G. STRUCTURE AND SCENERY OF THE FEDERAL CAPITAL TERRITORY.

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STRUCTURE AND SCENERY OF THE FEDERAL CAPITAL TERRITORY.

§ 1. Introduction.

A consideration of the physical features of the Federal Capital Territory cannot be circumscribed by the arbitrary limits which bound it. It is necessary to look somewhat further afield in order to obtain a proper perspective with regard to the objects within the immediate range of vision.

Canberra has been studied geologically in some detail by Pittman, Mahony, and Taylor. Monaro and Kosciusko have received attention at the hands of Clarke, David, Andrews, Taylor, Sussmilch, Browne, and others. The classical fossil localities of Yass and Cavan have been the Mecca of geologists, and have been described in detail by Shearsby, Harper, and others.

Andrews has codified our knowledge of the physiography of Eastern Australia, and has revealed the golden thread of unity which runs through all the intricate details of its fabric.

These and other authorities must be consulted by those who desire to obtain an intimate acquaintance with the basic structure which underlies the rolling hills and broad plains of beautiful Canberra.

§ 2. Geological Structure.

1. General.—(i) *The Origin of the Rocks.* The rocks which build up that limited superficial part of the earth's mass accessible to direct observation fall primarily into two categories.

(*a*) *Igneous Rocks. Firstly,* there are those which have cooled and solidified from a molten condition. These are termed "igneous rocks"* from their mode of origin. They include the "lavas" and "ashes" produced by volcanoes; but are by no means limited to such types. Enormously more important from every point of view are those masses of igneous rock forced upwards from the earth's interior, but not possessing sufficient driving force to bring them to the surface, which have come to rest at depths often very considerable. Such masses having cooled slowly and under enormous pressure assume characteristic textures; they bake and alter the pre-existing formations with which they come into contact, and, not infrequently introduce new and sometimes extremely valuable constituents into those formations.

The presence of such "intrusive" rocks at the surface now is due to the gradual wearing away of the rocky overburden, amounting in many instances to miles in thickness.

(*b*) *Sedimentary Rocks. Secondly,* there are the products of disintegration of rocks of various kinds at the earth's surface. These fragmental products are collected in various situations, but chiefly under water, and are gradually solidified and hardened into new rock types. Such rocks are grouped under the generic title of "sedimentary rocks." It is obvious that the materials composing a sediment may have been used over and over again.

(*c*) *Altered Rocks.* From either of the fundamental types of rock a third great group known as the "altered rocks" is derived. The alteration or "metamorphism" is produced either as a result of baking by intrusive rocks, or through the heat and pressure generated during the slow earth movements by means of which the mountains are elevated.

(ii) *Fossils.* Animals and plants living in the sea, in lakes or on land are entombed in the sediments as the latter are laid down, or leave their tracks on beach or mudbank. Such evidences of contemporaneous life are termed "fossils." Marine animals with hard shells or skeletons have the best chance of preservation, soft-bodied land animals the worst.

Fragmentary though the record of life on the earth necessarily is, it unfolds the pageant of evolution, and reveals the steps by which highly generalized progenitors, extinct millions of years ago, have gradually developed into the varied flora and fauna of the present-day world.

(iii) *Geological History.* Each type of rock gives evidence in its composition and structure of the long history and the many changes through which it has passed; and the geologist is able to trace with considerable certainty the kaleidoscopic changes which have affected any given region of the earth's surface.

It is possible to determine the order of succession of the different groups of rocks ("geological formations"), to discover the types of plants and animals living at the time they were deposited, and even to ascertain the geographical and climatic conditions under thich they were produced.

The whole "geological record" is divided, for convenience, into "groups" and "systems."† These provide the materials for a history extending over something like 1,600 million years.

Of course, not the whole of this history is found in its completeness in any one place. There are huge gaps everywhere; but, by comparing the records in various lands, the entire history can be pieced together into one continuous whole.

In the pages which follow a summary is given of the geological formations encountered in and about the Federal Capital Territory. These accounts are, of necessity, condensed, and for detailed information the reader is referred to the more technical accounts which have been published.

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* In nearly every instance, inverted commas indicate the use of words in a special technical sense.

† For table of geological systems see Appendix, p. 638.

2. **Ordovician.**—Along the north eastern fringe of the Territory there occur quartzites and black slates of Upper Ordovician age. These are amongst the oldest rocks encountered within the borders of New South Wales, with the exception of the area west of the Darling, which belongs, geologically, to South Australia.

Laid down originally as horizontal sheets of sand and mud on the ocean floor, these sediments were consolidated compressed and tilted until they now stand on end with their worn and ragged edges presented to the sky.

These changes took place before the deposition of the next succeeding geological system, and point conclusively to the action, even in those far-off days, of the same forces as those which act to-day, and have acted throughout the whole of the geological record.

The newer formations were laid down on the disturbed and eroded edges of the older ones, and such breaks or " unconformities " are the punctuation marks of geological history.

Careful search will reveal narrow bands amongst the black slates literally crowded with graptolites, sponges and other fossil forms; but great masses of these ancient ocean muds are barren of recognizable organic remains. It is not certain whether these Ordovician rocks are anywhere met with actually within the Territory.

They are intruded by masses of granite, apparently older than the granite of the great bosses like that of Tharwa, mentioned below.

3. **Silurian.**—(i) *Sediments.* Most of the rocks in the immediate vicinity of the city are of Silurian age. Now consisting of quartzites, slates and limestones, they were deposited originally as the sands muds and coral-reefs of a warm and moderately shallow ocean. It is as a result of baking by masses of hot rock intruded into them and through the crushing and twisting involved in slow earth movements during hundreds of millions of years, that they have been bent into remarkable folds, such for instance, as those which are to be observed in the road cutting behind the post office, hardened to their present consistency, and traversed by the joints and cleavages so conspicuous in the more massive members, as, for instance, in the road cutting north of Commonwealth Bridge.

(ii) *Fossils.* Although the seas of the period contained abundant animal life, fossils are by no means easy to find. The small, isolated coral reefs, like those behind the Bachelors' Quarters at Acton, and others at Red Hill, Coppin's Crossing, Jerrabombera Creek, Paddy's River, Majura and elsewhere, are built up of somewhat obscurely preserved corals of types long since extinct.

Shells of various types are recorded from a number of different localities, including Woolshed Creek on the Yass-Canberra Road, Red Hill and Coppin's Crossing. A very prolific shell bank under the road-bridge over Majura Creek near Duntroon yields beautifully preserved *Spirifers*, and trilobites and gastropods can be found by the enthusiast who is prepared to make a patient search.

Well preserved trilobites are recorded from Majura, Woolshed Creek, Red Hill and Coppin's Crossing.

The fossil collector must be prepared for long and often discouraging search as the price to be paid for a real " prize."

(iii) *Igneous Rocks.* During the deposition of the sediments, volcanoes of great size spread their ashes and poured out their lavas over large parts of the area. In many instances the molten material, instead of escaping at the surface in the form of lava floods, was squeezed or " intruded "* amongst the sediments already deposited. It is not always easy to determine whether a given mass of *quartz porphyry*, as the massive igneous rocks of this series are termed, was " extrusive " (a lava) or " intrusive "; and much interesting and important field and laboratory work awaits the budding geologists of Canberra.

In some cases, as on the slopes of Mt. Ainslie, it is quite easy to show that the rocks were formed above ground as lavas and ashes.

Towards the south, the Silurian sediments and quartz porphyries are intruded by great " bosses " of granite (e.g., Tharwa). These granites were injected, in molten condition, amongst the older rocks far beneath the earth's surface. They are not the

* See footnote on page 628.

products of "volcanic action" as so often thought, but their presence at the surface now is due to the gradual wearing away of the miles of rock overburden by which they were formerly covered.

(iv) *Economic Geology.* (*a*) *General.* Economically, the rocks of this system are not of great value. The heated waters, accompanying and emanating from the igneous intrusions, brought with them small amounts of metalliferous minerals, often associated with white quartz, "reefs" of which are not uncommon. Usually, however, the quartz was introduced without the metals.

(*b*) *Metals.* "Colours" of gold can be obtained almost anywhere along the creeks and rivers of the Territory. Small veins of lead, zinc and copper have been discovered, and have even been worked on a small scale. Outside the Territory there exists, at Captain's Flat, a very extensive and highly complex deposit of lead, zinc, copper and iron sulphides.

(*c*) *Building Stones.* The limestones in and about the Federal Territory are of considerable potential value as a source of lime and cement, and as building stones. The quartzites and sandstones of Black Mountain have been used for building materials to a small extent; but are not very suitable for the purpose. While some of the granites are of great beauty, and would make excellent building stones, their economic exploitation presents considerable difficulties.

(*d*) *Brick-making Materials.* Good bricks can be made from some of the shaly beds, but rapid variations of chemical composition, and the presence of considerable lime in certain strata, tend to make the lot of the brick-maker a far from happy one.

(*e*) *Quality of Soil.* Some of the soils derived from the decomposition of the rocks are of very fair quality, but most are rather poor and some very much so.

4. **Devonian.**—(i) *General.* At numerous places round the borders of the Territory there are wide extents of Devonian sediments, and they can probably be recognized within the bounds of the area at its north-eastern corner. How extensively developed they are in other parts of the district future investigation will show.

Two rather strongly contrasted types of sediment are referable to the Devonian system.

(ii) *Middle Devonian Marine Beds.* Some 25 miles below the junction of the Molonglo with the Murrumbidgee River there occur, at Cavan and Taemas, immense reefs of pure limestone interbedded with other sediments. This series has yielded a rich and varied marine fauna of Middle Devonian age, and represents the coral reefs and sediments of a warm and shallow sea.

(iii) *Upper Devonian Red Beds.* (*a*) *General.* Around Goulburn and Tarago, and between Talbingo and Tumut, there is a great development of red or chocolate shales, associated with sandstones and other rock types. Still more extensive occurrences of the same kind are encountered about Rydal, Koorawatha, Pambula and Eden in New South Wales, and there is an immense development of them in Eastern Gippsland. Consensus of opinion regards these deposits as essentially "sub-aerial" in origin. They were laid down on the continental surface, and not in ocean basins. Some authorities regard the red colouration as a criterion of aridity of climate at the time of deposition. In places, at all events, a slight degree of salinity favours this view; but the question of climate cannot be considered as definitely settled.

(*b*) *Fossils.* On the whole, fossils are rare, but some of the earliest types of land plants and fish of most archaic aspect have been recorded at various localities. The presence of beds containing marine shells at Mt. Lambie and Wolumla points to local and occasional incursions of sea water into the areas of deposition.

(*c*) *Age of Beds.* In age these beds are generally regarded as very late Devonian. They are certainly more recent than the limestones of Cavan, and indicate an extensive "emergence" of the continent and a retrocession of the ocean towards the end of Devonian time.

(iv) *Igneous Activity.* While, as stated above, it seems certain that some of the quartz porphyries of the Canberra area were formed contemporaneously with the deposition of the Silurian sediments, it is probable that these are in the minority.

Most of the intrusive and extrusive quartz porphyries of New South Wales and north-eastern Victoria were of Lower Devonian age. The criteria which prove this are much more clearly defined in Gippsland than in New South Wales.

That there was considerable volcanic activity just before the "red beds" began to be deposited is proved by the occurrence of lavas of very remarkable types at Twofold Bay and at Briagalong in Victoria. Such lavas may occur within or close to the Federal Capital Territory, and should be looked for about Talbingo and Tumut.

Most of the granite masses in and about the Territory are of Devonian and Carboniferous age, but too little detailed investigation has been carried out to enable the distinction to be made. The baking and alteration of the Silurian sediments (e.g., at Red Hill, etc.) and the introduction of such mineral deposits as there are probably belong to this latter period of igneous activity. Between St. John's Church and the river there is a considerable "blow" of white quartz. This appears to be due to the replacement of a small mass of limestone by quartz, as a result of the "intrusion" of the Ainslie quartz porphyries.

5. **Post-Devonian Formations.**—There is an immense gap in the local geological record after the close of Devonian time. There is no trace anywhere within the region of any marine sediments later than Devonian; and even fresh-water sediments belonging to formations between Devonian and Pleistocene are lacking. This hiatus is expressive of the fact that, for hundreds of millions of years, this particular part of Australia existed as dry land. At intervals it became ridged up into high mountains. These were worn down to their very roots by the gnawing tooth of time, and the granite masses which had been injected into their cores were revealed. Again they were raised, and again worn down; and so the age-long process was repeated. Occasionally and locally subsidence occurred, but the prevailing movement was upward.

The waste from the highlands was transported into the seas and lakes which came into being about their feet: came and vanished. Climates changed and varied; twice at least, thrice in all probability, they were covered with sheets of ice. At other times they were clothed with forests of sub-tropical luxuriance.

These and other changes can be read with perfect certainty and clearness in the deposits which build up the geological formations of New South Wales and Victoria.

6. **Cainozoic.**—And so we come to yesterday in a geological sense, a yesterday of not more than, say, a mere million years ago. The story of this last short span of time is written in characters different from those of the archaic alphabet of the geological record; but the history is clear and fascinating.

It is necessary to digress slightly, to explain the principles underlying the modern science of physiography, in order to make clear the sound basis upon which rests the interpretation of this recent history.

§ 3. Fundamental Principles of Physiography.

1. **Popular Fallacies.**—That small minority of people who ponder at all upon the why and wherefore of mountain and valley, recognizes that the stupendousness of the elements of the scenery calls for some stupendous factor in their genesis. In all probability the vast majority of this thoughtful minority appeal to stupendousness of *force* and *power* as the explanation of what they see. Earthquake, volcano and deluge, each capable of producing terror and devastation, must surely, they imagine, be the forces which alone could be capable of calling into being mountain heights and valley depths.

This impression is quite incorrect. Earthquake, volcano and deluge play their parts and leave their scars on the landscape; but their effects are transient and insignificant in comparison with those produced by the gentler, but more constant and continuous forces of nature. Slow and almost inappreciable earth movement, the rotting of the rocks under the action of air and moisture, the constant drag of gravitation, the blowing of the winds, and, far transcending everything else, the scour of running water, these are the forces which mould the continents, build the mountains and carve the valleys. Stupendousness is needed and is not absent; but it is the stupendousness of *time*—not of *force*.

2. **The Conception of the Peneplain.**—(i) *The Work of Running Water.* One of the most fruitful scientific conceptions of the last generation was that of the peneplain, developed by W. M. Davis of Harvard, some 35 years ago.

A land-mass having been uplifted well above sea level by earth movement, and its rocks having been disintegrated by weathering, running water transports every loosened particle down hill. Not in one wild rush, but step by step, with long pauses, and in most leisurely style, in general, the rock grains make their grand tour. Though the particles may lie for centuries *en route* in lake bed or river terrace, their ultimate resting place, in the vast majority of instances, is the sea.

Broadly speaking, the quiet forces of geological change tend literally to cast down the mountains and carry them into the midst of the sea. So long as there is an effective *gradient* for the streams the work goes on—rapidly where the grade is steep, slowly where the slop is gentle. The work is twofold—destructive and constructive: destructive in the higher lands, constructive in the depressions. Its net result is to smooth out all irregularities. In the earlier stages, while the topographic "relief" is high, the work is extremely rapid (in a geological sense); but, as the gradients become lower, it becomes exceedingly slow; and its latest stages are enormously protracted.

(ii) *The Ultimate Result.* Given sufficient time, the ultimate stage of perfection of erosion is the production of a slightly undulating land-surface, sloping upwards very gradually from sea level. To such a surface Davis applied the name "peneplain." The prefix is an important part of the word: a perfect peneplain is *almost* level, not absolutely so.

(iii) *Characteristics of a Peneplain.* A typical peneplain surface possesses some very characteristic features, amongst which deep weathering of the rocks is included. Under some climatic conditions the thick mantle of weathered rock material is covered by a case-hardened "skin" of chemically formed rock—a very characteristic feature in the scenery of the greater part of the interior of Australia, but not conspicuously present in the district under discussion.

(iv) *Interruption by Earth Movement.* So enormously protracted are the last stages in the process of peneplanation that this restless old world generally becomes impatient before perfection is attained. While there are still hills to be eroded and valleys to be "aggraded" (filled with sediment), earth movement supervenes.

If the land-surface sinks it is partially *drowned* by encroachment of the sea, and a new coastline is formed, the characteristics of which depend upon the degree of perfection attained by the process of peneplanation. Sydney Harbour, for instance, is a drowned immature river valley, Port Phillip a drowned old land-surface.

If, on the other hand, the land-surface is uplifted, a new "cycle of erosion" is instituted. The gradients of the streams are increased and their energies are "rejuvenated." They set to work with renewed vigour to carve a new landscape out of the "uplifted peneplain." Its *nearly level* surface is attacked and roughened; new valleys are carved out; and, as the process develops, only "residuals" of the peneplain surface are left as *isolated hills rising to one general level.*

§ 4. Geographical Unity of Eastern Australia.

The later stages of the geological history outlined above were extraordinarily favourable for the development of features of the type just described. Andrews has shown that the major geographical features of Eastern Australia, from Tasmania to Cape York Peninsula, are due to the development of one great peneplain, and to its subsequent modification by successive warpings, differential uplifts, saggings and founderings. Rising to 7,328 feet at Kosciusko, and to over 6,000 feet at Bellenden Ker, it sinks just to sea level at Botany Bay; and, lest it be thought that excursions so far afield savour of undue stretching of the liberty demanded in the first paragraph of this article, it must be stated that the heights of Canberra and the summits of the mountains of Tidbinbilla and Brindabella are remnants of this same peneplain.

§ 5. Life History of a River.

1. **The "Age" of a Valley.**—(i) *Human Analogy.* (*a*) *General.* In order to understand the individual elements of scenery about Canberra, it is essential to examine in slightly greater detail the "life history of a river." It will be found that

there is an extraordinary analogy, in many ways, between the life history of a human being and that of a river. In a new sense, different from that of the Greeks, we can personify the streams and follow their lives as individuals, families and tribes.

(*b*) *Youth.* A stream is born when the uplift of a land-surface produces a gradient down which the water can flow. In its hasty and turbulent youth the stream dashes noisily along its course, wholly destructive in its energies, and with neither time nor "inclination" to wait and build up anywhere the damage it has done. In sober fact, the work of the stream at this stage is erosional. It is engaged in cutting its channel as a deep narrow notch in the upland surface. Its gradient is steep enough to give it the necessary kinetic energy to do this, and the inclination of the bed is too great to permit of the building up of deposits of any but the most temporary kind. The cross section of a "young river valley" is V-shaped.

From the human standpoint young streams have their uses. Actively eroding fresh and undecomposed rock structures, they reveal mineral deposits of economic value, the presence of which could not be detected, by ordinary methods, under a deep mantle of weathering. By reason of the narrowness of their valleys and the solidity of their sides, they offer favourable sites for the engineer to construct his weirs for water conservation and hydro-electric schemes. The Cotter River, and the Murrumbidgee at Burrinjuck spring to the mind at once.

Unsuited for agriculture or sheep-farming, their rugged slopes breed a small population of hardy cattle-men and timber-getters.

(*c*) *Adolescence.* As time goes on the stream, having reduced its gradient considerably, passes into the stage of adolescence. Still hasty, irresponsible and destructive in gorge and rapid, its more sober periods are marked by quiet reaches; and, in these, it begins its work of repair of the land-surface by depositing alluvial flats of rich silt. No longer in such a desperate hurry to reduce its channel to sea level, it spreads itself laterally, attacks its banks, first on one side, then on the other, and begins to widen out its V-shaped cross section.

(*d*) *Maturity.* The coming of maturity finds the stream sobered down considerably. Still subject, at considerable intervals, to periods of mild excitement where it sweeps over an occasional rapid, its flow is mostly placid, and its activities are almost wholly constructive. Its broad U-shaped valley is filled with fertile alluvial lands supporting an agricultural population with thriving towns. The moderate slopes of its valley sides favour human transportation and activity of all kinds, and the amenities of life are more abundant in mature river valleys than in any other situation.

(*e*) *Senility.* Senility of river development is synonymous with local perfection of peneplanation. The old-age stream meanders sluggishly through low-lying silty plains of its own making. These are often marshy, mosquito-infested and unhealthy. Only low and occasional remnants of the older land-surface protrude as inconspicuous mounds from the uniform monotony of the silt plains. Yet, in spite of their somewhat depressing characteristics, old river valleys, by virtue of their extent and the richness of their soils, support teeming populations.

(*f*) *Limitation of the Human Analogy.* The human analogy must not be pressed too far. Though we speak of "an old head on young shoulders," the members of the human body mature and age simultaneously. Not so in a river. The degree of development of any part of a river is only partially dependent on the lapse of time. Environment has a far more potent effect than it has on the physical characteristics of a man. Topography and rock structure impose their effects locally, and it is the rule rather than the exception to find the criteria of age of a river valley alternating with one another in different parts of its course. Universally, we find characters of youthfulness at the source of a stream, and maturity towards its mouth; but it is by no means uncommon to find mature sections up-stream and juvenile ones down-stream, as the result of local peculiarities. Thus, the Molonglo is highly mature at Foxlowe and Canberra, but exceedingly juvenile between Burdong and Queanbeyan. The Murrumbidgee exhibits the characteristics of early maturity at Point Hut Crossing, but those of youthfulness at Tharwa and Kambah.

The causes of some of these peculiarities will be considered later.

2. River Piracy.—(i) *Interdependence of Rivers.* Rivers, like human beings, do not live to themselves alone; they form families and communities, and the activities of each stream profoundly affect those of its neighbours. Space does not permit any

detailed analysis, but it may be pointed out that, just as a rain gutter on a road spreads its tentacles and encroaches on the roadway unless its depredations are checked, so each stream and each group of streams is constantly increasing the area of its watershed by increase in length at its sources.

(ii) *Migration of Divides.* Sooner or later keen competition for territory sets in at each "divide." In a general way, the stream most favoured in point of volume and gradient encroaches on the watershed of its less powerful neighbour. Divides, at first level upland, become carved into steep ridges. The line of the divide migrates into the territory of the weaker stream, and very numerous instances exist where quite considerable rivers have been "beheaded" and "dismembered" by the process of "river piracy."

§ 6. Application of General Principles to the Federal Capital Territory.

1. The Rounded Hills.—One of the most characteristic features of the Territory is the existence of a series of beautifully rounded summits, rising hundreds of feet above the plains. Majura (2,920 feet), Mt. Ainslie (2,762 feet), Black Mountain (2,668 feet), Red Hill (2,368 feet), Mugga Mugga (2,672 feet), Stromlo (2,520 feet) and others all show a marked family resemblance to one another. All are "residuals" of the Kosciusko Peneplain, still more extensive remnants of which form the wooded plateaux east and north of Queanbeyan. The intervening valleys and plains must be filled up in imagination, and we see the undulating surface of the peneplain reconstructed. Since this surface was produced, by the method described above, *at or near sea level*, the present summit levels indicate a net uplift of at least about 3,000 feet in this area.

It is to be noted that the rounding of the summits suggests that erosion has already carved away the whole of the original level surface, and has commenced to eat into the immediately underlying portions of the crust. The actual peneplain level was probably somewhat higher than even the summit of Mt. Majura.

2. Canberra Plains.—That this uplift was not completed in a single mighty act is shown by the development of the Canberra Plains. Stretching their fingers out amongst and between the hills, these extensive plains form a gently undulating surface at about the 2,000-ft. contour.

This has all the characteristics of a mature river valley, and such it is. Called into being by an uplift of something under 1,000 feet in this particular part of Australia, the streams set to work to dissect the uplifted peneplain. Aided by a very protracted period of stability of the earth's crust, their valleys attained a high degree of maturity. Not only were valleys carved in the uplands, but these valleys encroached on one another until, as pointed out above, the intervening "residuals" of the peneplain lost their flat tops. In some instances, notably in the Queanbeyan Hills, they remain as long flat ridges, but, about Canberra itself, more uniformly distributed and somewhat deeper erosion has isolated them as rounded summits. It follows, then, that erosion has removed the whole of the actual peneplain surface immediately round Canberra, and that the existing hills do not reveal the full altitude of the original level of that uplifted structure.

The "Mature Valley Level" forming the Canberra Plains is as widely distributed in Eastern Australia as is the peneplain itself. The difference in altitude between the two erosion levels varies from place to place; a fact which, taken in conjunction with the varying altitude of the peneplain levels referred to above, shows that uplift was differential, and that considerable warping of the surface occurred.

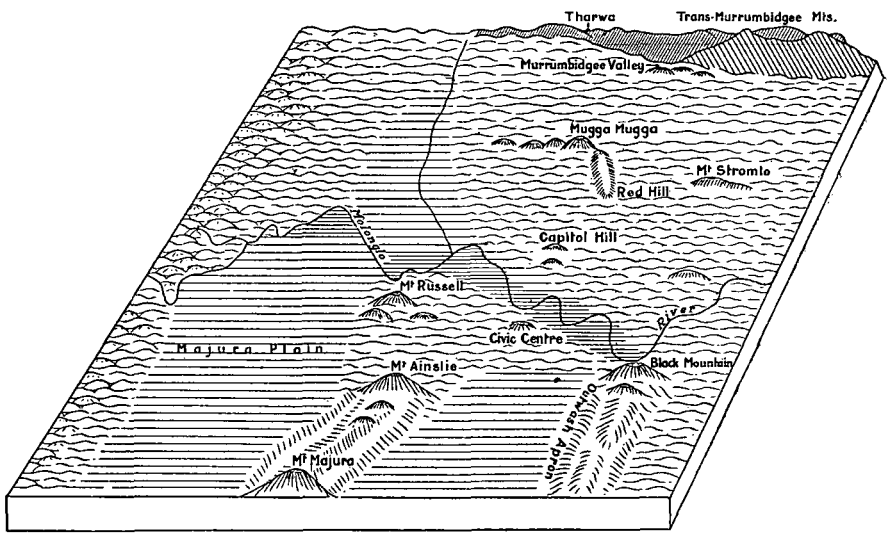
3. The Trans-Murrumbidgee Mountains.—(i) *Murrumbidgee Fault.* To the west of the Murrumbidgee there rise two parallel ranges of mountains, between which lies the valley of the Cotter River. In the eastern group there are such peaks as Tidbinbilla (5,134 feet), McKehey (4,915 feet), and Orroral (5,266 feet). The western group includes some of Australia's highest mountains, such as Gudgenby (5,694 feet), Kelly (6,000 feet), Bimberi (6,262 feet), Gingera (6,092 feet), Franklin (5,400 feet), and Coree (4,657 feet).

All of these peaks, belonging to one original structure, are also remnants of the Kosciusko Plateau. Their conspicuously greater altitude, as compared with the Canberra Hills, is due to the existence of a mighty "fault" running along the Murrumbidgee Valley. Owing to the development of earth stresses the crust was

fractured, and differential movement occurred on opposite sides of the crack. Since parts of the original peneplain have been rendered discontinuous, this movement must have occurred since the date of development of the peneplain, and probably well within the last million years.

(ii) *Continuity of Earth Movement.* It must be remembered that this movement is not due to earthquake or volcanic eruption. Both earthquakes and volcanic eruptions undoubtedly *accompanied* the movement; but they were effects, not causes. The movement did not take place as one mighty cataclysm, but in a series of small warps and jumps. Each of these doubtless caused a severe earthquake. That the movement may not have ceased completely even yet is shown by the fact that this part of Australia is subject to slight earth tremors, and that, very occasionally, these attain appreciable dimensions.

(iii) *Moulding of the Fault Scarp.* So relatively slow was the movement of dislocation that erosion was able to proceed to quite a marked degree simultaneously, so that the "fault scarp" of the left bank of the Murrumbidgee, instead of rising as a sheer 2,000-ft. precipice, has been rounded, moulded and breached by stream action.



Much generalized block diagram illustrating the distribution of physical features in the neighbourhood of Canberra.

The relatively juvenile character of the whole process is shown by the youthfulness of development of streams like the Cotter and Paddy's River, which flow through the fault block.

The valley of the Murrumbidgee was not the cause of the fault; but, *vice versa*, the Murrumbidgee Valley has followed and eroded the line of earth weakness produced by the fault.

4. **Canberra Valley.**—(i) *Majura Lake.* Since the date of the formation of the "Mature Valley Level," the purely local sculpturing action of the forces of nature has been preparing the valley for the building of the National Capital.

Owing, probably, partly to slight earth movement, partly to the deposition of sediment, a considerable part of the Majura Valley appears to have been converted into a fairly extensive lake basin. This became filled up and reclaimed by the deposition in it of sediment. These lake-beds are being dissected by the present-day streams, and interesting sections are exposed in the banks of Majura Creek and elsewhere.

It is known that giant marsupials like *Diprotodon*, *Nototherium*, *Thylacoleo* and others, now extinct, inhabited Australia during the periods of formation of the peneplain and the "mature valley." There is an extremely high degree of probability that their

remains, and even those of ancient aboriginal man himself, will be revealed in these lake-beds by careful search. Such search can be recommended to the nature-loving section of Canberra's population. Any bones or other relics discovered in these beds should be submitted to expert investigation, lest valuable scientific data be lost.

(ii) *Piedmont Beds.* Wet-weather streams, rushing down the steep hill slopes, carried with them torrents of mud and stones. Slackening in speed as they reached the plains, the streams deposited their loads of debris as flat cones in front of each gully. By gradual accretion, these individual "alluvial fans" came into confluence, and formed a sloping "outwash apron" along the foot of the hills. After any fall of rain this process can be seen, exquisitely developed on a pocket-edition scale, along the sloping bank just west of the post office. This homely example will help the observer to appreciate the origin of similar structures, on a very much grander scale, along the eastern foot of Black Mountain and elsewhere.

(iii) *Breccia Accumulations.* In this "outwash apron" of Black Mountain there are contained immense beds of "breccia" composed of angular fragments of rock, heaped up pell-mell, and cemented together. The origin of these breccias calls for considerable research; but it is suggested that they are the product of a "pluvial epoch" contemporaneous with the glaciation of Kosciusko. It is well known that the heights of the Australian Alps were covered with ice caps for thousands of years. It is fairly certain that, in the lower lands about Canberra, the rainfall at that time was exceedingly heavy. Torrents produced in this way would certainly be competent to produce breccias of the type described.

(iv) *The Future of the Molonglo.* An interesting stage in physiographic development has been reached at the present time. As pointed out above, the hollow in which Canberra stands is a typically mature river valley. Through it the Molonglo flows, with characteristics rather those of adolescence than of maturity. Down-stream from Coppin's Crossing its gradient to the Murrumbidgee is steep, and its characteristics are juvenile.

As a result of the rapid deepening of the Murrumbidgee during "post-mature-valley time" the Molonglo is experiencing rejuvenation. Our very distant descendants will be faced with the problem of dealing with the erosion of the rejuvenated stream, and, slowly but surely the stream will conquer. As this contest will not become acute within the next 50,000 years or so, it need cause no immediate anxiety.

(v) *Clay Deposits.* In a few places where actual remnants of the peneplain surface have escaped erosion, the products of deep weathering of that surface (§ 3, part 2, above) have been preserved.

In the Gungahlin District, certain hill tops are composed of very pure white clay, capped with ironstone, which represents the "skin" of chemically formed rock. Similar deposits are known at Bungendore.

That these clays do not consist of deposits washed down and left in a depression is shown by the fact that they are intersected by exceedingly fine, but continuous quartz veins, exactly like those which traverse the unweathered slates. These veins were introduced at the time of injection of the igneous rocks, and therefore antedate by hundreds of millions of years the formation of the peneplain. Such thin and fragile structures are quite incapable of withstanding the slightest mechanical transport, so that the clays must have been formed in the place where they are found.

It is probable that these local, high-grade clays, the discovery of which is extremely recent, will form the basis of a thriving local ceramic industry.

§ 7. Lake George.

Although not falling strictly within the scope of the present article, attention must be directed briefly to two structures in the near vicinity of the Federal Capital Territory, and closely associated with the development of its physical features.

As the traveller approaches Canberra from the Sydney side Lake George forms a striking feature. It is bounded on the west by a precipitous line of hills, unbroken save by Geary's Gap. A curious fact is that this valley constitutes a local "area of internal drainage." Water enters it from a small local catchment to the east; but no water leaves it except by evaporation.

Taylor has shown that it is an extremely recent and most interesting physiographic feature.

The western scarp is a north and south "fault" or earth crack, resembling, on a small scale, the great fault which has formed the Murrumbidgee Valley. This fault has allowed the country to the east to sag to the extent of several hundred feet. Before the movement occurred, the headwaters of the Yass and Molonglo Rivers flowed in a westerly direction across the area. As the barrier gradually rose across their courses, the feeble streams attempted to saw their way through it. The Molonglo was *just* sufficiently powerful to succeed in the attempt. With no energies to spare for the widening of its valley, it just managed to carve a narrow gorge through the fault block, and, as a result, we have the picturesque scenery north of Queanbeyan.

Lake George Creek, less powerful than its southern neighbour, kept up the unequal fight for a long time, and carved out Geary's Gap. Overcome in the struggle, it had to confess itself vanquished. It ceased to reach the Yass River, and now empties its limited contributions into the exit-less basin of Lake George.

In considering the development of Lake George it must be borne in mind that the climate of the region has not always been the same as it is now. While weather statistics fail to reveal any short-period variation of considerable amount, there is ample evidence of very profound change in sub-recent times, geologically speaking. Reference has been made to the proofs of ice action at Kosciusko, and to the probability that there was, contemporaneously, a very rainy period at these lower levels. The greatly increased erosion of the land surface, and the correspondingly increased amount of sediment carried by the streams, are evidenced by the cutting of Molonglo Gorge, and by the building of extensive lake terraces in Lake George. In these lake terraces, of which several may be recognized at different levels, it is well nigh certain that extraordinarily interesting fossil remains await the patient searcher.

§ 8. The Upper Murrumbidgee.

The upper course of the Murrumbidgee is extraordinary.

The river rises in peaty depressions on the high plains which constitute the Kosciusko Plateau. Its upper reaches exhibit the characteristics of maturity. The gentle gradients of the high uplands are insufficient to cause deep erosion of the channel, and the deep young valley encountered further down stream has not yet had time to work its way backwards into the high plains.

After flowing north for some distance it swings round to the west, then turns south, then east, and finally north again. Thus, it flows in a veritable spiral. At Michelago it passes through country less than 2,300 feet above sea level. Apparently without rhyme or reason it plunges northwards, and saws a difficult channel through a rampart of granite mountains towering to heights of over 6,000 feet above sea level.

Space does not permit a description of the details of this extraordinary feature. These details have been elucidated by Taylor and Sussmilch. Here it must suffice to say that the Murrumbidgee originally rose in the high mountains about Tharwa and Naas, and flowed north. The streams which now form its headwaters belonged originally to southward flowing rivers, such as the Snowy and the Genoa. These streams have been diverted, and, in part, *reversed* as a result of faulting earth movement and the accumulation of floods of lava.

The beds of some of the ancient streams were filled with molten "basalt," and remain to this day as witnesses of the changes which have taken place. Preserved under these lava cappings are ancient gold-bearing alluvials, forming "deep leads" like those of Kiandra, and from them a considerable amount of gold has been won. Well preserved in these old-time alluvial deposits are the seeds and leaves of forest trees of European aspect, which antedated the period of ascendancy of the eternal gum-tree of Australia.

§ 9. Conclusion.

In a general way the major features of the geology and physiography of the Federal Capital Territory are reasonably well known. In matters of detail there is an almost untrodden field, and even in the larger aspects of the question there are many problems awaiting investigation.

APPENDIX.

TABLE OF GEOLOGICAL SYSTEMS.

	Recent.
	Pleistocene.
Cainozoic	Pliocene.
	Miocene.
	Oligocene.
	Eocene.
Mesozoic	Cretaceous.
	Jurassic.
	Triassic.
Palaeozoic	Permo-Carboniferous.
	Carboniferous.
	Devonian.
	Silurian.
	Ordovician.
	Cambrian.
	Pre-Cambrian.

Absolute Age of geological formations cannot be determined with any considerable degree of accuracy. Approximate estimates are possible. Thus, for instance, Ordovician rocks are believed to be *of the order of* 500 *millions years old*, but the margin of error is great. Of much greater importance is the *relative age* of a given formation. This is determinable from its fossil contents.

Fossils are few and usually ill-defined in rocks older than Cambrian. Given suitable conditions of deposition, most formations from Cambrian up are fossiliferous.

(The names given above are those recognized in Australia.)