Across Canada with Princeton.

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THE Princeton 'Summer School of Geology and Natural Resources,' led and organised by Prof. R. M. Field, has completed its second annual excursion. We started from Princeton on July 15 and returned on Aug. 24. Meanwhile, we traversed and retraversed the North American continent by routes that very seldom intersected. Except for two nights on the steamer between Vancouver and Victoria, we slept on the Pullman that bears the arms of the School. This car has been specially constructed with kitchen, shower-bath, lecture-lantern, screen, etc. Most of our travelling was done at night, to leave the days free for geology. Of twenty-five main halts, one at Bellefonte introduced us to the Pennsylvanian Appalachians and another to the southern side of the Niagara gorge; the rest were in Canada. Last year's trip was wholly in the United States. Next year's is planned for intensive study of the Appalachians. For 1929, there is talk of a motor-car raid upon Scotland and Switzerland.

This Summer School is interesting as typical of modern America. In Europe it would be unthinkable. In America, at the present time, if a project is original, striking, and 'worth while,' it can be achieved. British readers will grasp the scope of the Princeton organisation when they find the Director of the Geological Survey of Great Britain among the eighteen members of Council. Of the others, two are Canadian, while a third of the total are acknowledged leaders in the world of transport.

Obviously, the success of the undertaking depends equally upon transport and guidance. Railway facilities were supplemented by motor-cars and occasionally by steamers; and it is characteristic of the lavish hospitality of the land that the motor-cars were in many cases supplied by well-wishers whose names even we cannot hope to remember. The indispensable guides were arranged for by the Director of the Geological Survey of Canada, by the Universities of Toronto, Winnipeg, Vancouver, and Harvard, and by various mining companies and private individuals. Our debt to them is fundamental, and it is proper to pay tribute to the glorious freedom of discussion which was extended to us wherever we went.

Two important *motifs* have actuated Prof. Field in bringing this wonderful Summer School into existence. He wished to arrange for an annual international congress of comparative geology and to have it attended by young and old together. It is part of the constitution that every year a citizen of the British Commonwealth and another from the outside world shall be invited as guests. On the present occasion, I had the great good fortune of accompanying my old friend, Prof. L. W. Collet, of Geneva, across the Atlantic to learn far more than we had even dared to hope. The party, all told, was twenty-seven men, ranging from professors to undergraduates. The interest of the latter was strengthened by the thought of an examination at the end of the course; and from their questions we others learnt many a lesson.

Perhaps, as British 'observer,' I may be permitted to record some of the impressions of the trip. In the first place, the North American Continent is, broadly speaking, a magnified mirror image of much of Europe. North America has three major divisions: (1) an Atlantic border of Palæozoic mountains (Appalachian System); (2) an immense central region (Laurentia of Suess) that has suffered no mountain-making deformation since the dawn of the Cambrian; and (3) a Pacific Cordillera (Rocky Mountains, etc.) characterised by Mesozoic and Tertiary compression. Both the Atlantic and Pacific mountains have been folded and thrust over the margins of the intervening stable element. The latter is seldom spoken of as Laurentia, but its main pre-Cambrian exposure is familiarly styled the Canadian Shield, while its Cambrian and later systems are for the most part included in the Great Plains. If now we turn to Europe, we find: (1) a Palæozoic border chain that runs through Scandinavia and Britain; (2) a central region that we may christen Baltica, a region of Cambrian and post-Cambrian tranquility; and (3) a Mesozoic-Tertiary cordillera (Carpathians, Crimea, Caucasus). Here again the mountain elements (1) and (3) are folded and thrust upon the margins of the buffer state (2). Moreover, in the latter we find a Baltic Shield to match the Canadian Shield, and a Russian Platform, extending through Denmark into East Anglia, to serve as counterpart of the Great Plains of North America.

The pivot of our comparison is furnished by the mountain chain of Scandinavia. This chain is markedly symmetrical. On one side, in Sweden, it is carried forward along the Törnebohm thrust-zone on to undisturbed early Palæozoic rocks of Baltica. On the other side, as exposed in the north-west Highlands, it has travelled along the Moine thrust-zone on to undisturbed early Palæozoic rocks recognised by Suess as part of Laurentia. Across the Atlantic, the Scotto-Scandinavian mountains reappear in Newfoundland and Nova Scotia, and the Moine thrust-zone is represented by the well-known dislocation-belt of St. Lawrence and Lake Champlain.

Beyond this point the reader must proceed warily. It is only a part of the Appalachian System that corresponds with the Scotto-Scandinavian chain. The Appalachian System is a complex of two of the important mountain systems of Europe. In fact, the geology of the Atlantic States of North America is summarised in the words: *Where mountains cross.*

Let us join Marcel Bertrand's pupils and define for tectonic purposes Caledonian as meaning early Palæozoic, Hercynian as late Palæozoic, and Alpine as Mesozoic and Tertiary. Bertrand, after reading Dana in 1887, recognised part of the Canadian and New England Mountains of the Appalachian System as Caledonian, while he separated the Pennsylvanian Appalachians as Hercynian. The data have been greatly clarified of recent years, and the progress of knowledge as presented by authors like Clark (1921), Collins (1924), and Young (1926) has immensely strengthened Bertrand's comparisons with Europe. Young's account is particularly explicit. "Before the close of the Devonian period," he says, speaking of the eastern mountains of Canada, their strata "were folded and faulted, and invaded by granite batholiths" (Geol. and Econ. Mins. Can., p. 89; 1926). In Pennsylvania, of course, the folding is post-Carboniferous.

Many thoughts spring to the mind of the European geologist who finds himself standing in Pennsylvania on Hercynian mountains *outside* the line of the type Caledonian chain.

(1) The westward convergence of the two Palæozoic chains—so far apart in Poland and Lapland, already in contact in South Wales and Ireland—has led to their actual crossing in the United States.

(2) Not only have the mountains crossed, but also the stratigraphy. In Pennsylvania there is an immense concordant succession from Cambrian to

Carboniferous. In the anticlines we find our Durness Limestone (Beekmantown) as if we still stood in the north-west Highlands of Scotland. In the synclines we discover Upper Carboniferous Coal Measures (Pennsylvanian) derived from the waste of a growing Hercynian chain, and our thoughts are transferred at once to South Wales, the Ruhr, and Poland.

(3) In much of the Canadian part of the Appalachian System, a limestone facies within the Lower Carboniferous serves as a punctuation mark between Caledonian and Hercynian movements, just as it does in the British Isles and in Belgium.

(4) It is as if the Atlantic did not exist or, in other words, as if Wegener, after all, were a true prophet.

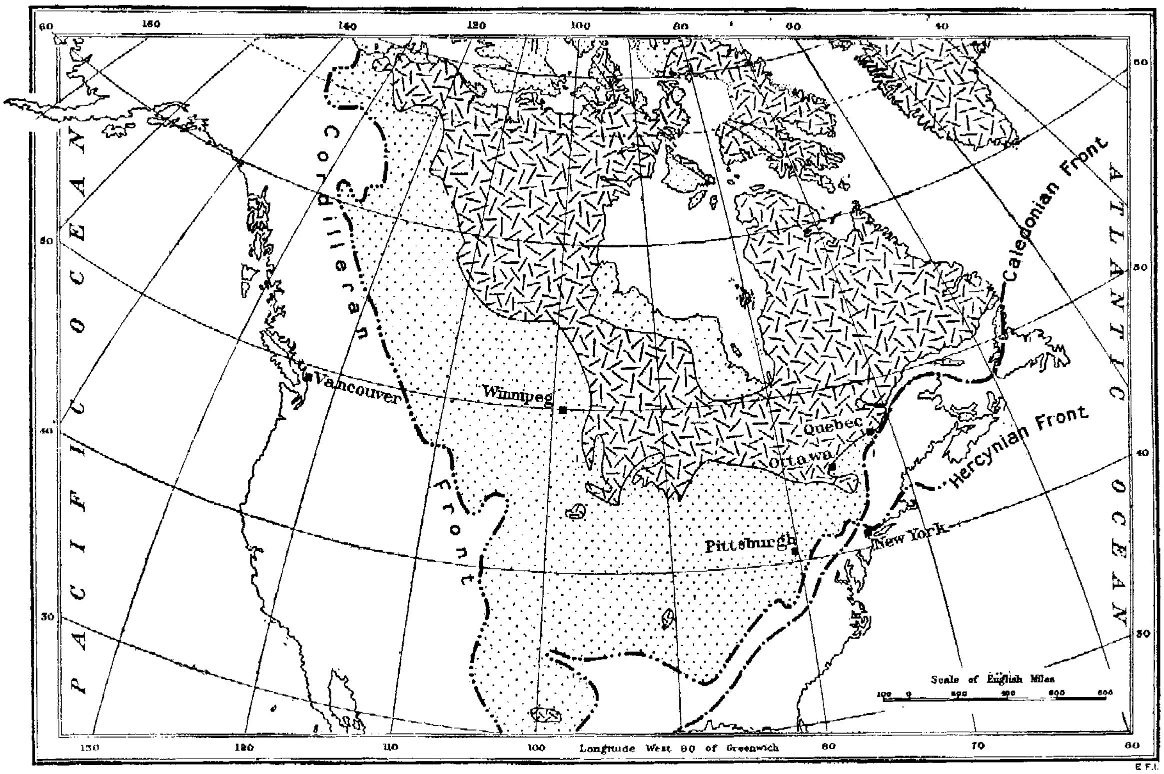

Fig. 1.—Tectonic map of North America. The interior region (Laurentia of Suess) has remained unaffected by mountain folding since pre-Cambrian times. Its pre-Cambrian outcrops are shown by strokes, its Cambrian and later by stipple. Modified after M. Bertrand (1887), Bailey Willis and G. W. Stose (1911), E. Blackwelder (1912), W. H. Collins (1924), G. A. Young (1926).

The thrust-zone of St. Lawrence has been mentioned as a continuation of the Moine thrust-zone of the north-west Highlands. Its interest is intensified by the fact that the thrusts have involved a transport of facies comparable with that so famous in the Alps. This last point is clearly set out in Raymond's guide for the 1913 International. Collet and I were able to add details here and there, simplifying the mapped course of certain thrusts, complicating others by recognition of successive slices—but this has only increased the charm of the story.

According to plan, the excursion maintained frequent contact with Ordovician rocks so far east as Winnipeg. The Cambrian to Middle Ordovician facies of Laurentia differs profoundly from that of the Caledonian Atlantic border. In the former district, one finds a wealth of pure carbonate rocks (marine limestones and dolomites), and there is little contamination except for wind-rounded sand. Such sand is represented, for example, in the Croixian and Potsdam sandstones (Upper Cambrian), in a post-Potsdam sandstone near Ottawa (Lower Ordovician), in the St. Peters and Winnipeg sandstones (Middle Ordovician), and in the basal Trenton limestone at Montmorency Falls, Quebec (also Middle Ordovician). There is a sufficiently close analogy between all this and the chalk and desert-sand association of the Franco-British Cretaceous (*Geol. Mag.*, p. 102; 1924). The Cambrian to Middle Ordovician deposits of Laurentia may be interpreted as having accumulated in a warm shallow sea that bathed the shores of a low desert continent. The same facies extends into the Pennsylvanian Appalachians, where the carbonate rocks may reach as much as 8000 ft. in thickness. It is called the American facies; and in our own country it has long been recognised as characteristic of the Durness succession of the north-west Highlands.

The Caledonian facies is, on the other hand, commonly spoken of as Atlantic, British, or European. It consists of muds and sands, washed down by rivers from the rain-swept heights of the growing Caledonian chain. Its fossils are graptolites, and other creatures, including species familiar in Wales, southern Scotland, and Scandinavia.

Conglomerates or breccias, varying in age from Cambrian to Middle Ordovician, are frequent in Canada and the northern States along the frontal part of the Caledonian chain. They are often interbedded among shales of British facies, but their boulders are mostly limestones of American facies. These boulders are fossiliferous; and while many of them are about the same age as the associated shales, others are distinctly older—for example, Cambrian boulders frequently occur in breccias interbedded among Ordovician shales. The matrix, too, of every breccia that we examined near Quebec contains quartz sand that is absent from the accompanying shales. Altogether, there can be no doubt that these breccias have been correctly determined as sedimentary deposits. Exceptionally, a bed of breccia contains, or at any rate accompanies, a mass of limestone so large that the tendency has been to interpret it as a relic of a bed still *in situ*. One such limestone mass, in a quarry near Lévis, opposite Quebec, measures 60 ft. in length and 30 ft. in height. Collet and I returned to this exposure after the excursion was over. We satisfied ourselves that the mass had ploughed into the underlying shales and splattered them through the accompanying breccia. We felt that we were looking at a submarine landslip that had travelled down a steep slope subject to earthquakes; and standing there we thought of Schardt and of his interpretation of the *blocs exotiques* of the Alpine Tertiary. The comparison, however, must not be pushed too far, since at Lévis the boulders are of foreland rather than of mountain facies. It is extremely interesting that one has to travel hundreds of miles to match the material of these boulders at the outcrop. It seems necessary to accept Raymond's suggestion that their source is hidden under overthrusts.

Space forbids more than a mention of our visit to Niagara, to the vent agglomerates associated with the peridotites of Quebec, to the Pleistocene interglacial beds near Toronto, to the pre-Cambrian glacial beds at Cobalt, to the flat pre-Cambrian of Port Arthur and Fort William on Lake Superior, to the Keewatin and other folded pre-Cambrian formations of the same region, Rainy Lake and Porcupine, to the late Glacial lakes that drained to the Mississippi and New York while ice blocked escape to Hudson Bay and the St. Lawrence, to the Turner Oil Field on the first anticline of the foothills of the Rockies. In the Rockies themselves, thanks to our guides, Kindle, Mackay, and Raymond, we saw thrust after thrust in the districts of Jasper and Banff. We also examined, near Walcott's famous fossil quarry above Field, a spectacular example of secondary dolomitisation. In a cliff face, showing horizontal bedding, an abrupt wavy line runs nearly vertical for several hundreds of feet and separates black limestone from pale buff dolomite. As the bedding goes through the line without any change, it is clear that the dolomitisation has been affected by circulating magnesian solutions. I can only suggest that the portion which has remained limestone was, at the critical time, charged with oil.

In the interior Plateaux of the Cordillera we saw granite intruded into folded Tertiary tuffs at Copper Creek, Lake Kamloops—so far as we know, a new observation. At Vancouver we were shown the great post-Jurassic granodiorite of the Coast Range, with late Eocene conglomerates and sands overlying its weathered top. In Victoria we were particularly interested in a complicated thrust-zone that brings (?) Carboniferous slates over Eocene pillow lavas.

A few words must be added regarding Sudbury, Ontario. Here an elliptical annular outcrop of plutonic igneous rocks surrounds an exposure of the pre-Cambrian White Water Series of sediments, an exposure that measures no less than 34 miles in length and 11 miles in breadth. The igneous girdle varies from 1 to 4 miles in width. The outside country consists of a pre-White Water complex. According to the orthodox reading, the igneous rocks of Sudbury were intruded flatly as a sill along the unconformable bottom of the White Water Series, and then the whole was bent into a basin. Knight, however, in 1917, pointed out that a sill of such extent would surely show transgressive relations. Since no trace of the White Water Series has been found anywhere along the outer boundary of the Sudbury intrusion, Knight interprets this sedimentary series as preserved within a cauldron-subsidence and the intrusive girdle as a ring-dyke. He was delighted to hear that similar phenomena on a smaller scale have been fully established in both Scotland and Norway during the last twenty years. It is scarcely necessary to point out that those who accept Knight's interpretation must dispense with the particular gravitational differentiation hypotheses that have grown out of the sill conception of Sudbury structure. These hypotheses have been much criticised on quite other grounds.

The advantage of international comparisons was further illustrated by the recognition of 'flinty crush-rock' at Harvard, and by Tanton's demonstration to us of Grout's principle (*Bull. Geol. Soc. Am.*, **36,** fig. 5, p. 358; 1925) for elucidating the order of deposition of folded strata. This rather elusive principle was independently employed in an isolated case in the Scottish Highlands in 1913, but there now seems hope of its fairly frequent application—in which case extremely important discoveries are certain to result.

The account given is unrepresentative, in that it has not touched upon economic problems. This is merely due to consideration of space. The gold of Porcupine and Hedley, the silver of Cobalt, the nickel of Sudbury, the asbestos and chromite of Black Lake, the coal of Brule, and the oil of Turner Valley were all examined with the greatest interest; and time was found at Port Arthur, Iroquois Falls, and Vancouver to watch timber ground into pulp or sliced into planks. For a Britisher, it was certainly an inspiring sight to see the new 4000 ft. shaft in the Porcupine gold field entirely equipped with English machinery.

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The Storage of Fruit.

IT is estimated that in 1924 the value of the fruit and vegetables consumed in Great Britain approximated to £100,000,000, imported fruit accounting for nearly half of this figure. The importance of this industry, with its especial liability to wastage of the products dealt with, is sufficient justification for researches into the factors which affect the keeping qualities of fruit and vegetables, apart from the purely scientific interest of such investigations. In its Report for the years 1925 and 1926[1] the Food Investigation Board describes the results of a number of researches into the various factors favouring or preventing deterioration of fruit on storage, the work including both chemical studies of apples and pears of different types during ripening and storage as well as investigations into the suitability of various kinds of store.

In the case of apples, and the conclusion is presumably applicable to similar types of fruit, it has been found that the best keeping varieties contain the least nitrogen and the most sugar, and exhibit the lowest respiratory activity. The inference is that the life-expectation of gathered fruit depends upon the amount of living protoplasm it contains and upon the extent of the accumulated sugar

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[1] Department of Scientific and Industrial Research. Report of the Food Investigation Board for the years 1925, 1926. Pp. vi+80+2 plates. (London: H.M. Stationery Office, 1927.) 2*s*. 6*d*. net.