NOTES ON CANADIAN STRATIGRAPHY AND PALEONTOLOGY. I

Cordilleran Province

IN 1911 and 1912 Dr. R. A. Daly carried on geological studies along the line of the Canadian Pacific railway between Golden and Kamloops, British Columbia, a distance of 224 miles. A preliminary statement of results was published in Guide Book No. 8 of the International Geological Congress and the complete report has recently become available.[1] The transverse section of the eastern half of the Canadian Cordillera thus made known roughly parallels the International Boundary section and is about 120 miles north of it.

Three major geological provinces are recognized. The first of these is that underlain in the main by the Shuswap terrane and includes a portion of the Selkirks and the northern half of the Columbia mountains. The Shuswap rocks are of "Early Pre-Cambrian" age and consist of metamorphosed sediments and volcanics, aggregating over 28,000 feet in thickness, intruded by innumerable sills and laccoliths of granite as well as by batholithic masses of the same plutonic rock. The whole is essentially a very large mass of ideal crystalline schists, the result of static metamorphism. The author very properly makes a distinction between recrystallization which results from deep burial and that accompanying orogenic movement. The former he terms static or load metamorphism, restricting the term dynamic metamorphism to the latter phase. In the alteration of the Shuswap terrane both contact and dynamic metamorphism have played minor parts.

Unconformably overlying the Shuswap schists on the east is an enormous mass of bedded rocks belonging to the Beltian and Cambrian systems. These make up the greater part of the Purcell and higher Selkirk mountains. The Belt series consists of quartzites, limestones, and metargillites attaining a thickness of 32,750 feet and is overlain by 7,750 feet of quartzite referred to the lower Cambrian. No evidence of unconformity between the Beltian and Lower Cambrian was observed. The clastic sediments of these series were derived in the main from the erosion of the Shuswap terrane. The absence of ripple marks and mud cracks leads to the conclusion that most of the Beltian-Cambrian sediments in the region traversed are off-shore deposits. No horizons of playa or flood-plain sediments were identified. Much of the finer quartz silts are believed to have originated as wind-borne dust, blown out to sea. The limestones are interpreted as chemical precipitates resulting from the bacterial decay of animal matter. Extrusive lavas are in some places interbedded with the sediments. The entire series has been moderately metamorphosed and its structure is that of a great synclinorium nearly forty miles broad. East of the Purcell range the Columbia River valley is believed to be underlain by Upper Cambrian and Ordovician beds which have been faulted into contact with the Beltian formations.

West of the Shuswap terrane, Beltian and early Paleozoic rocks are absent, and the upper Paleozoic and younger formations are believed to rest on the pre-Cambrian complex. This constitutes the province of the Interior Plateaus. Its geology is allied to that of the Coast and Vancouver ranges as it is in the western geosynclinal belt of the Cordillera, which forms a strong contrast to the eastern belt. Until the close of Mississippian time the western belt was in the main a land surface, while in the eastern belt sedimentation was in progress. Structural complexity here is of a high order. At the base is the Cache Creek series, 13,700 feet of limestone and clastic sediments, of probably Pennsylvanian age. Unconformably overlying this series are the conglomerates, breccias, sandstones, and massive lavas of the Nicola series. This has an estimated thickness of 5,300 feet and is referred to the Triassic and Jurassic periods. The youngest bed-rock formation in the area is a thick mass of Tertiary volcanics with interbedded sediments, which is believed to be of Oligocene age.

[1] "A Geological Reconnaissance between Golden and Kamloops, B. C., along the Canadian Pacific Railway," R. A. Daly, Geological Survey, Canada, Memoir 68, 1915.

Another important contribution to Cordilleran stratigraphy is that of Dr. S. J. Schofield.[2] Intensive studies of a large portion of the Purcell range south of the Canadian Pacific railway have been carried on for a period of five years. The area mapped includes about 2,500 square miles immediately north of the International Boundary, but the problems encountered involved reconnaissance work extending over much greater areas. The region includes a part of the section traversed by Dr. Daly in 1901 to 1906 and discussed by him in his report upon the geology of the Forty-ninth Parallel.[3] The detailed examinations of the more recent survey make necessary a number of changes in the somewhat tentative correlations and structure determinations of the earlier reconnaissance work.

The bed-rock of the Cranbrook area may be referred to two systems. By far the greater part belongs to the Belt terrane which is unconformably overlain by remnants of Devono-Carboniferous limestones. Neither the base nor the summit of the Beltian system, as determined in the Rocky Mountains, is exposed in the Purcell range. The Purcell series is composed of 22,500 feet of sediments, largely clastic, which by their numerous horizons of mud cracks, ripple marks, casts of salt crystals, and red beds suggest a continental rather than marine origin for most of the strata. Near the top of the series are recurrent basaltic flows whose extrusion was accompanied by the intrusion of gabbro sills. Probably the most significant departure from Dr. Daly's conclusions is that relative to the age of the uppermost of the Purcell formations. In the Forty-ninth Parallel report nearly 11,000 feet of strata were regarded as of Lower and Middle Cambrian age. The later survey has resulted in determining that the entire series is of pre-Cambrian age and that the uppermost beds were deposited some time before the close of Proterozoic times.

Throughout the entire Paleozoic and Mesozoic eras, with the exception of the interval during which marine limestones of Devonian and Mississippian age were deposited, the region seems to have been subject to erosion. Orogenic movements, possibly at the close of the Jurassic period, formed a great series of anticlines and synclines and were followed or accompanied by intrusions of granite bosses and batholiths. Subsequently erosion reduced the area to an old-age topography, which was later uplifted and is now represented by the summit levels of the mountain range. Here, again, Dr. Schofield differs from Dr. Daly, who attempted to explain the present topography in terms of one-cycle erosion. From the excellent illustrations accompanying the report, as well as from the facts cited, the reviewer would agree with the author of the recent memoir. However, the reference of the peneplain to the Cretaceous period does not seem to be justified by the meager data available. The present topography may well have been developed by the dissection of the graded surface since late Tertiary times. A study of the relations of the summit peneplains of the adjacent ranges to the mid-Tertiary lavas of the Interior Plateaus should yield evidence enabling the determination of the dates of rejuvenation.

Quaternary deposits include fossiliferous sands and gravels overlain by glacial drift. The former are presumably of interglacial age and indicate a climate as warm as that of the southern United States at the present time. These are found in the Rocky Mountain Trench, a topographic feature extending from the International Boundary northward into Alaska, which is believed to be the result of erosion controlled by fault planes.

Paleozoic Strata of Central Canada

The "Hudson Bay Exploring Expedition" of 1912, under the leadership of J. B. Tyrrell, secured collections of fossils from the little-known region which forms the southern shore of Hudson bay. The collections include a large number of fossils from the Silurian outcrops along the Severn and Fawn rivers as well as certain Ordovician species from the region southeast of Port Nelson in northern Manitoba. These have been described recently by

[2] "Geology of Cranbrook Map-Area, British Columbia," S. J. Schofield, Geological Survey, Canada, Memoir 76, 1915.

[3] Geological Survey, Canada, Memoir 38, 1913.

Dr. W. A. Parks,[4] who recognizes among them 132 distinct forms. Of these 48 are ascribed to known species and 31 are new to science. Gastropods and cephalopods, some of which are of unusually robust proportions, predominate. The general aspect of the Silurian fauna indicates a horizon comparable with the Guelph, while the Ordovician species suggest the fauna of the Trenton.

The upper portion of the Lockport member of the Niagara formation in Ontario is a thin-bedded bituminous dolomite with intercalations of shale. These beds ordinarily attain a thickness of thirty to forty feet, and Dr. M. Y. Williams, who has recently discovered in them an eurypterid horizon,[5] proposes for them the name "Eramosa beds." The eurypterid, a new species of *Eusarcus,* was found near Guelph, Ontario, associated with several brachiopods, a bryozoan, and two species of *Conularia.* The fauna presents a typically Lockport facies, but contains recurrent Rochester forms as well as a single prenuncial Guelph form. The association of the eurypterid with a purely marine fauna is suggestive of a marine habitat for the former, but, contrary to the author's statement, does not necessarily prove such an environment. Such an association might result if non-marine arachnids were washed down a river to the salt waters at its debouchure. Apparently all the specimens of *Eusarcus* are in this instance fragmentary.

For a number of years the Devonian formations and faunas of the western peninsula of Ontario, between Lakes Huron and Erie, have been under investigation by Dr. C. R. Stauffer, whose final report has become available.[6] The formations studied may be arranged in tabular form as follows:

Devonian	Upper	Portage-Chemung?	Port Lambton beds.
		Genesee?	Huron shale.
	Middle	Hamilton	Ipperwash limestone.
			Petrolia shale.
			Widder beds.
			Olentangy shale.
		Marcellus	Delaware limestone.
		Onandaga	Onandaga limestone.
			Springvale sandstone (local facies).
	Lower	Oriskany	Oriskany sandstone.
		Helderberg	wanting, or possibly represented, in part, by the Detroit River series.

The Detroit River series is an eastern extension of the Upper Monroe of Michigan and little light is thrown upon the problem of its correlation. Its fauna in Ontario indicates the same curious mingling of late Silurian and mid Devonian elements which characterizes its occurrence in southern Michigan.[7] Dr. Stauffer apparently favors the reference of the group to the Upper Silurian, but closes his discussion with the statement that it is the "official practise of the Canadian Geological Survey" to treat these beds as part of the Devonian system.

The Oriskany sandstone is separated from subjacent and superjacent beds by unconformities and is believed to be identical in age with the formation of the same name in New York state. Its fauna is distinctly a southern and eastern one, and there is no evidence in

[4] "Palaeozoic Fossils from a Region Southwest of Hudson Bay," W. A. Parks, *Trans. Roy. Can. Inst.*, Toronto, Vol. XI., 1915, pp. 1–96.

[5] "An Eurypterid Horizon in the Niagara Formation of Ontario," M. Y. Williams, Geological Survey, Canada, Museum Bulletin No. 20, 1915.

[6] "The Devonian of Southwestern Ontario," C. R. Stauffer, Geological Survey, Canada, Memoir 34, 1915.

[7] Grabau, A. W., and Sherzer, W. H., Mich. Geol. and Biol. Surv., Pub. 2, Geol. Ser. 1, 1910, pp. 217–221.

support of the supposed mingling of Oriskany and Onandaga faunas at this place. That conception seems to have resulted from the failure to discriminate the lithologically similar Springvale sandstone which is in reality a local facies of the Onandaga.

The Onandaga fauna is composed of three important elements. Many forms lingered over from the Oriskany of this general region. Others seem to be related to the inhabitants of the Lower Devonian embayment of southern Illinois. The most distinctive element is that including the corals; it bears such marked relationship to contemporaneous European faunas as to indicate a shallow-water connection with that continent. The line of migration was probably, as suggested by Weller some years ago, via the Arctic regions and James Bay.

The Delaware limestone of Ontario is essentially the western equivalent of the Marcellus shale of New York. Its fauna is transitional between those of the Onandaga and Hamilton.

The Hamilton fauna is much the same in Ontario as in New York. In the main it is a derivation from the Onandaga fauna but it also contains many immigrants from South America. In one locality the Hamilton rocks are largely limestone and there the resemblance of its fauna to that of the Onandaga is very close.

The Upper Devonian strata are for the most part heavily drift covered and known only from well records. The worms and lingulas of the black shale, correlated with the Huron of Ohio, indicate its contemporaneity with the Genesee of New York. Nothing is known of the fauna from the green shales of the Port Lambton beds.

Quaternary Geology

In the region adjoining the International Boundary between Rainy Lake and Lake of the Woods, unconsolidated deposits of Quaternary age overlie the pre-Cambrian crystalline rocks. The study[8] of the surficial sediments has revealed the presence of a single small remnant of leached and weathered till deposited by probably pre-Wisconsin ice advancing from the Keewatin center. It is overlain by drift, reddish where weathered, but ordinarily gray in its lower portion, which was deposited over the whole region by ice of the Wisconsin stage moving southwestward from Labrador. Shortly after the retreat of this ice the district was invaded from the northwest by the Keewatin ice sheet of the same stage, which deposited calcareous till and boulder-clay and formed a marginal glacial lake. The latter was enlarged as the ice margin withdrew and glacio-lacustrine clays conceal the till over large areas. The clays show seasonal lamination and the reviewer infers from the author's statements that this "Early Lake Agassiz" existed for about 750 years after the withdrawal of the ice before its waters were drained. An interval, sufficiently long to permit of extensive weathering and the establishment of drainage systems, followed the disappearance of this lake and then the region was gradually transgressed by the waters of Lake Agassiz. These advanced southward with increasing depth of the lake as the northward-flowing streams were ponded by a slight readvance of the Labrador ice sheet. The lacustrine sands, gravels, and clays are overlain by Recent deposits of wind-borne sediment and the peat and swamp muck which filled shallow depressions in the lake floor after its waters had drained away.

A less complex series of Quaternary deposits form the surficial materials of the Island of Montreal.[9] Boulder-clay covers the pre-Cambrian and early Paleozoic rocks nearly everywhere on the island and is in some places overlain by the Leda clay and Saxicava sands. Only one drift sheet, the Wisconsin, has been identified. The clays and sands are deposits in an arm of the sea which occupied the St. Lawrence valley during the "Champlain substage" immediately following the retreat of the Labrador ice sheet. Both formations con-

[8] "The Rainy River District, Ontario, Surficial Geology and Soils," W. A. Johnston, Geological Survey, Canada, Memoir 82, 1915.

[9] "The Pleistocene and Recent Deposits of the Island of Montreal," J. Stansfield, Geological Survey, Canada, Memoir 73, 1915.

tain an abundant fossil fauna, largely of marine molluscs. The Saxicava formation includes beach gravels which are found at 27 different levels of general importance so far as the island is concerned. The highest of these is at an altitude of 617 feet above tide. Postglacial movements are represented by minor faults and folds as well as by the continental deformation which altered the shore-lines of the Champlain sea. The latter is attributed to isostatic adjustment consequent upon the removal of the ice-load.

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SPECIAL ARTICLES

THE THEORY OF THE FREE-MARTIN

THE term free-martin is applied to the female of heterosexual twins of cattle. The recorded experience of breeders from ancient times to the present has been that such females are usually barren, though cases of normal fertility are recorded. This presents an unconformable case in twinning and sex-determination, and it has consequently been the cause of much speculation.

The appearance of an abstract in SCIENCE[1] of Leon J. Cole's paper before the American Society of Zoologists on "Twinning in Cattle with Special Reference to the Free-Martin," is the immediate cause of this preliminary report of my embryological investigation of the subject. Cole finds in a study of records of 303 multiple births in cattle that there were 43 cases homosexual male twins, 165 cases heterosexual twins (male and female), and 88 cases homosexual female, and 7 cases of triplets. This gives a ratio of about 1♂♂:4♂♀:2♀♀, for the twins instead of the expected ratio of 1:2:1. Cole then states:

> The expectation may be brought more nearly into harmony with the facts if it is assumed that in addition to ordinary fraternal (dizygotic) twins, there are numbers of "identical" (monozygotic) twins of both sexes, and that while in the case of females these are both normal, in the case of a dividing male zygote, to form two individuals, in one of them the sexual organs remain in the undifferentiated stage, so that the animal superficially resembles a female and ordinarily is recorded as such, although it is barren. The records for monozygotic twins accordingly go to increase the homosexual female and the heterosexual classes, while the homosexual male class in which part of them really belong, does not receive any increment.

[1] Vol. XLIII., p. 177, February 4, 1916.

Cole thus tentatively adopts the theory, which has been worked out most elaborately by D. Berry Hart, stated also by Bateson, and implied in Spiegelberg's analysis (1861), that the sterile free-martin is really a male co-zygotic with its mate.

Cole's figures represent the only statistical evidence that we have on this subject. Let us follow his suggestion and take from the heterosexual class enough cases to make the homosexual male twins equal in number to the homosexual female pairs; this will be approximately one fourth of the class, leaving the ratio 2:3:2 instead of 1:4:2. Which one of these is the more satisfactory sex ratio I leave others to determine; I wish only to point out the fatal objection, that, according to the hypothesis, the females remaining in the heterosexual class are normal; in other words, on this hypothesis the ratio of normal free-martins (females co-twin with a bull) to sterile ones is 3:1; and the ratio would not be very different on any basis of division of the heterosexual class that would help out the sex ratio. Hitherto there have been no data from which the ratio of normal to sterile free-martins could be computed, and Cole furnishes none. I have records of 21 cases statistically homogeneous, 3 of which are normal and 18 abnormal. That is, the ratio of normal to sterile free-martins is 1:6 instead of 3:1.

This ratio is not more adverse to the normals than might be anticipated, for breeders' associations will not register free-martins until they are proved capable of breeding, and some breeders hardly believe in the existence of fertile free-martins, so rare are they.

My own records of 41 cases of bovine twins (to date, February 25, 1916), all examined *in utero*, and their classification determined anatomically without the possibility of error,