studied important collections in Philadelphia and Washington and, in the course of establishing reliable correlations both within and beyond the continent, had consulted some leading figures in American geology.

At Hayden's urging, they sought a wider audience and wrote, through the Smithsonian, to most of the leading palaeontologists and stratigraphers of Europe, among them Roderick Murchison. Murchison may have been kept informed of their work, moreover, by notices of their publications in the *American Journal of Science* and the occasional republication with revision in European journals.[26]

Hector crossed the entire Canadian plains in the years 1857-59, ranging more widely than Henry Hind, the geologist with the largely contemporaneous Canadian expeditions. Hector thus was able to extend his classification of the Cretaceous System to embrace more of the rocks geographically and stratigraphically.

All of Hector's geological excursions were on horseback, a significant difference in mode of transport from the canoe Hind relied on for many of his explorations. No matter what the mode of conveyance used for geological fieldwork, however, then, as today, each had constraints on its use and offered its own special problems. Not least of Hector's problems was Palliser's particularly British attitude to animals. Palliser did not consider horses to be expendable, for example, which, while a humanitarian stand, was not one attuned to the practicalities of a prairie expedition in the middle of the nineteenth century.[27]

The printed record of the Palliser Expedition comprised a bewildering variety of publications, many of which were substantially repetitious. The official account of the expedition's findings was in four Parliamentary Papers,[28] compiled from letters and other materials forwarded from the field and from information supplied by members of the expedition upon their return.[29] But publication of these official documents was preceded by reports on the progress of the expedition in scientific periodicals, particularly the *Proceedings* and the *Journal of the Royal Geographical Society*, the organization that had been the original sponsor of the expedition. Of these preliminary reports, the one that bore

most strongly on Cretaceous studies in the Western Interior was a progress report by Palliser,[30] which contained Hector's *First General Report on the Geology of the Country examined by the Expedition during the Season of 1857*, datelined Fort Carlton, in what is now Saskatchewan, 14 December 1857. The most extensive summary of geological observations made during the entire Palliser Expedition, however, was presented by Hector to the prestigious Geological Society of London. Accompanied by a geological map, his presentation subsequently was printed in the *Quarterly Journal* of that society.[31]

THE CANADIAN EXPEDITIONS

In 1856, Henry Youle Hind (1823-1908) went on a railway survey through what is now northwestern Ontario with Sandford Fleming, the engineer who later was to be in charge of surveying the route for the Canadian Pacific Railway. This experience and subsequent writings on 'The Future of Western Canada,' 'Our Railway Policy,' and 'The Great North-West' made Hind known as one who urged Canadians to move west into territory many feared would become occupied by Americans. In Toronto at that time, there existed a small but influential group of Canadian expansionists led by the editor of *The Globe*, George Brown. Brown's group successfully lobbied the Legislative Assembly of Canada, then sitting in Toronto, to dispatch an exploring expedition to the interior west of Lake Superior. Subsequently, Hind was designated the expedition's 'geologist and naturalist.'[32]

This first Canadian expedition to the southern part of Rupert's Land -- the Red River Exploring Expedition -- was under the general direction of George Gladman, a former employee of the Hudson's Bay Company. He failed to provide the required leadership, however, and Hind, with characteristic ambition and forcefulness, essentially usurped Gladman's position and wrote the report covering the entire 1857 survey. Moreover, by his performance, Hind established himself, together with Simon James Dawson, as a leader of the second expedition -- the Assiniboine and Saskatchewan Exploring Expedition -- in 1858.

Besides Gladman, and Hind with his assistant, the 1857 expedition comprised two civil engineers who acted as surveyors: W.H. Napier, CE with an assistant, a rodman and two chainmen, and Simon J. Dawson, CE with two assistants and two chainmen. It was not a large party of professionals compared to the American surveys and was even smaller by one than the five-man scientific group the British government so reluctantly supported.

Hind was born in Nottingham, England, and educated there and in Germany and France before sailing to Canada when twenty-three years old. He never earned a university degree and did little, if any, formal work in geology or the other sciences in Europe. Nevertheless, in later life he described himself as 'by profession a geologist,' which was not a pretentious claim because through extensive reading and private study and through prolonged fieldwork he acquired a sound and

substantial theoretical and practical knowledge of geology which equalled or surpassed that of those geologists receiving their training in universities. In 1856, the largely self-taught Hind began to lecture in geology, in addition to chemistry, at the University of Trinity College, Toronto, where he was Professor of Science.[33] In recognition of his accomplishments, he was awarded an honorary MA degree by the university in 1853. He received an honorary DCL from King's College, Windsor, Nova Scotia, later in his life (1890). He was also elected a Fellow of the Royal Geographical Society.

A memorandum from Sir William Logan, Director of the Geological Survey of Canada, transmitted to Hind instructions for the survey he was to undertake in 1857. Like Hector, Hind probably was also aware of existing maps showing the geology of neighbouring regions. As his writings show, he certainly was thoroughly familiar with the studies Meek and Hayden had made of the Cretaceous rocks in the Nebraska Territory. He may have believed, indeed, that their work deserved wider distribution because he reprinted substantial parts of it in his own report, but more likely Hind found such reprinting a convenient means of embellishing his own account. The latter interpretation would be in line with the statement 'that Hind, if not a plagiarist, was reckless in his use of others' work,'[34] although in fairness it must be said that Hind did give proper acknowledgement to Meek and Hayden individually and as partners for the passages he took from their publications.

Hind never travelled farther west across the prairies than The Elbow of the South Saskatchewan River, and therefore he never saw the Cretaceous rocks of the Rocky Mountain Foothills as Hector did. But Hind examined the banks of the South Saskatchewan River, a short stretch of the North Saskatchewan River and most of the Saskatchewan River much more closely than his British counterpart. He saw sections of Cretaceous rocks underlying the widespread blanket of glacial drift because he travelled by canoe, that typically Canadian conveyance so suitable to the many rivers and lakes of the Precambrian Shield but used also on the few, large, entrenched waterways of the prairies. The canoe, however, had its drawbacks. To haul it on a Red River cart was cumbersome and, once in the water, there was no choice but to follow the river's linear course downstream. The freedom to roam was distinctly Hector's, although there was not much to see but glacial deposits, grasslands and herds of buffalo.

Although slightly less confusing than the published record of the Palliser Expedition, that of the Canadian expeditions of 1857 and 1858 was also substantial. It consisted of two official reports, printed by order of the Legislative Assembly in 1858 and 1859, and a well-illustrated, popular and successful narrative which combined the more important aspects of the two reports.[35] The 1857 journey went little beyond the Red River Settlement (present-day Winnipeg), and understandably, therefore, the report on it contained little information bearing on the occurrence of the Cretaceous System.

Hind's *Northwest Territory*, on the other hand, reporting on the journey of 1858, contained field observations on the Cretaceous rocks of the eastern plains, and, of equal or greater importance, a whole chapter by Meek on fossils from the Assiniboine and Saskatchewan country.[36] Simon Dawson's report,[37] which is appended to Hind's, included a letter from Elkanah Billings, palaeontologist of the Geological Survey of Canada,[38] dealing with Cretaceous fossils. In turn, that letter contained correspondence received by Billings from Meek and Hayden.[39]

The exploits of the Assiniboine and Saskatchewan Exploring Expedition also were recorded in part in photographs, an innovation for the time. Principally at the insistence of Hind, a photographer named Humphry Lloyd Hime was attached to the party.[40] Only forty-seven photographs are still extant. Most of these are of the Red River Settlement and surrounding country. A few show the Qu'Appelle River valley, but none reveal any Cretaceous outcrops. A number of Hime's photographs were lost at the conclusion of the expedition and before Hind published his report.

HECTOR'S CONTRIBUTION: FALTERING STEPS TOWARD LOCAL AND REGIONAL CLASSIFICATION

Hector studied Cretaceous strata in three widely-disparate areas: 1) Long River and vicinity in present-day southwestern Manitoba; 2) The Elbow of the South Saskatchewan River and the Cypress Hills in present-day southwestern Saskatchewan; and 3) the central and western part of present-day southern Alberta.

Hector provided a record of his geological observations in southwestern Manitoba. It is an important record because it includes the first name (Long River shale) given to a Cretaceous stratigraphical unit in the Western Interior of Canada.[41] The name, however, was applied by Hector only casually; it was not adopted by any subsequent investigators and now, effectively, has been abandoned.

From recent studies of the Manitoba escarpment and immediately adjoining plains, it is clear that Hector's Long River shales of the Assiniboine River and Pembina River valleys belong to the unit of beds later called the Odanah[42] series of the Fort Pierre Group by Joseph Burr Tyrrell in 1890. The Odanah claystones subsequently came to be regarded as a facies or member of the Riding Mountain Formation but most recently have been categorized as a member of a revived Pierre Shale Formation in the eastern plains.[43] The Odanah is unique within the Pierre Shale sequence, and the name is now used also in adjoining parts of the United States.

Tyrrell unquestionably was correct to identify the siliceous claystones as a distinct stratigraphical unit, even though in general he considered the Cretaceous rocks of Manitoba to fit 'very well into the groups that were first marked out by Messrs. Meek and Hayden'[44] in the Nebraska Territory. From

an historical perspective, it is unfortunate that he did not preserve Hector's original name.

Hector attempted one of the earliest, long-range, biostratigraphical correlations of the Cretaceous rocks of Manitoba when he referred dark-purple clays with *Baculites compressus* Say to his Group C, which in turn he correlated with Meek and Hayden's Formation No. 3 of the Nebraska section on the Missouri River.[45] The influence of Meek and Hayden's methods and writings on Hector was evident in the way he established his successions of lithologically distinct units. Hector gave these units letter designations, with A applied to the youngest and some subsequent letter to the oldest; a modern geologist would reverse the order in an exposed section. He equated the units believed to belong to the Cretaceous System to one or more of the five numbered formations in the Nebraska reference section and relied on ammonites, and in particular on *B. compressus*, for his long-range correlation.[46] Until quite recently, the name *B. compressus* was used for more than half-a-dozen successive species of slender, straight ammonites which occur in the upper Pierre Shale. It is likely that Hector recovered his specimen from the Odanah Member or from the shales occupying a limited interval below this member. It is surprising that Hector should use *B. compressus* to make a correlation with Formation no. 3 on the upper Missouri River, for by 1857 Meek and Hayden had established that *B. compressus* was a recurrent fossil in Formation no. 4 and implied that it might serve as a guide to that formation.

At the end of September 1857, Hector reached The Elbow of the South Saskatchewan River, carefully studied the exposed silty clays and listed many of their lithological characteristics -- colour, nature of the weathered surface, presence of selenite crystals, masses of fibrous calcite, and septaria -- which now identify these clays as the Snakebite Member of the Bearpaw Formation. Using the details recorded by Hector, and those provided by subsequent investigators on the lithological sequence within the Snakebite Member, it is apparent that Hector examined the beds between 15 and 45 m above the base.[47] Hector collected many of the fossils that the septaria and other concretions contain, including the ammonite *Baculites* and numerous bivalves, among them *Inoceramus*. These he took to England, where they were identified by a palaeontologist of the Geological Survey. The modern Institute of Geological Sciences (successor to the Geological Survey) unfortunately has no knowledge of the whereabouts of the collection today. However, Hector's description of the host beds was sufficiently detailed to conclude that the stratigraphically most useful of the fossils, the baculites, would have been referred in his day to *Baculites compressus* but today to *B. reesidei* Elias.

To Hector must go the credit for making the first correlation of what is now the Bearpaw Formation of Saskatchewan. He placed the clays exposed at The Elbow in Group C of his fivefold division of the Cretaceous System, and to this group he also ascribed beds cropping out on the flanks of the Cypress

Hills. Hector appreciated that the distinctive beds with numerous concretions, nodules of fibrous calcite with cone-in-cone structure, and partings of altered volcanic ash (bentonite) formed a lithozone that could be identified in both the South Saskatchewan River valley and the Cypress Hills. Furnival,[48] Lines[49] and Caldwell[50] later recorded the presence of this lithozone at many localities in addition to The Elbow. As he had done for outcrops in Manitoba, Hector also attempted longer-range correlation of the exposures in Saskatchewan with those described by Meek and Hayden from the Nebraska Territory.[51]

After having seen more Cretaceous rocks in what is now Alberta in 1858 and 1859, Hector prepared a geological map (Fig. 1) on which he recognized three divisions of the Cretaceous System in the prairies: *d*, upper; *e*, middle; *f*, lower with lignite; and, in addition, and older *g*, 'Disturbed Cretaceous Strata of the Rocky Mountains.'[52] In modern terminology,

FIGURE 1

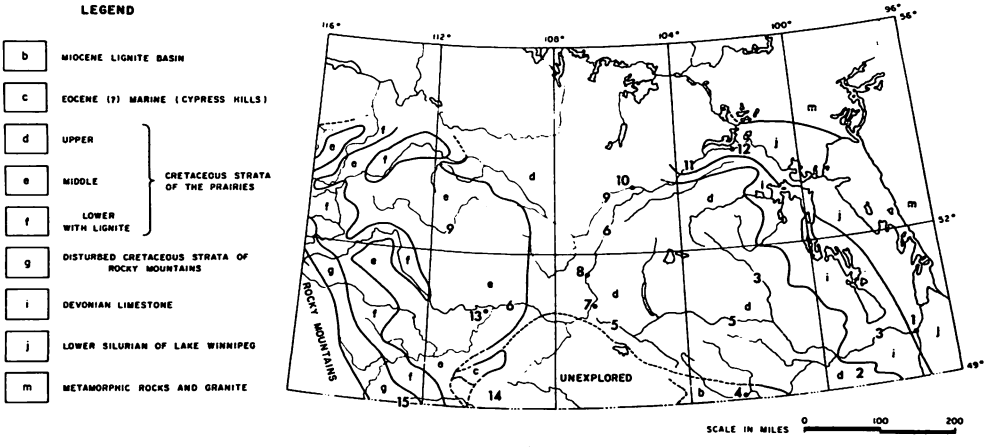

Figure 1: Hector's geological map of 1861, redrawn and modified. The numbers have been added to indicate geographical names mentioned in the text. 1 - Winnipeg (Red River Settlement). 2 - Long River, Little Souris, and Two Creeks. 3 - Assiniboine River. 4 - Roche Percée. 5 - Qu'Appelle River. 6 - South Saskatchewan River (South Branch). 7 - The Elbow. 8 - Outlook. 9 - North Saskatchewan River. 10 - Cole Rapids (Coal Falls). 11 - Saskatchewan River. 12 - Cumberland House. 13 - Cabri. 14 - Cypress Hills. 15 - Chief Mountain.

Hector's *d* probably would be equivalent to the Upper Cretaceous Bearpaw Formation but also include other Cretaceous rocks up to the Lea Park Formation; *e* to the Upper Cretaceous Judith River Formation (formerly the Belly River Formation); *f* to several Upper Cretaceous and Lower Tertiary formations; and *g* to the the folded and thrust-faulted Jurassic and Cretaceous rocks of the foothills. Hector's time-stratigraphical, systematic classification was thus highly idiosyncratic. In retrospect, it documents the dangers of founding such a classification largely on rock-stratigraphical correlation of a few, limited outcrops. This method of stratigraphical classification was not uncommon in his time, and Hector should not be criticized for following it for that reason. Nevertheless, the episode is instructional for historians of geology and modern scientists in the shortcomings of a procedure which is based solely on physical characteristics and ignores fossil content.

HIND'S CONTRIBUTION: A STRONGER BIOSTRATIGRAPHICAL EMPHASIS

Like Hector, Hind examined exposures of Cretaceous strata in three principal areas of the Interior Plains. One of these, including the Assiniboine River, Little Souris River and Two Creeks in present-day southwestern Manitoba, and another, including The Elbow and a segment of the South Saskatchewan River in present-day Saskatchewan, were much the same as areas visited by Hector. The third area, including 'Coal Falls' on the North Saskatchewan River, a few kilometres above the confluence with the South Saskatchewan River, was farther north than the Palliser Expedition travelled.

In discussing the observations of Hector and Hind at The Elbow, Caldwell[53] points out that Hector was more informative on the lithology of the exposed sediments, Hind more informative on the fossils contained within the sediments and their interbedded concretions. These same relative emphases are to be found in Hector's and Hind's descriptions of some other Cretaceous localities and of the Cretaceous System as a whole, giving the impression that Hind was the more palaeontologically aware of the two explorers. He may have been more familiar with the success Meek and Hayden were beginning to enjoy on the Upper Missouri by dint of diligent collection, description and stratigraphical deployment of their fossils. It is unlikely that he happened upon more richly fossiliferous strata, and equally unlikely that, in his instructions, he had greater stress placed on the importance of fossils by Logan (noted as a stratigrapher and structural geologist), than had Hector in his instructions by Murchison, an internationally renowned palaeontologist.

Hind's initiative led to many of the fossils collected on the Assiniboine and Saskatchewan Exploring Expedition being sent to Meek and Hayden at the Smithsonian Institution. Hind certainly valued Meek's identification of them:

> For the determination of the Cretaceous fossils, I am indebted to Mr. F.B. Meek, who ranks as

> the highest authority on this continent on fossils from the secondary (Mesozoic) rocks. I am happy to have this opportunity of expressing my thanks to Mr. Meek for his very valuable co-operation. The excellent paper contained in Chapter XIX, proceeding from such an authority, give(s) a value to that portion of the Report and Map which will be appreciated by (g)eologists.[54]

Hind then credited 'Mr. Billings, the distinguished palaeontologist of the Canadian Geological Survey' with determining some Palaeozoic specimens and lending 'his invaluable assistance in super-intending the preparation of the drawings and wood-cuts of the specimens figured at the close of this Report.' These illustrations include a number of Cretaceous fossils. Meek's 'excellent paper,' which Hind reproduced essentially *verbatim* in his *Narrative* of 1860, was an important palaeontological contribution. Most notably, it contained descriptions of some new molluscan species, one of which, a species of the bivalve *Leda* (now *Malletia*), Meek named

> in honour of Prof. Henry Y. Hind of Trinity College, Toronto, in (c)harge of the Assiniboine and Saskatchewan Exploring Expedition, to whose zeal and industry we are indebted for much interesting information respecting the geology and topography of the country explored.[55]

Another bivalve species, the well-known and widely-distributed *Anomia flemingi*, Meek named for 'Mr. John Fleming, one of the gentlemen connected with the Saskatchewan expedition,' and yet another he named *Inoceramus canadensis*. Meek thus showed considerable sensitivity to the Canadian origin of these fossils and to the Canadian collectors who had supplied them.

Hind's reliance on fossils (or relative lack thereof), particularly those composing assemblages characteristic of the main stratal divisions, may explain his long-range correlations being more reliable than Hector's. For example, on the basis of fish scales alone, he assigned shales occurring in the valley of the Assiniboine River to the equivalent of Formation No. 2 of the Nebraska section. If these shales came from the fish scale-bearing Ashville Formation recognized today, then the assignment and implied correlation were correct by modern standards. The problematical exposure at 'Coal Falls' provides another example. Hind realized that the outcrop was of doubtful value because the Cretaceous shales may not have been *in situ* but incorporated into the glacial drift so readily seen overlying them. Nevertheless, he recovered a limited faunal assemblage which he submitted to Meek and Hayden, and they found it to contain, 'fish scales, sharks' teeth and *Inoceramus*' (Table I). Such an assemblage suggested to Hind[56] that the Cretaceous shales at 'Coal Falls' could be assigned tentatively to the equivalent of either Formation No. 2 or Formation No. 3 of the Nebraska section. The locality on the North Saskatchewan River is known today as Cole

Rapids. It appears that Hind misspelled the name. Certainly there is no coal in the bedrock at Cole Rapids, nor would any be expected because the bedrock is formed by the marine Lower Colorado Group, with an overlying feather-edge of the marine Upper Colorado Group beneath a cover of Pleistocene strata.[57] Leaving aside the confusion surrounding the name, Hind was correct in his suggested correlation with the section in the upper Missouri River valley, because the modern Lower Colorado Group would correlate with most of Meek and Hayden's Formation No. 2, and the Upper Colorado Group with part of Formation No. 2 and most of Formation No. 3.

Hind's most important contribution to the Cretaceous stratigraphy of the Interior Plains, however, stemmed from his work in the South Saskatchewan River valley. His collections from The Elbow and other parts of the valley included some of the bivalves and cephalopods listed in Table 1. From this assemblage, and knowing that Hind proceeded downstream from The Elbow to beyond the present-day settlement of Outlook, it seems likely that he collected from clays of the Snakebite Member at The Elbow and from sandstones of the Ardkenneth Member exposed on the east bank of the river just over 2 km north of The Elbow. Hind also was more successful than Hector in placing The Elbow beds in a regional stratigraphical context. He recognized their kinship to those belonging to Formation No. 4 of the Cretaceous section established by Meek and Hayden in the Nebraska Territory, a formation now called the Pierre Shale and of which the Bearpaw Shale is a partial correlative. Hind clearly recognized the wide distribution of what is now the Bearpaw and stated that Formation No. 4 was the most important of the Cretaceous System in the northwest.

Exposures of what is today described as the Outlook Sand Member of the Bearpaw Formation in the South Saskatchewan River valley south of the modern Outlook road and rail bridges were first investigated by Hind.[58] Hind's detailed description and graphical illustration of the section, annotated and amended respectively to meet modern standards for the description of a type section, have been presented elsewhere.[59] His section is shown in Figure 2.

Nowhere in the tract of the valley in which the Outlook Sand crops out can such an extensive section as that described by Hind be found today. Hind's section, therefore, may have been composite, but it is based on the exposures in the west bank of the river at the Outlook road and rail bridges. The section must have been measured at extremely low water but, under comparable conditions today, the lowest two divisions of his sequence would not be visible. Vast quantities of sediment are being shifted by the constantly-changing current pattern of the river, and the sediment now present beneath the cliffed exposures at the road bridge may have accumulated in the more than one hundred years since Hind examined the same outcrops. Today, the base of the exposed section falls about the boundary between Hind's divisions *f* and *g*, and the section is between 9 and 12 m thick.

TABLE I

HIND'S FOSSIL COLLECTIONS AND STRATIGRAPHICAL CORRELATIONS*

FOSSIL	FORMATION	LOCALITY
Avicula linguaeformis [*Pholopteria linguaeformis* (Evans and Shumard)]		The Elbow
Avicula nebrascana [*Oxytoma nebrascana* (Evans and Shumard)]		The Elbow
Rostellaria americana [*Drepanochilus evansi* (Cossmann)]	5	S. Sask. R. Valley
Scaphites conradi [*Discoscaphites conradi* (Morton)]		S. Sask. R. Valley
Nautilus dekayi [*Eutrephoceras dekayi* (Morton)]		S. Sask. R. Valley
Anomia flemingi n.sp. (Meek)		Little Souris R.
Inoceramus canadensis n.sp. (Meek)		Little Souris R.
Leda hindi [*Malletia hindi* (Meek)]		Little Souris R.
Leda evansi [*Malletia evansi* (Meek and Hayden)]		The Elbow
Natica obliquata (Hall and Meek)	4	Two Creeks
Avellana concinna [*Oligoptycha concinna* (Hall and Meek)]		Two Creeks
Ammonites placenta [*Placenticeras* sp.]		S. Sask. R. Valley
Ammonites sp. indet.		Two Creeks
Scaphites nodosus (?) [*Scaphites (Hoploscaphites) nodosus* (Owen)]		S. Sask. R. Valley
Inoceramus		Coal Falls
Fish Scales	3	Coal Falls
Shark teeth		Coal Falls

*With the addition by Caldwell in square brackets of the modern names of the species and their authors.

FIGURE 2

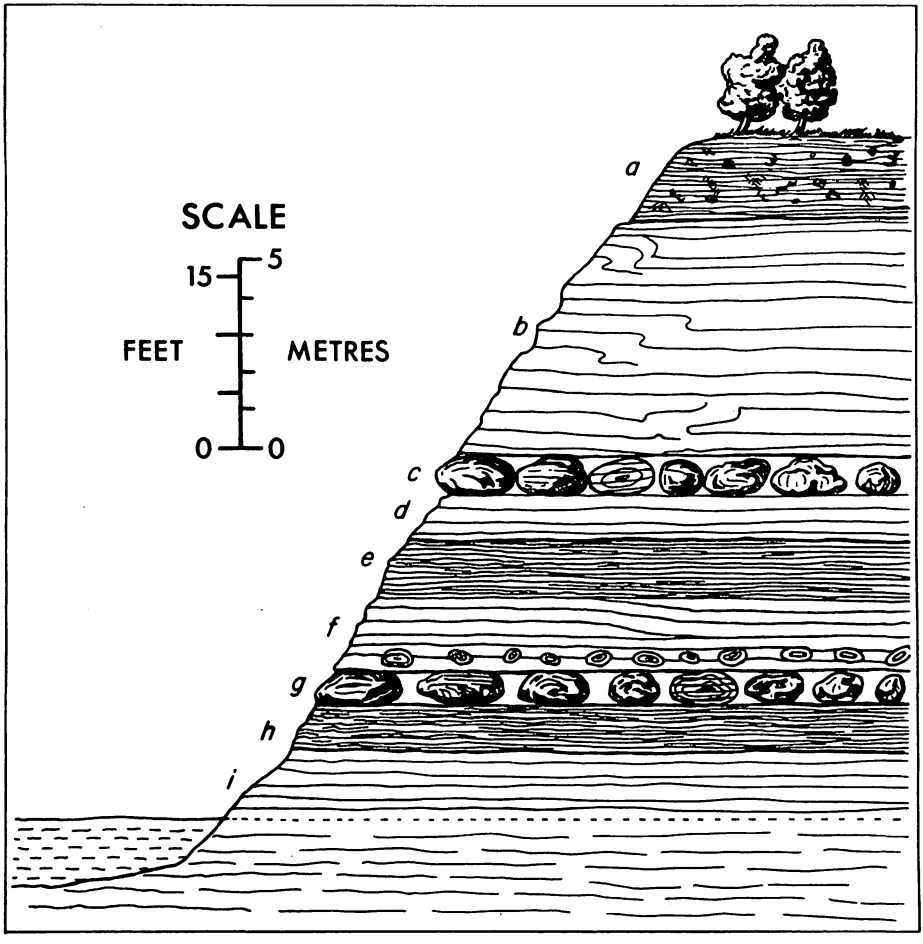

Figure 2: H. Y. Hind's section through the sand beds near Outlook, taken with slight emendation from Hind (1860, *Narrative*, v. 1, p. 381). For at least forty years these beds were referred to the Belly River Formation. They are now included in the Bearpaw Formation as the Outlook Sand Member.

Hind oversimplified the development of concretionary layers near the base of his division *f*. Apparently three layers are present: the lowest is composed of limy concretions packed with *Corbula sprouli* Warren; the intermediate layer is formed by sparse limy concretions with abundant *Oxytoma nebrascana*; and the upper is composed of similar concretions with a rich and impressively varied fauna in which bivalves are dominant.

These three kinds of concretions lie at about the level to which the river sediments now are banked and they occur loose on these sediments along the river bank.

Aside from these modifications, Hind's detailed account remains valid, and, as it applied to the exposures upstream from the Outlook road bridge, modern geologists accept it as a description of the type section of the Outlook Sand. By such action, they acknowledge a notable early contribution to Saskatchewan geology.

THE EVIDENCE OF THE DAWSON AND BARNSTON COLLECTIONS

Simon J. Dawson, who later was to settle in Port Arthur on Lake Superior and become the member of Parliament for Algoma, was a conscientious and industrious co-leader of the Canadian expeditions. His writings made clear, however, that he subordinated himself to the more forceful and self-assured Hind. Although Dawson made many sound observations about geology, he lacked Hind's knowledge and understanding of the subject. He made no pretension to being a geologist -- witness his introductory remarks to the 'Geological Formation of the Country' in his Report of 1859:

> No practical geologist having accompanied the party, I was careful to collect such specimens of fossils, shale, and coal as I conceived would best illustrate the geological formation of the region. These I submitted to Sir William Logan, and Mr. Billings...[60]

During the Canadian expedition of 1857, Dawson, Hind and W.E. Napier each led separate parties. Dawson sought information on the route from Lake Superior to the Red River, which meant that he was separated from Hind, the 'practical geologist,' a great deal of the time.[61] Be that as it may, Dawson contributed to the earliest biostratigraphical studies of the Cretaceous System in the southern Interior Plains. The fossils that he collected or otherwise obtained and sent to Ottawa aroused the profound interest of Elkanah Billings, the Geological Survey of Canada palaeontologist, who, in his letter to Dawson, wrote in part:

> Your collection furnishes us with almost indisputable evidence that a considerable portion of the territory belongs to the [C]retaceous [P]eriod [System], or the great chalk formation so largely developed in the Old World. This one fact, I believe to be now sufficiently established, is of the greatest value, as it affords a starting point, or foundation, upon which the materials collected by future explorers can be readily worked out.
>
> The specimens were quite sufficient to enable me to determine the general question of their geological age, but as it was advisable to have also the opinion of scientific men who have made the [C]retaceous rocks their special study, I forwarded some of the fossils to Messrs. Meek and Hayden,

> who are now at Washington engaged upon the collections of the [g]overnment explorations of the United States. These gentlemen are the highest authorities in America on all points relating to the secondary [Mesozoic] and [T]ertiary formations of the central portion of the continent. Their opinion is very cautiously given, but it is the more valuable on that account.[62]

Meek and Hayden's letter was included in the one Billings sent to Dawson. Regarding a certain molluscan fossil identified by Meek and Hayden, this 'letter within a letter' states that:

> One specimen identified by the American authorities [Meek and Hayden] was an [a]mmonite ... undoubtedly identical with a species very abundant in the [C]retaceous beds of Nebraska. It is the form usually referred to *A. placenta* of DeKay ... In Nebraska it occurs in formation No. 4, of the [C]retaceous series of that region.
>
> The only question in regard to your specimen is, whether it may not have been carried by the Blackfeed Indians from some of the Upper Missouri localities. This tribe you know ranges from the head waters of the Missouri far north-west into the Hudson's Bay Territories; and in common with other Indians they are in the habit of carrying with them shells or any other bright object that may attract their attention or excite their curiosity. The matrix of the specimen you have sent is exactly like that in which most of our Nebraska fossils are enveloped, in formation No. 4, as you will see by the specimen of *Inoceramus sagensis* we send you. The shell itself is also precisely in the same state of preservation. Still it is quite probable that rocks belonging to the [C]retaceous [S]ystem may occur in the region where the Indian says he obtained this specimen, which conclusion the other specimens from near Fort Garry seem to favor. If so, *Ammonites placenta* is one of the very species we would expect to find there, since it is known to have a great geographical range.[63]

Nowhere in the expedition records was it stated directly 'where the Indian [said] he obtained this specimen,' and although the above speculation by Meek and Hayden was intriguing, it shed no further light on where the ammonite was found. Billings' letter brought an answer somewhat closer with the statement that,

> The [a]mmonite procured from the Indian belongs to No. 4, and that this formation does exist in the north-west I have some additional evidence in several fossils placed in my hands by Geo. Barnston, Esq., of the Hudson's Bay Company, after I had

> forwarded yours to Meek & Hayden. These were procured from a man who said he found them in the bed of the Saskatchewan. One is undoubtedly *Scaphites Nicolletii* [*sic*] and another *Nautilus DeKayi*, both characteristic of formation No. 4.[64]

Meek implied that Dawson's specimen of *Ammonites placenta* came also from the valley of the Saskatchewan River in the chapter Meek wrote on the Cretaceous fossils collected by Hind on the Assiniboine and Saskatchewan Exploring Expedition. In his introductory remarks, he stated that, 'Amongst the specimens collected on the Saskatchewan are *Ammonites placenta**, *Nautilus Dekayi*, and apparently a variety of *Scaphites nodosus*.' As to the particular specimen of *A. placenta* being referred to, all ambiguity was removed by a footnote:

> When this specimen was first sent to Dr. Hayden and the writer, we were not aware of the fact that any other Cretaceous fossils had been found in that region, and suggested that it might possibly have been carried north by the Indians from some of the Upper Missouri localities. The other specimens, however, obtained from there, remove all doubts in regard to the existence of Cretaceous rocks on the Saskatchewan.[65]

In the taxonomic portion of the same chapter, Meek gave the geographical locality of the specimen of *A. placenta* as 'the South Branch of the Saskatchewan.' The Indian who found the specimen may have told Dawson he had obtained it from that locality, and Hind would not question this in the light of the Barnston specimens and his own exploration of the South Saskatchewan River valley which produced many other fossils indicative of the presence of an equivalent to Formation No.4.

The *Ammonites placenta* that Billings received from Dawson and referred to Meek and Hayden, and the *Nautilus Dekayi* and *Scaphites 'Nicoletii'* that Billings received from Barnston all came from beds that today would be grouped in the Bearpaw Formation. In the light of much more recent studies of the Bearpaw Formation one can be even more specific on the probable geographical locality and stratigraphical level of the Dawson and Barnston cephalopods. The old *Ammonites placenta* is now referred to the ammonite genus *Placenticeras*, of which two species are found commonly in the Bearpaw Formation as high as the Snakebite Member. *Nautilus Dekayi* is a nautiloid cephalopod now referred to as *Eutrephoceras dekayi* (Morton), which in recent times has been recorded only in the Snakebite Member of the Bearpaw Formation at two localities in the South Saskatchewan River valley. Warren[66] reported *E. dekayi* from the Bearpaw Formation at three other localities in Saskatchewan. The associated fauna suggests that two of these localities are in the Snakebite Member or equivalent beds. Landes[67] also reported *E. dekayi* from the Bearpaw Formation, his specimen coming from the Manyberries section on the flanks of the Cypress Hills in southeastern Alberta. Again the associated fauna leaves little doubt that the specimen came

from higher beds equivalent to the Snakebite Member in the South Saskatchewan River valley. Despite Billings' confident assertion, it would be surprising if the scaphitid ammonite submitted by Barnston should truly be referred to as *Scaphites nicolleti*, which species is mainly a fossil of the post-Bearpaw Fox Hill Formation in the northern United States. More probably, as Meek[68] suspected, the scaphitid was a specimen of the species *Scaphites (Hoploscaphites) nodosus* (Owen), which is common in the Snakebite Member. The the Dawson and Barnston cephalopods in all likelihood came from the Snakebite Member, low in the upper half of the Bearpaw Formation. If this is so, then they must have come from beds that form part of the valley of the South Saskatchewan River between about 80 km south and 30 km north of The Elbow.

The Dawson and Barnston collections provided, therefore, not only an important step in the recognition of the Cretaceous System in Saskatchewan, but also another indication of the importance of what is now the Bearpaw Formation (and in particular its richly fossiliferous Snakebite Member) in the South Saskatchewan River valley to that recognition and to the initial biostratigraphical correlations with Meek and Hayden's standard section on the upper Missouri River of the Nebraska Territory.

AN APPRAISAL

A comparison of early- and mid-nineteenth century studies of Cretaceous stratigraphy in the Western Interior of North America to the south and the north of the 49th parallel shows that such studies in British North America relied heavily on prior, and more detailed, studies conducted to the south, particularly on those by Meek and Hayden in the Nebraska Territory. Both Hector and Hind were followers rather than initiators. Such an evaluation does not reflect adversely on the scientific competence of Hector and Hind but recognizes some geological and historical factors that influenced the work of these men. Among them were the chronology of events leading to the railroad surveys, the manner in which their own studies were conducted, and the accessibility of key exposures of Cretaceous rocks.

Although Alexander Mackenzie was the first to cross North America to reach the Pacific Ocean on 22 July 1793, scientific exploring expeditions of the continent's interior began with the Lewis and Clark Expedition of 1804-06 in the central part of the Interior Plains. It was south of the 49th parallel too that the railroad surveys began. The drive toward opening the west and connecting the Atlantic and Pacific Oceans came earlier in the more populated and prosperous United States than in the Canadas. For the same reasons, the support given to western exploration was greater in the United States where, moreover, it involved military personnel and motives. Both the British and the Canadian expeditions, in contrast, comprised only civilians.

The extensive cover of glacial drift in the northern part of the Interior Plains does not make for easy observation of

bedrock stratigraphical sequences. Nevertheless, both Hector and Hind must be lauded for careful evaluation of Cretaceous sections whenever and wherever possible, for recognizing the potential of the outcrop belt in the valley of the South Saskatchewan River, and for attempting the earliest long-range regional correlations of the Cretaceous System in what is now the prairie provinces.

Not only were there notable differences between the surveys north and south of the 49th parallel, the differences between the Palliser Expedition and the Assiniboine and Saskatchewan Exploring Expedition are also worth examining. It should be recalled that two parallel expeditions were fielded, one sponsored by the mother country in grudging admission of an obligation to explore a colonial hinterland, the other sponsored by the colony itself, just then on its way of becoming a nation, in a defiant move to counter events south of the international border.

Although both Hector and Hind were immigrants, their attitudes toward their new country, its society and their chosen science showed some striking dissimilarities. Young, gentle Hector, fresh from a professional university training and with a thorough grounding in natural science, contrasted sharply with the older, brash Hind, the self-made man whose principal aim in life appeared to have been to prove himself to his fellows. To Hector the exploration of what is now western Canada was a phase in a geological career that would reach its height when he became the Director of the Geological Survey of New Zealand, the country in which he finally settled. Hind, on the other hand, stayed in Canada and became a nationalist more fervent than most.

For Hector it was the Geological Survey of Britain and its Director, Sir Roderick Murchison, who provided a large measure of the scientific support he required; for Hind, that support was provided by the Geological Survey of Canada and its Director, Sir William Logan. But for both Hector and Hind it was the work done in more southerly parts of the Western Interior by Meek and Hayden that became indispensable. Thus Canada owes the United States a debt that needs to be acknowledged.

NOTES

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