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MELBOURNE.

THE PHYSIOGRAPHY

OF THE

PROPOSED FEDERAL TERRITORY AT CANBERRA

BY

GRIFFITH TAYLOR, B.Sc., B.E., B.A., F.G.S.

(PHYSIOGRAPHER, COMMONWEALTH METEOROLOGICAL BUREAU).

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H. A. HUNT,

COMMONWEALTH METEOROLOGIST

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Melbourne, 22nd August, 1910.

SIR,

I have the honour to submit the following paper by Mr. Taylor on the physiography of the proposed Federal Territory at Canberra for approval for publication.

Mr. Taylor has treated the subject of his work in an exhaustive manner. He has correlated the topography, the vegetation, the soil, meteorology, and seismology of the districts, and has summarized and discussed its economic aspects under the headings of—

(*a*) Communication;
(*b*) Vegetation;
(*c*) Mining;
(*d*) Crops;
(*e*) Rainfall.

The stereogram or relief map of the area will be invaluable in projected operations of the various departments in establishing the capital and its surroundings, and to the Meteorological Department, particularly so as it will enable a better appreciation of the climatic peculiarities of the areas, both as to incidence and general conditions of weather. As this Department is hampered in its functions by the lack of physiographical knowledge, it is hoped that this valuable and unique work (so far as Australia is concerned) may be the initiation of a scheme to include in detail a physiographical survey of the whole of the continent, more especially of the Eastern States and the south-western portion of Western Australia.

Mr. Taylor has made some interesting notes on the Cotter River and its watershed, and, from what he has said with regard to Mounts Bimberi and Tidbinbilla, it may be concluded that, in addition to an unfailing supply of water from that river (which local experience has already established), it is not likely, from the inaccessibility of its source, to be readily polluted, and, from the elevation of that source, is probably subject to an annual average rainfall equal to that of Kiandra, viz., 64 inches, or even more, as it is over 1,000 feet higher, and is exposed to the same rain-bearing winds.

I have the honour to be,

Sir,

Your obedient servant,

H. A. HUNT,

Commonwealth Meteorologist.

The Secretary,
Home Affairs Department.

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PLATES.

FIG. 1.—The topography of the Federal Territory (see also Fig. 12). The circle shows the position of the proposed city. The contours are only approximate.

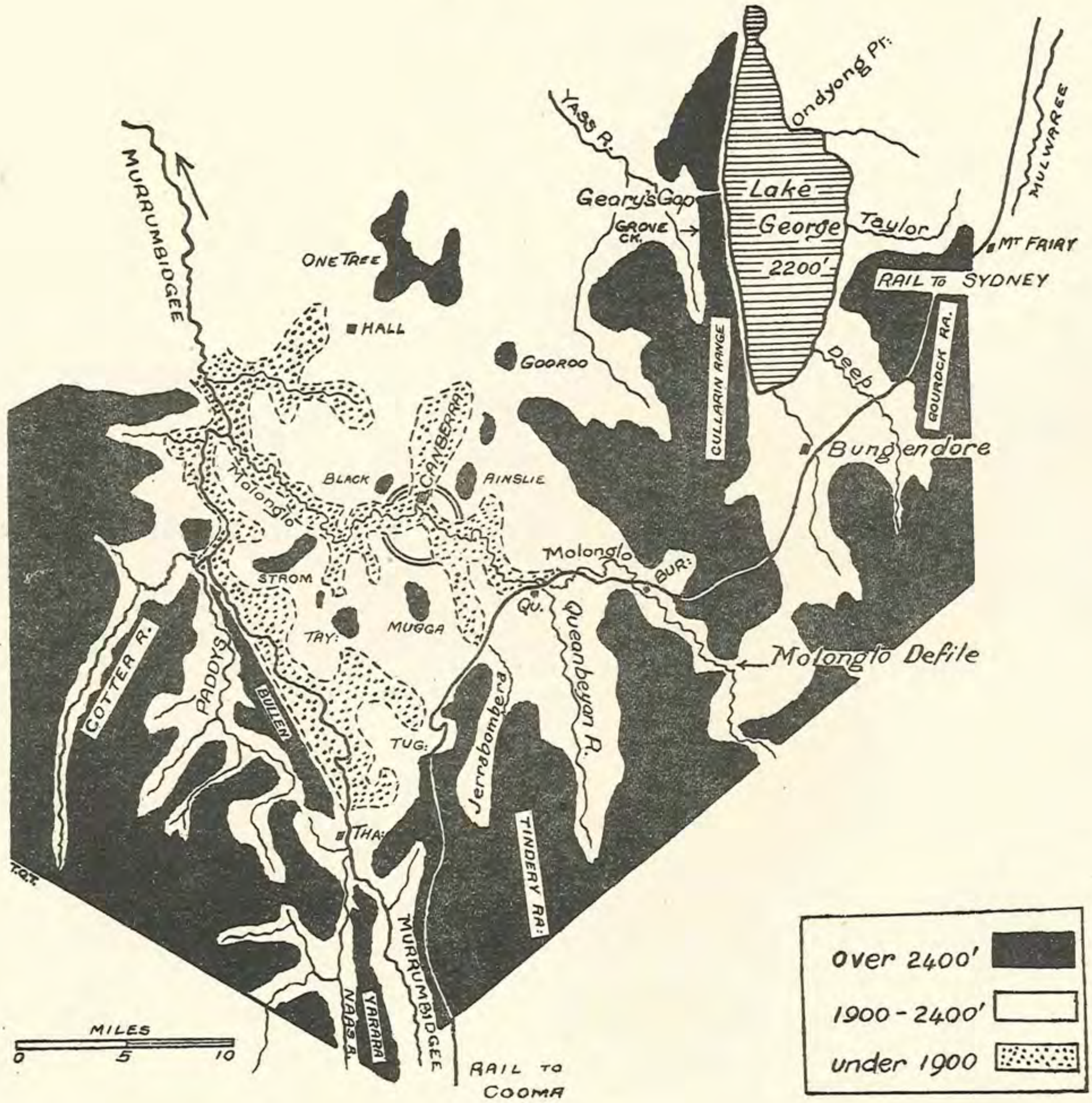
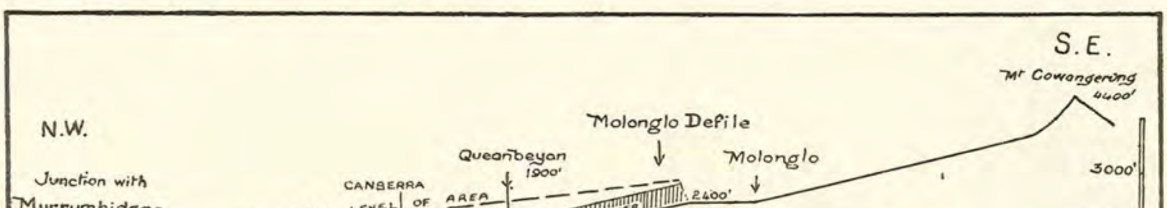


FIG. 2.—Profile along the Molonglo River, showing the section of the defile (hatched) and the step in the grade above Queanbeyan.



THE PHYSIOGRAPHY OF THE PROPOSED FEDERAL TERRITORY AT CANBERRA.

BY GRIFFITH TAYLOR, B.Sc., B.E. (SYD.), B.A. (CANTAB), F.G.S.

INTRODUCTION.

In 1907 I had made a physiographic survey of the Lake George area.* It abuts on the Federal Territory, and is structurally a portion of the region on which the proposed capital is to be built. By direction of the Home Secretary and the Commonwealth Meteorologist, in July, 1910, I prolonged my survey to the west for a distance of 30 miles, and collected data for the construction of a stereogram or relief map of the area. A photograph and description of this accompanies the report.

I preface this brief account of the physiography of the Federal Territory by two extracts from the first volume issued by the Maryland Weather Service, perhaps the most complete in the United States, for it records the meteorology of the Federal Capital, Washington.

In this classical work, issued in 1899 by the Johns Hopkins University, over 200 pages are devoted to a description of the physiography of the country around Washington. The following paragraphs emphasize the close relation of physiography and meteorology, and specifically state the necessity for a physiographic survey under conditions analogous to those in Australia.

"The climate of a particular district is furthermore determined by so many factors of a general and specific nature that the consideration of many topics, apparently more or less remote from what we commonly regard as climate, must be undertaken. Thus, for example, we must understand the topographic and physiographic features of the region if we would rightly interpret its climate, but, in order to comprehend these features properly, a knowledge of geology is necessary."

Again, the Director (W. B. Clarke) writes :—

"It is impossible to fully comprehend our climatic conditions without a knowledge of the distribution of our land and water areas, of the location and elevation of our mountains, and of the extent and position of our plains. Such investigations of the natural physiographic features of the State have a very practical significance to the inhabitants of Maryland, and for those who are considering residence amongst us."

I propose to describe briefly the topography of the area included within a 20-mile radius of Canberra. Then to give a short general account of the land-forms which constitute the elements on which a physiographic study is based (this section will be illustrated by examples drawn from the district). Lastly, I shall endeavour to reconstruct the ancient topography, before the occurrence of the *two great faults* which have determined the present somewhat abnormal topography.

TOPOGRAPHY.

(a) *Lake George Area.*

Let us imagine the reader travelling in the train on the Goulburn–Cooma railway line. He rides along the creek known as Mulwaree Ponds (see Fig. 1), which drains into the Wollondilly at Goulburn. He is, therefore, on the eastern slope of the Great Divide. (This is a better name than the Great Dividing Range, for, as we shall see later, there are many localities where this watershed is by no means a mountain *range*.) Near Mount Fairy the train ascends to 2,500 feet, and is in fact crossing the Great Divide. But it does not reach the Murrumbidgee River system for some 20 miles. Here we enter one of those rare topographic features—an area of inland drainage.

In a few miles the train descends to Bungendore, and a little to the north lies the large bare plain which constitutes the dry bed of Lake George. If we compare the land features on the two shores of the lake we are struck with their dissimilarity. In an earlier paper I have written as follows :—

"On the eastern shore the lake outline is somewhat irregular. Ondyong Point, Rocky Point, Cunandooley, and Native Dog mark the spurs projecting from the Gourock Range into the lake. In *broad* valleys between these spurs lie the streams which water Lake George; Murray's Creek, Taylor's Creek, Deep Creek, and Turallo Creek. It will be noticed that these creeks converge on the locality known as Geary's Gap.

"Reverting to the western shore, we are struck by the absolute dissimilarity. Standing at the level of the lake we seem to be confronted by a great wall extending northwards for over 20 miles from the Molonglo Plain. No broad valley breaks its continuity. Indeed, to one cycling along the foot of the Cullarin Range, it seems unbroken by any definite gap, while for a large part it presents a steep face 500 feet high to the lake. From the eastern shore, however, one is able to see a well-defined gap about half-way along the western shore, where the old Southern Road crossed the Cullarin Range. This depression—Geary's Gap—was well known in the days before the railway, but is now practically unused by travellers. Less than 2 miles south of Geary's Gap, a stream (Grove Creek) rushes down to the lake. Contrast its course with that of Taylor's Creek, on the eastern shore. The latter stream flows through a broad valley, a mile or two wide, scooped out of the granite, and shows the even grade of a *long-established* river. The Grove Creek is barely a mile long, yet descends nearly 300 feet. Its course is interrupted by falls 25 feet high, and finally it emerges from a gorge or miniature canyon with steep sides 200 feet high. Evidently it is a stream which has barely reached the *youthful* stage."

In this Lake George region, therefore, we have examples of two types of valleys, and, as we reach the Murrumbidgee, on the west of the Federal site, a similar contrast within a similarly circumscribed area will be met with. The same explanation (see page 8) holds for both cases, and gives the key to the whole topography of the Territory.

(b) *Molonglo River Valley.*

Proceeding west from Bungendore, which is situated in the broad plain south of Lake George, the line ascends by a rather stiff grade up the Cullarin Scarp. It passes through a tunnel, and then descends to Burbong, whence it follows the Molonglo River to Queanbeyan. Let us trace the Molonglo River back (eastwards) from Queanbeyan. At the latter town it flows through open country, with no sign of a gorge, but, as we travel up its valley, the latter becomes a deep V-shaped gully, and then a small canyon, a hundred feet deep. Instead, however, of reaching the source of the river, as we might expect from such a variation, we suddenly emerge on a large plain of a similar nature to that of Lake George.*

* The Lake George Senkungsfeld; a study of the evolution of Lakes George and Bathurst, N.S.W. Proc: Linn: Soc: N.S.W. 1907, Vol. 32, page 327.

* The absolute level of this plain and the surrounding contours indicate that it is a land-locked basin like Lake George, with a *lower breach*, however, to west.

The character of the river is shown in the sketch section (Fig. 2). It will be seen that the river, instead of following an even grade from source to junction, is interrupted by a well-marked step at Molonglo, with a strong slope thence to Queanbeyan. This points to some profound interruption in the normal course of the river's life. So that evidently the Cullarin Range, from its effects on Lake George and the course of the Molonglo, is worthy of special study in the section dealing with the origin of Canberra topography.

(c) *Murrumbidgee Valley.*

From Queanbeyan (see Fig. 1) the railway goes southwards to Cooma, crossing a broad level plain, drained by Jerrabomberra Creek, and then gradually ascending towards Michaelago. Two rapid curves, near Tuggeranong, carry the line up to 2,500 feet, and here we get into the main valley of the Murrumbidgee River.

Here we notice a strong difference in the character of the two banks of the big river. Just as at Lake George, the eastern shore is low and undulating, but the western is abrupt and continuous for many miles (see Fig. 3).

Even the rough contours shown in Fig. 1 demonstrate this. The western margin of the Cullarin Range is similar to the even margin of the Bullen and Yarara Ranges. The normal *lobes* of the Gourock Range are similar to the lobes projecting from the Tindery Range. Those tributaries of the Murrumbidgee which cut through the Bullen–Yarara Range emerge through gorges several hundred feet in height. So that the sites suitable for weirs lie just where the tributary streams of the Murrumbidgee cross this pair of abnormal ranges, On the east of the Capital site is the Molonglo defile, on the west of the site the lower waters of the Cotter and Naas–Gudgenby streams.

(d) *The Tharwa Gap.*

A little south of Tuggeranong is the village of Tharwa (THA), where there is one of the few bridges across the Upper Murrumbidgee. To the north is the wide valley with its steep western slope, already described. But to the south the mountains shut in, and a most interesting set of physiographic features is presented to us.

The contours of the various tributaries of the Murrumbidgee are here quite abnormal. If a normal river valley be dammed, as in the case of the Barren Jack reservoir (Fig. 4), the water line (which is a contour) has the form of a "fork" with two or three tines. But in the region around Tharwa, on the Murrumbidgee, many of thes tributaries run into the main river in the wrong direction, *i.e.*, they run upstream. For instance, in Fig. 5, the Gudgenby, Naas, and Chippendale tributaries are normal, but Sawyer's Creek, Booroomba Creek, Guises' and Deep Creeks are all heading upstream, and, as we shall see later, this characteristic is even more strikingly shown in the more southern tributaries. Hence, a contour of these branches is not a " fork " but resembles a "boat hook." In Fig. 6 these features are emphasized. A sketch of one of these "boat-hook bends" is given in Fig. 7. Booroomba Creek here runs into the Gudgenby in this way.

Near the actual junction of two large river systems—one of which has been captured by the other—we get a curious set of contours, sketched approximately in Fig. 8. A little consideration shows that this is due to the interlacing or crossing of two pairs of tributaries. In this case, the channels of two streams originally flowing to the Snowy (Sawyer's and Guises'), cross two streams (Gudgenby and Chippendale), which flow normally into the conquering Murrumbidgee. To this feature I give the name "crossed-fork contours."* In some form it is to be expected on the line of every important river capture in which the two main streams involved are more or less collinear. (The "captures" will be clearly understood by comparing Fig. 16 with Fig. 17.) All these irregular streams once behaved with perfect propriety, and formed part of the Snowy River system, far to the south; but they have been led astray, if one may say so, by the faults of the Murrumbidgee. They afford a striking confirmation of the physiographic processes which have brought about the topography of the Territory.

(e) *The Canberra Plain.*

Let us leave the question as to where the ancient watershed between the Snowy and Murrumbidgee lay, and return to the topography nearer the Canberra site. To the west of Queanbeyan, which is situated at the foot of the Jerrabombera Ridge, the valley opens out very greatly, and, in place of hilly or undulating country, such as we have examined so far, the landscape consists of isolated knobs, or, rather, series of knobs, rising from almost level plains. This is shown clearly in Fig. 1. There are five very striking knobs surrounding the proposed city area. Ainslie (2,762 feet) to the north-east, Black Mountain (2,658 feet) to the north-west, Mugga (2,662 feet) to the south, Taylor (2,800 feet) and Strom (2,600 feet) to the west; all rise about 800 feet above the Canberra Plains. These cones really resemble volcanic cones, such as those which add so to the picturesqueness of Auckland, but they are merely "residuals" (monadnocks) of an older land surface of about 3,000 feet level. They consist of hard rocks, usually an eruptive rock allied to diorite, but containing much free quartz, and, therefore, better known as "dacite." Black Mountain is chiefly quartzite, an altered sandstone, which may have been hardened by the eruptive rock dacite. It must be clearly understood, however, that the volcanic action implied by the presence of dacite is of very ancient date, and has had no direct effect in producing the topography now existing.

The sketch (Fig. 9) shows the appearance of these series of knobs. The detailed geology of the district is now in course of investigation, but it seems very probable that the very regular arrangement of the tributaries of the Molonglo, shown in Fig. 10, is due to some structural arrangement of hard and soft strata. The strike of the rocks is almost north and south, and it is known that there is an alternation of limestones and sandstones in the district. Little tributaries, cutting the sides of these north-south ridges, have converted them into the picturesque features, of which the Ainslie–Majura–Gooroo unit is sketched in Fig. 9.

(f) *The Canberra Monadnocks.*

The uniform height of these knobs, as already stated, points to their being the relics of an old level land surface of the nature of a "peneplain." This is the name given by geographers to a large tract of country cut down by river erosion to a fairly uniform level (pene — almost), but composed of varying rocks, and not of one class of sediment, like a true plain. (See Fig. 11, at A.) On a small scale, the bed of Lake George is a true plain, and not a peneplain, for it is the level surface of a homogeneous silt deposit, and

* For instance, a beautiful example on the Mitta Mitta River (Victoria), 24 miles north of Omeo, marks the exact position of the Old Divide. The numerous tributaries with splendid "boat-hook bends" to the south of this "crossed-fork" all flowed into the Tambo River originally. It is sketched in the inset in Fig. 8A.

FIG. 3.—Cross-section from Castle Hill (West) to Molonglo Plains (East) showing the asymmetric valley of the Murrumbidgee, and the two fault scarps.

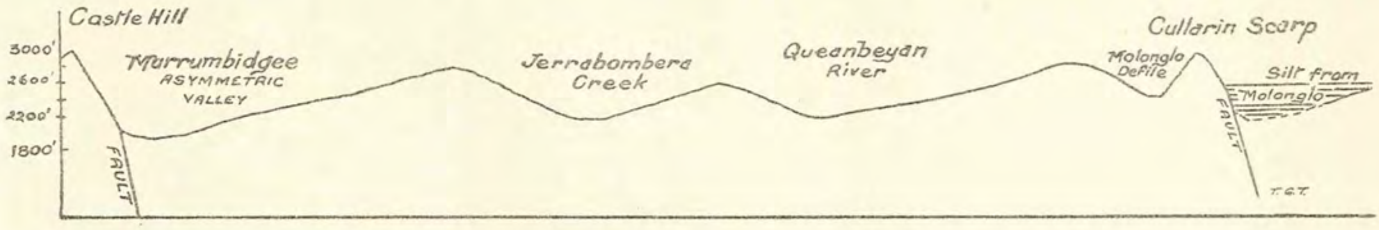
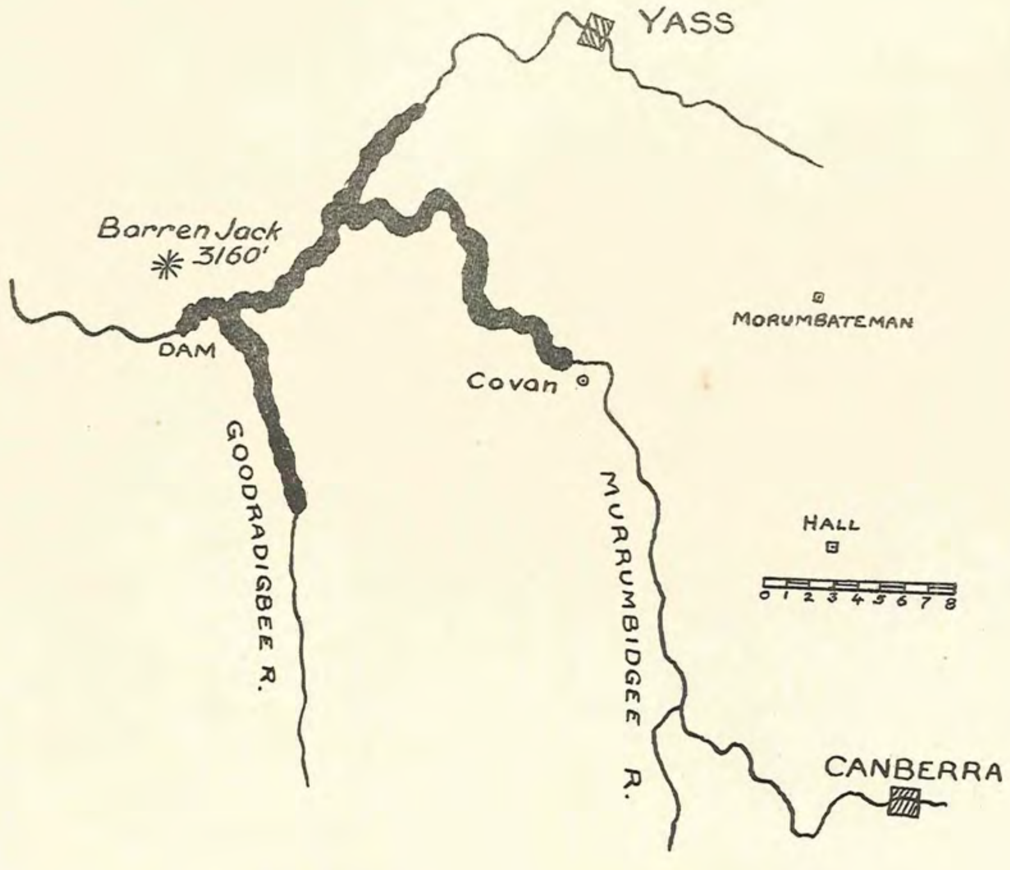


FIG. 4.—The contours of a river branching normally; showing also the relative positions of Yass. Barren Jack, and Canberra.



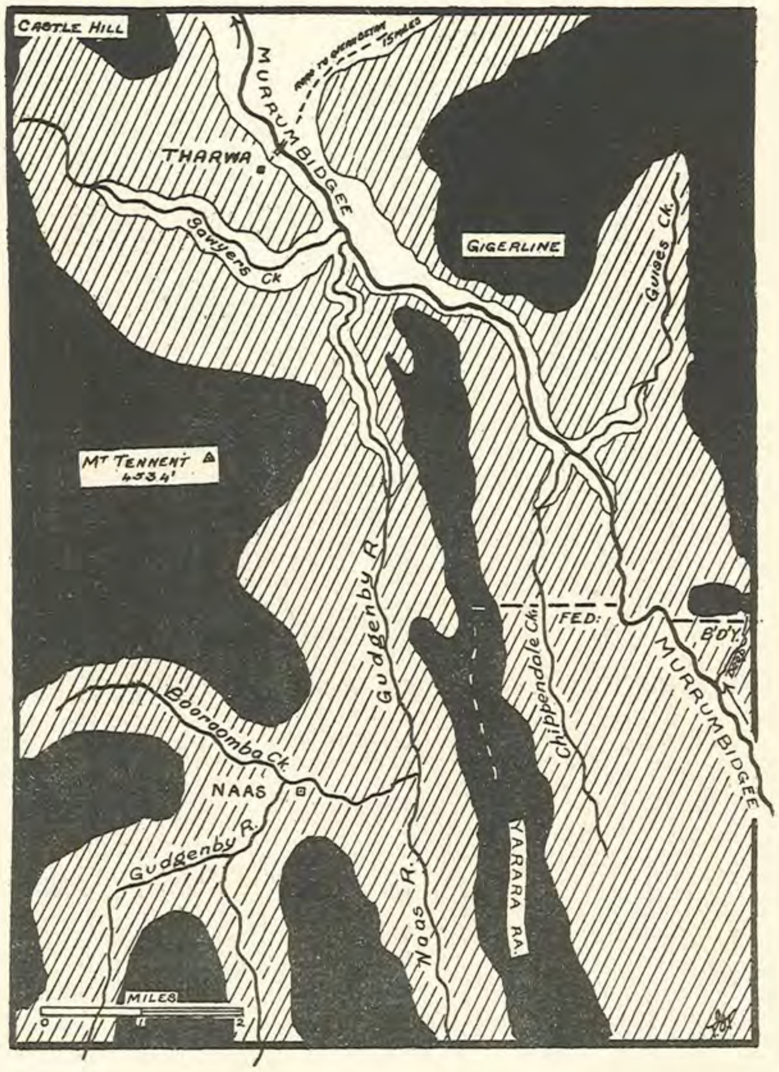


FIG. 5.—The Tharwa gap, showing where the Murrumbidgee cuts through the Old Divide. Contours approximately 2,000 feet and 2,400 feet.

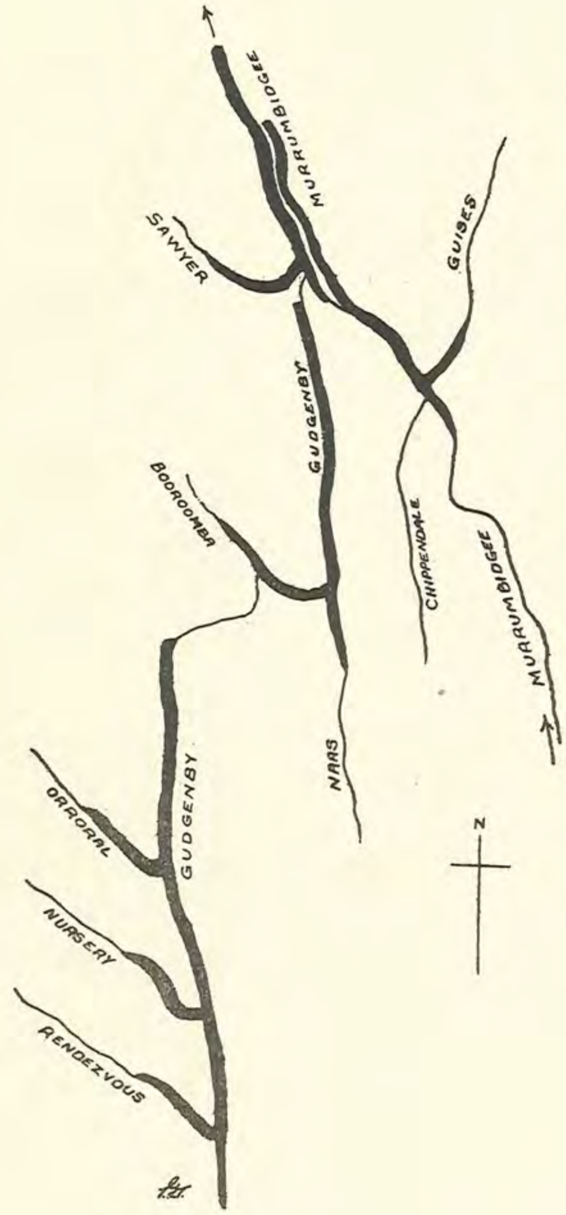


FIG. 6.—Some of the "boathook bends" on the Upper Murrumbidgee and its tributaries.

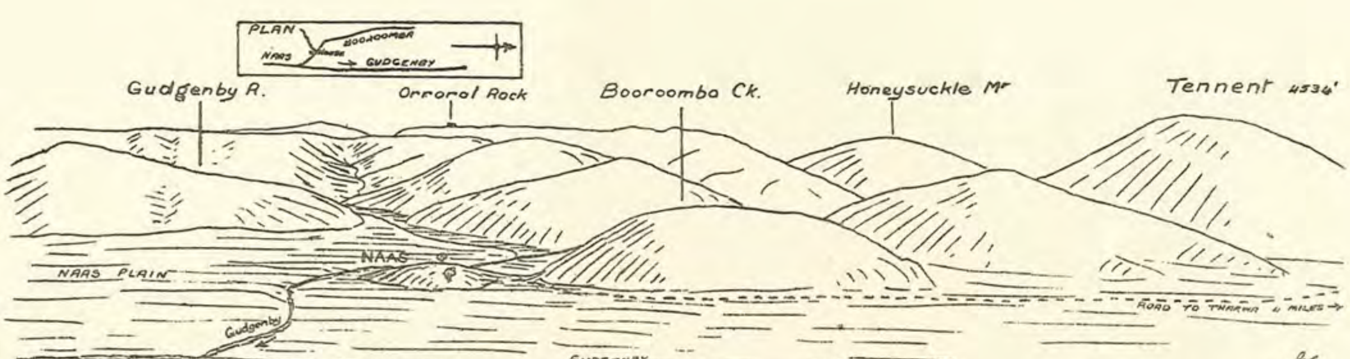


FIG. 7.—Sketch of a "boathook bend"; the junction of Booroomba Creek and the Gudgenby River.

FIG. 8.—" Crossed-fork " contours at the Old Divide, Tharwa. (The two forks are shown separately on the right.) A similar feature in Victoria is inset in the figure.

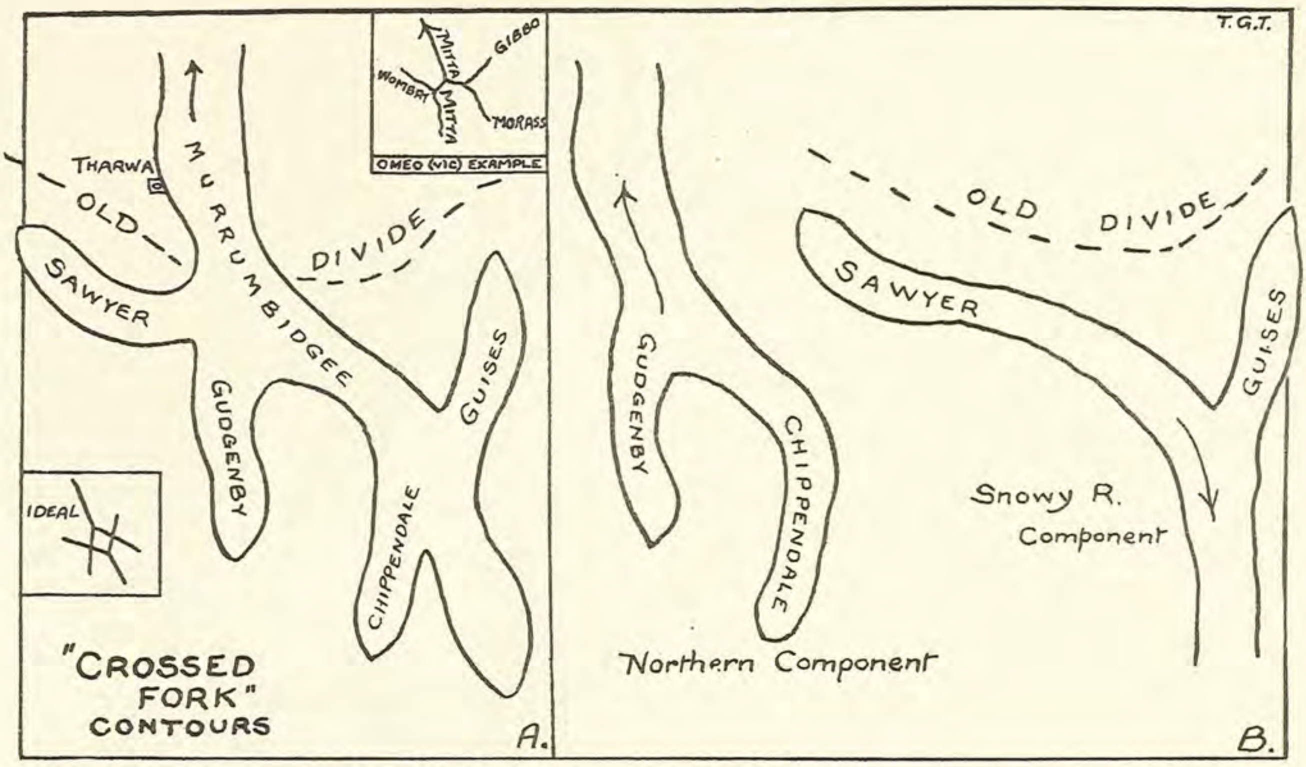


FIG. 9.—Sketch of the Canberra site looking north from Mugga, showing the alternation of plains with monadnock ridges.

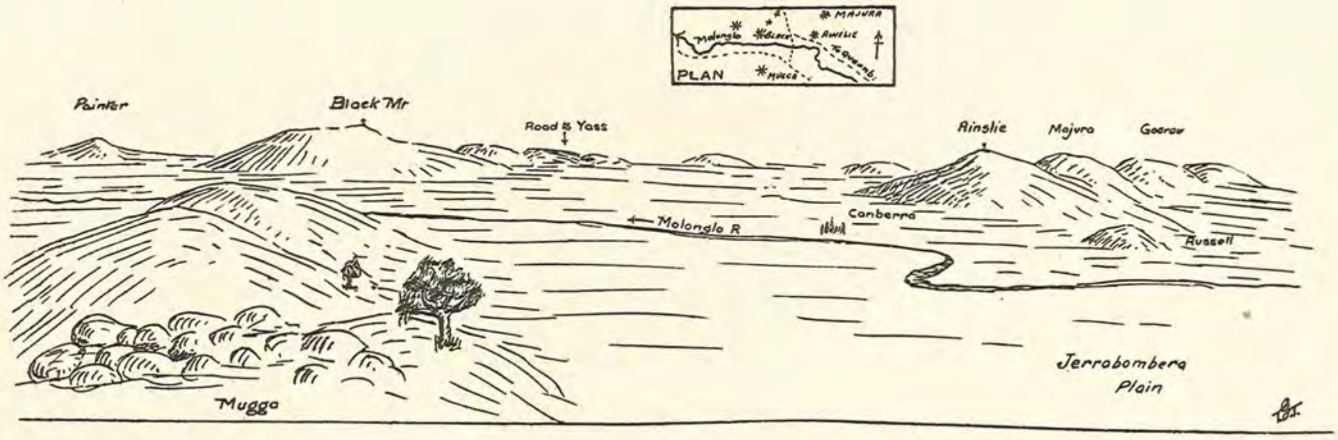


FIG. 10.—Diagram showing the symmetrical arrangement of the Molonglo tributaries. The black area represents highland, but the boundary is not of constant level.

FIG. 11.—Generalized diagrammatic sections in the Canberra region.

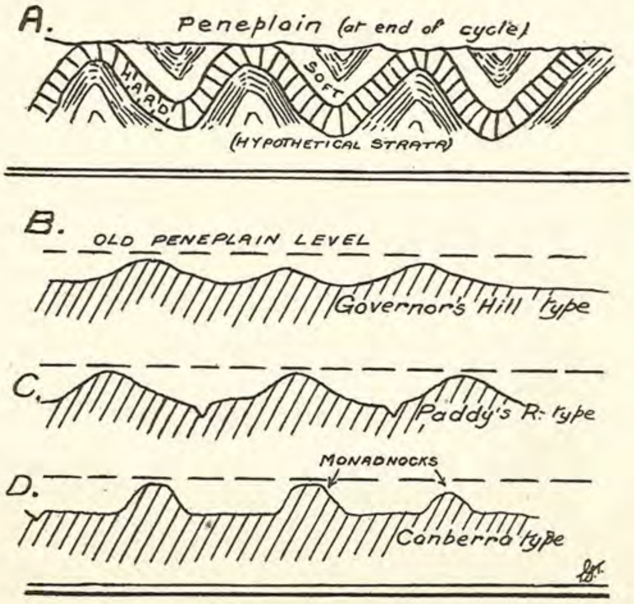


FIG. 12.—The Physiographic divisions of the Territory (highlands shaded). The heavy black line defines the Territory.

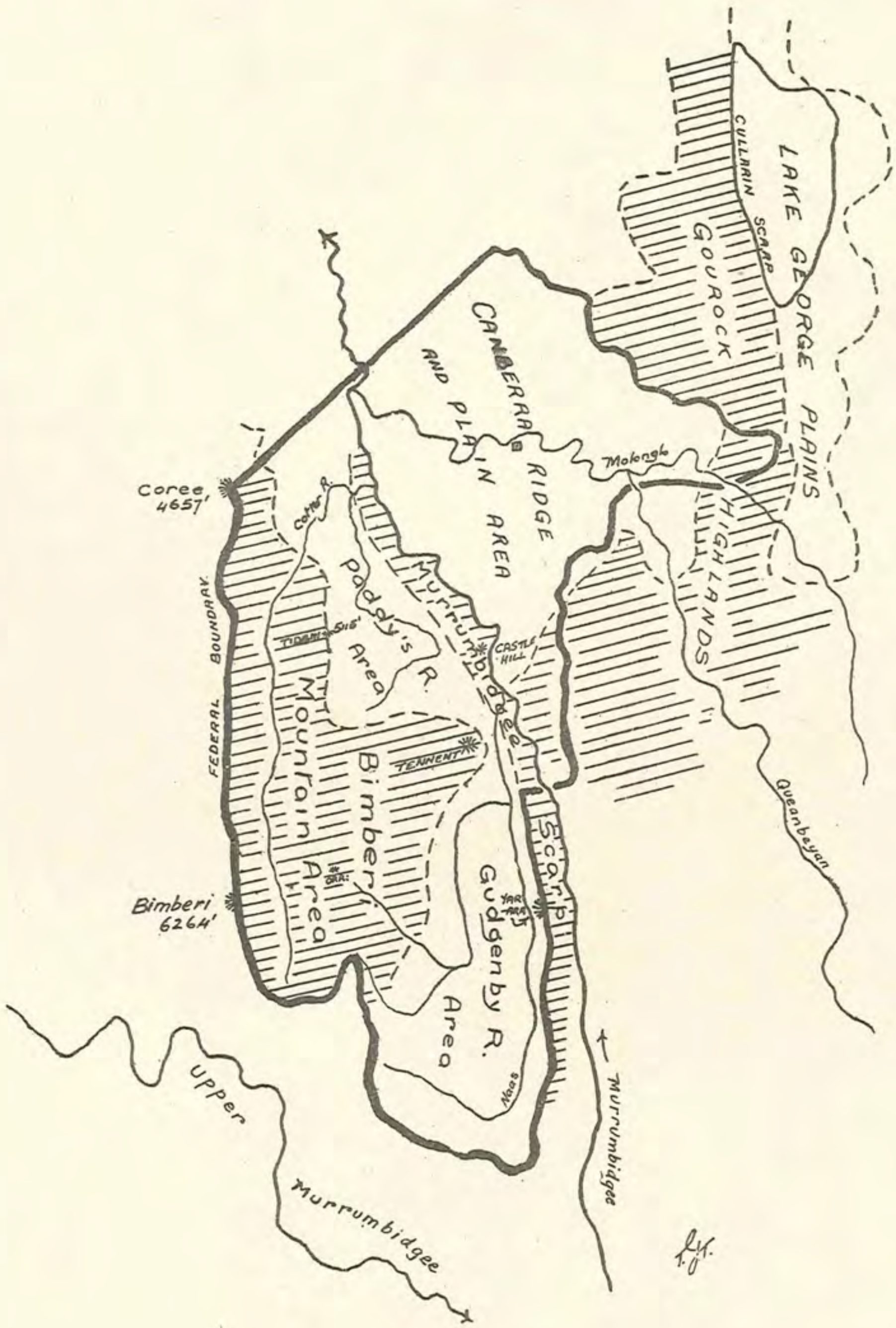
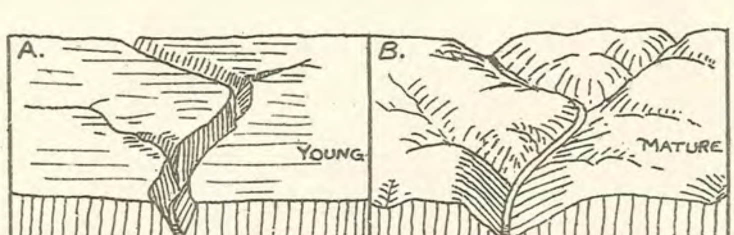


FIG. 13.— A —Sketch diagram of a "young" main valley (such as the Shoalhaven below Larbert, on the proposed Capital-Coast Railway).

B —A similar system approaching maturity (such as the Paddy's River area). Both figures after Davis.



is due to the constructive action of rivers, rather than to the destructive erosion which carves out the level peneplain. In Fig. 11 the peneplain in the top figure, consisting of rocks of varying texture all worn down approximately to sea level, might later be raised up several thousand feet. Then the rivers would start cutting out fresh valleys, and would naturally leave the harder rocks, which would for a long time preserve the general level of the preceding land surface. These hills are termed monadnocks by geographers. Something of this nature has probably given rise to the knobs of Ainslie, Mugga, Taylor, &c., but till the geology of the Territory is investigated, this cannot be satisfactorily proved.

(g) *Trans–Murrumbidgee Area.*

To the west of the Murrumbidgee the character of the country changes somewhat abruptly. There are no flat plains with isolated knobs, but restricted valleys bounded by high mountains, rising to 4,000 or 5,000 feet. The Cotter River is an extraordinarily long "gash." Probably, as Professor David has suggested, correlated with an adjoining area of uplift. The lower portions run through precipitous gorges, while Paddy's River, which occupies a comparatively open valley at its head, also enters the Cotter (near its junction with the Murrumbidgee) by gorges a hundred feet or more deep. (To the south the Gudgenby Basin (see Fig. 12) resembles that of Paddy's River.) Further to the west again, surrounding the valley of the Cotter, are the high ranges whose summits Coree (4,657 feet), Tidbinbilla (5,115 feet), Orroral (5,266 feet), and Bimberi (6,264 feet), are among the highest in Australia. Indeed, the Territory reaches within 60 miles of Kosciusko, and includes a cluster of peaks over 5,000 feet high, in addition to those mentioned.

(h) *Summary.*

Summarizing the topography of the Territory and adjoining areas, we may classify it under six heads, which are shown in Fig. 12.—

1. Lake George Plains, at about 2,200 feet elevation;
2. The Gourock Highlands, rising to 3,000 feet within the Territory, but reaching 3,500 feet further to the south;
3. The Canberra "Ridge and Plain" area consisting of ridges, of 2,600 feet elevation, alternating with plains of some 1,800 feet. These are shown in Fig. 10, run chiefly north and south;
4. The Murrumbidgee Scarp (Bullen–Yarara), an isolated ridge rising to 3,084 feet at Castle Hill, and 4,068 feet, at Yarara, to the south. It extends from McDonald, in the north, along the west bank of the Murrumbidgee, to the southern limit of the Territory;
5. A broad belt of country separated by the Old Divide, at Tennent, into the (northern) Paddy's River area, and a (southern) Gudgenby River area. It is characterized by continuous rounded ridges and moderately broad valleys, save where the two tributaries empty into the Murrumbidgee, where gorges replace the broader valleys;
6. The rugged mountainous area in the west of the Territory. It is traversed by the deep gorge of the Cotter. The highest point is Bimberi (6,264 feet).

PART 2.

The Evolution of a Land Surface.

It happens in certain localities that the later sediments are not represented. Hence fossil organisms are no longer present to give us the key to the evolution of the land surface. For instance, in the eastern portion of New South Wales the land has remained above sea level during the immense periods of time in which the Himalayas and Andes have been elevated from the sea. It is to the labours of American geologists and geographers, notably Professor Davis, of Harvard, that we owe the methods whereby the forms of river valleys have, to a certain extent, taken the place of fossils in our investigation of the movements of the earth's crust in the later periods of geological time.

Let us rapidly trace the sequence of events in a normal "cycle of erosion."* and then we can see how to explain the interruptions which have, as we already know, affected the Canberra area.

If a land surface composed of varying rocks, and probably covered by level marine deposits, were elevated gradually above sea level, it would come into the sphere of influence of erosion by wind and water. For our purpose, we can ignore the effect of wind, ice, or other influences, and confine our attention to river erosion.

Our elevated surface would constitute a true plain, and the rains falling on it would be carried to the ocean by a system of streams with normal forked tributaries. The most important points to remember are that rivers cannot erode their beds below sea level, which is their base level; and that the higher a river bed is above this base level the greater power of erosion it has, and (other things being equal) the deeper will be the valley it produces.

If the land be elevated, say a thousand feet, deep gorges will be cut into the surface by the rivers, with steep V-shaped banks (see Fig. 13A). These features characterize *young* rivers, and, conversely, a river with such a cross-section usually implies *late up-lift*. After a long interval of time (provided no fresh crustal movement has taken place) these youthful features disappear. The tributaries eat down the sides of the gorges, and the valleys broaden. The surface becomes "dissected." (Fig. 13B.) In a *mature* land surface we find the rivers depositing material in their valleys, rather than cutting them out. The divides between adjacent rivers are much lowered, and very often this stage is marked by a re-adjustment of divides, whereby a more favourably-situated stream "captures" the headwaters of an adjacent river. Further erosion tends to soften the face of the country, to smooth out the ridges, and fill up the hollows; thus forming a curious contrast to the effect of time on the face of man, where deep wrinkles and a smooth countenance occupy just the opposite stages in his evolution.

This "*senile*" type of land surface approaches to that structure we have termed a peneplain (Fig. 11A). The hard knobs have been gnawed away, and a monotonous undulating surface is the result. Obviously, in these circumstances, the aged rivers can accomplish but little in the way of erosion, and indeed the topographic "cycle" is almost complete.

But it is the exception for a country to remain undisturbed by earth movements through the thousands of years necessary for a complete "cycle." Even if it remains stable, as a whole, yet local dislocations will (within the

* The complete sequence of the phases experienced normally by the earth's surface during a prolonged period of cutting down by wind and water is called a "cycle of erosion."

disturbed area) have all the effect of a general movement, and this explains the curious mixture of young, mature, and old features which we meet with around Canberra.

Let us see if we can pick out examples of the types sketched above.

In the dry bed of Lake George we have an area which (on a very small scale) may be taken to represent the most youthful stage of all. It is younger than our hypothetical land surface—for it represents the deposits while still under the sea. The latter (marine deposits) have no tendency to be removed, for they are below base level (in this case, approximately, the low-tide mark). In the case of the Lake George silts—they also have no outlet until the Molonglo or Yass Rivers shall eat back into the inclosed basin.

We have no representative of an extended recently-elevated land surface in or near the Territory. Perhaps the mouth of the Murray—an area of recent uplift—can be taken as characteristic of a young surface in its "infantile" stages. But of the next stage—that of youthful dissection by water erosion—we have fine examples within the Territory. The small canyon, about 12 feet deep, with vertical sides—cut by the Jerrabombera Creek into a soft alluvial plain—is a miniature example of a young valley, and is of the nature of the gullies shown in Fig. 13. But we can get small gullies with steep sides on any surface whose grade is steep. *For steepness implies youth.*

The sketch in Fig. 14 shows the character of the country on the two sides of the Murrumbidgee. On the east (nearer) side is open undulating country, which we associate with the mature river valleys. On the west (scarp) side are little narrow rivulets running down the steep face and obviously young. What age is the Murrumbidgee system, with these contradictory banks?

The explanation is that the western bank has been elevated, in comparison with the eastern, in quite late geological time. Hence the streams have not had time to gnaw away this sharp ridge, which extends from Bullen for 20 miles south.

As a land surface reaches maturity the whole surface is rounded, and no sharp ridges are left. This stage is shown by the Paddy's River area, or the Gourock Highlands (Fig. 11C). In a later period the approximation to a peneplain becomes apparent, and gradually only the more resistant portions are left sticking out. This is the case in the Canberra Plains, shown in Fig. 11D and sketched in Fig. 9.

So that in our quite restricted area we have most contradictory results for the land surface. On our physiographic map (Fig. 12) we may classify the features as follows:—

1. Lake George Plains	Infantile, undissected country below base level.
2. Murrumbidgee Scarp and Cullarin Scarp	Showing youthful features with moderately deep gorges.
3. Gourock Highlands, Paddy's River area, Gudgenby area	Mature valleys, well defined rounded ridges.
4. Canberra Plains	More mature stage of erosion with big flood plains and relics of older land surface preserved as knobs.

PART 3.

Evolution of the Canberra Topography.

(*a*) *Pre-uplift Features.*

In an earlier article on the physiography of the Lake George district I have endeavoured to find the age of the fault scarp (Cullarin Range), which dammed back the lake, by estimating the amount of silt deposited in the enclosed basin. The method was rough, but the result is, perhaps, as near the truth as could be expected with our very incomplete knowledge. The fault is dated at approximately fourteen thousand years ago. Probably this is too recent, and twenty or thirty thousand would be a better estimate.

The country to the east of Lake George consists of broad valleys, with moderately high hills (*e.g.*, Governor's Hill) projecting 700 or 800 feet above them. (See 11B.) Much the same topography is met with around Canberra, with, however, more alluvial deposited in the form of broader plains. And again, in the Paddy's River area, the topography exhibits the same features; though a narrow gorge excavated in the lower portion of Paddy's River valley shows where some factor (a relative uplift) has led to increased cutting powers of the water.

We deduce from this that the last cycle of topography reached a fairly mature stage. It had not quite cut the country down to a new peneplain level, though only the knobs remain at Canberra.

There is another interesting feature present in two of the areas, whose sections are shown in Fig. 11. In the plains C and D, a distinct notch has been cut as the latest work of the Paddy's and Molonglo Rivers respectively. Why is there no notch in Governor's Hill area? Because, in the latter, the relation of the little creeks to their base level (Lake George, which has no outlet) has not been changed, while in the preceding cases the faulting of the valley of the Murrumbidgee has caused a very definite lowering of the base level, and its tributaries are rapidly deepening their beds, especially near their outlets into the big river.

(*b*) *The Canberra Tilt Block.*

Now supposing this "late mature" landscape were effected by earth adjustments in the form of two huge sub-parallel faults (see Fig. 15) in such a way that the block between the faults tilted appreciably—say 300 feet, the western margin sinking and the eastern margin rising by that amount, we should get the structure shown in Fig. 15. The head-waters of the Yass River—if they could not cut down through the fault scarp so quickly as the latter rose—would be cut off and form a lake. Such has happened, and Lake George is the result, while the older watercourse, with large rounded boulders, is to be seen at Geary's Gap, perched several hundred feet above the lake. Many other interruptions might be expected. For instance, as the fault scarp lies about 15 miles west of the old Main Divide, it is probable that the head-waters of the Lachlan have also been cut off (Fig. 15). The lakelets of the Breadalbane Plains may be relics of the Lachlan system, and so also the curving head-water of the Wollondilly. The latter seems to have captured the upper Lachlan to make up for the huge tributary annexed by the Shoalhaven, which it used to receive from the south. These changes are shown in Figs. 16 and 17.

On the sinking side of the tilt-block it is natural to find a large river. We should not expect this at Lake George, for here the fault practically coincides with the main watershed. But 40 miles from the Divide a large

FIG. 14.—Sketch of the Murrumbidgee scarp, from the foot of Strom, looking West across the River Murrumbidgee.

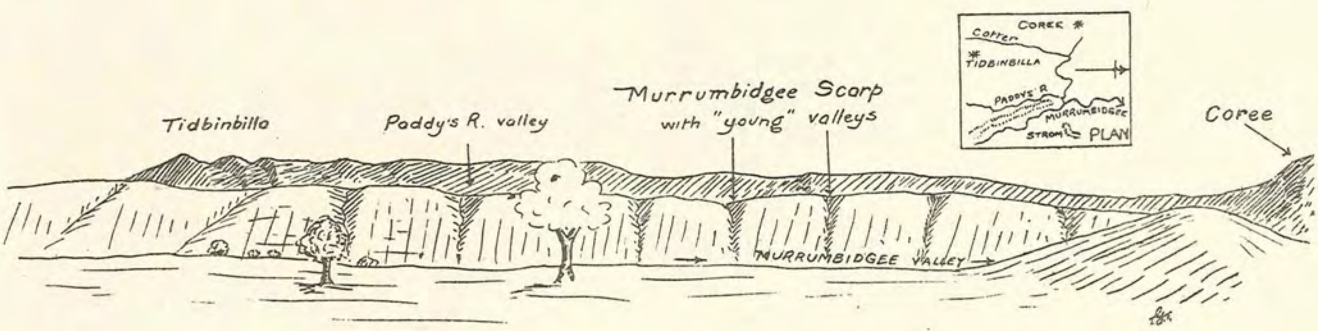


FIG. 15.—Block diagram illustrating the Canberra "tilt-block."

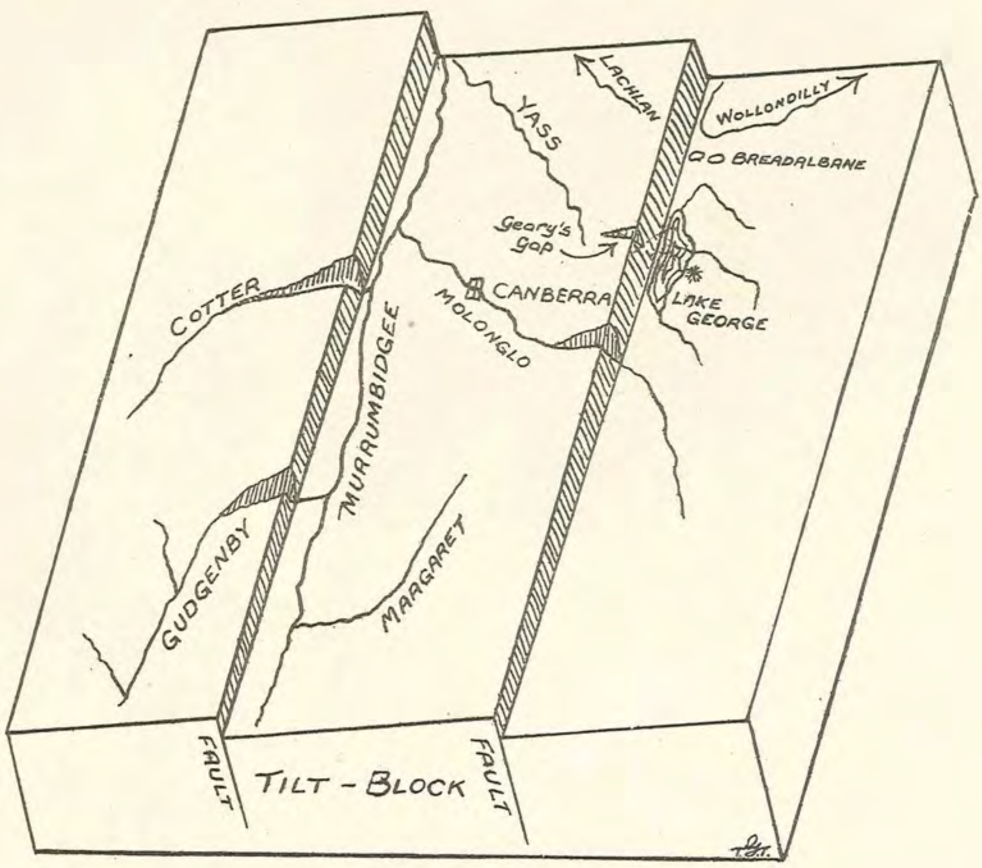


Fig. 16.—Sketch map of the present drainage of the region surrounding the Territory. The black circles indicate localities of special physiographic interest.

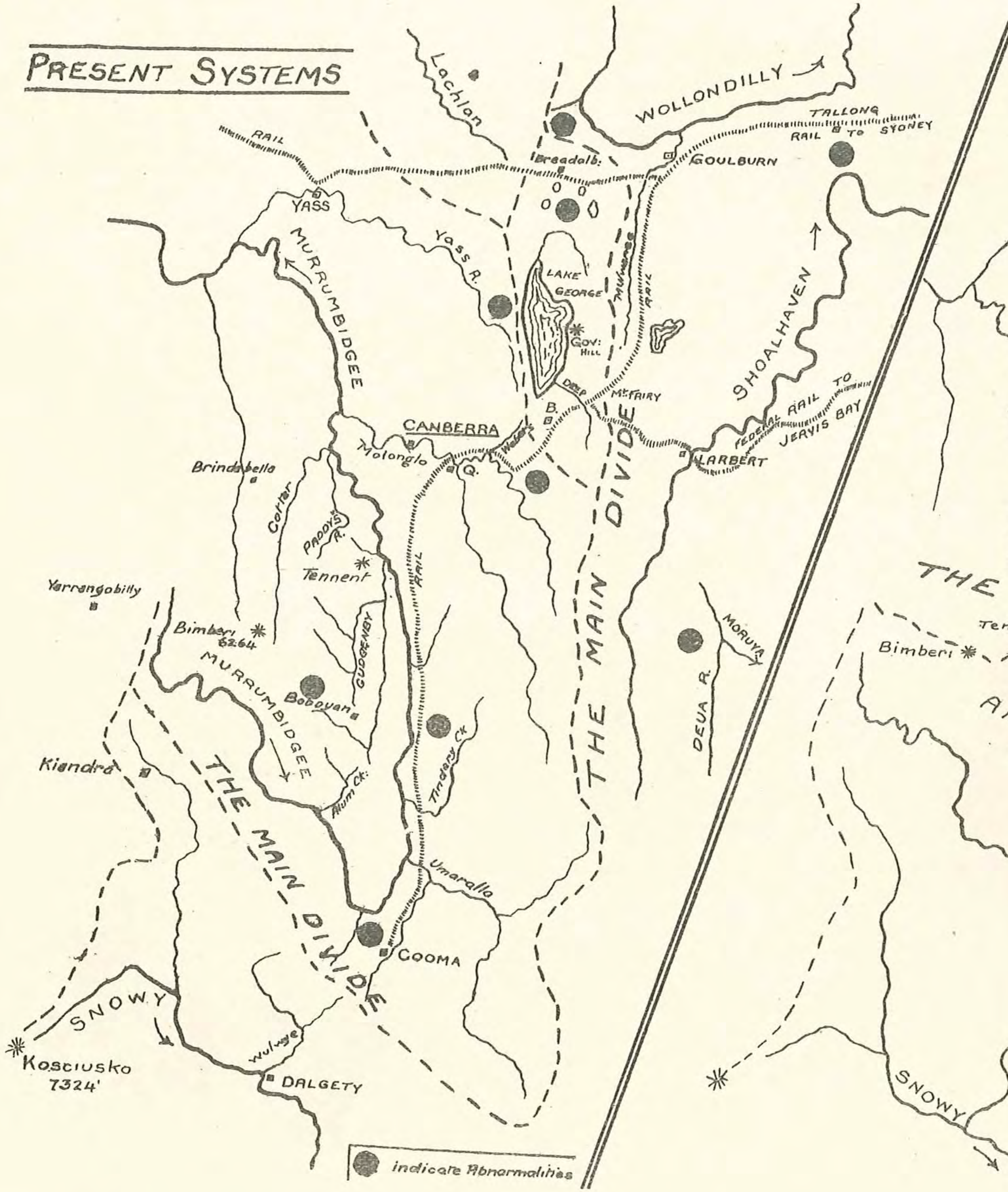
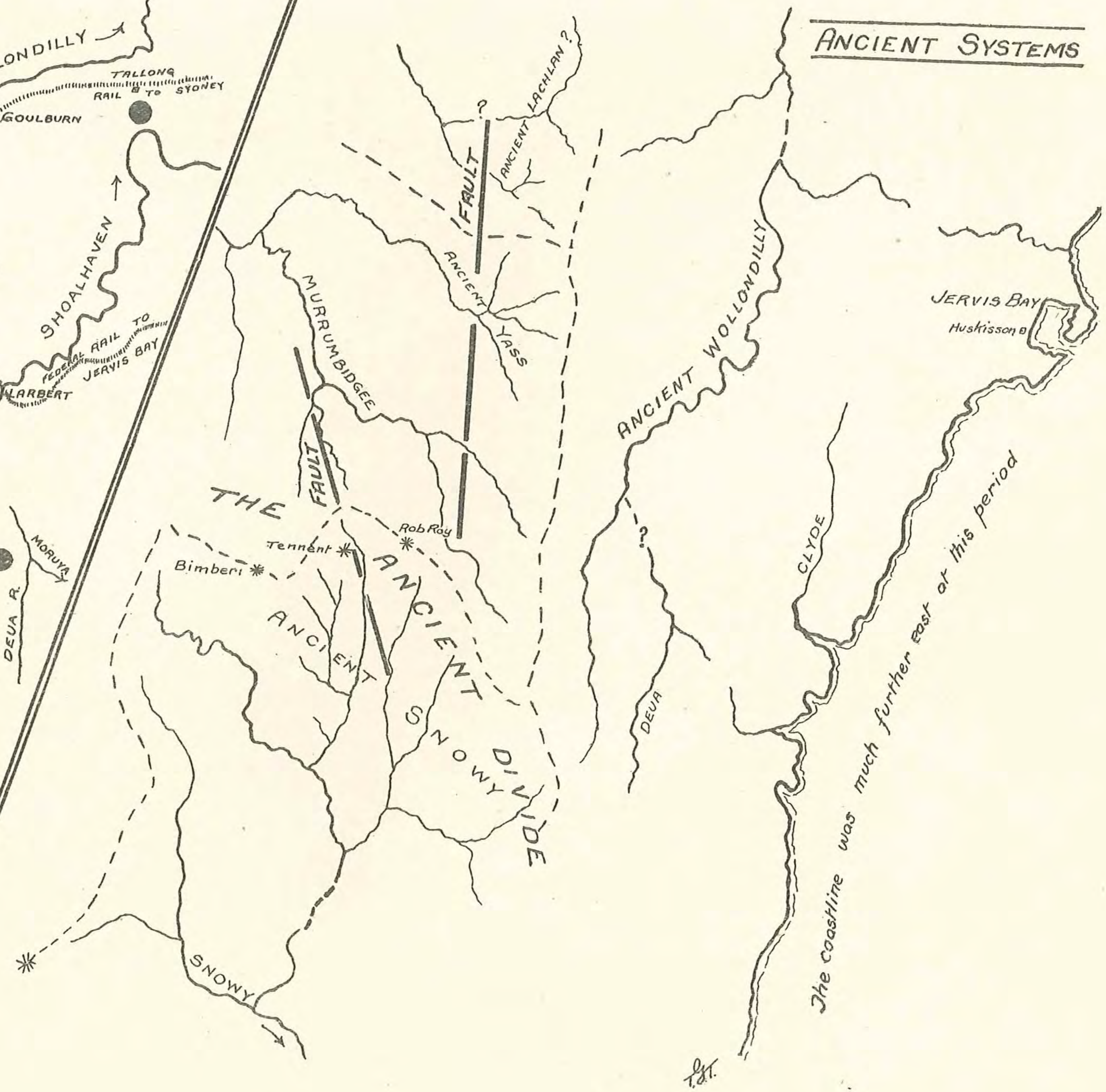


Fig. 17.—The ancient river systems, before the period of extensive faulting and folding which led to capture and reversal in most of the rivers, and moved the coastline considerably to the West.



amount of drainage would be deviated into the new valley, the middle Murrumbidgee, for this would form a rapid "get-away" due north. Not only would streams which formerly ran into the lower Murrumbidgee be deflected somewhat, but also the head-waters of the system to the south might be expected to be influenced. We have seen that this is so from the numerous "boat-hook" bends of the Gudgenby and Murrumbidgee (see Fig. 6). The most gigantic "boat-hook" of all is the whole upper Murrumbidgee, near Cooma (see Fig. 16). If these rivers have changed their course so greatly, other phenomena besides the change of direction ought to be present. The Murrumbidgee fault valley is from the tributaries point of view equivalent to a definite lowering of their "base level." In other words, it has the same effect as an up-lift; so that we get a renewal of cutting force, or a rejuvenation, as it is technically termed. This gives rise to the narrow "young" gorges—several hundred feet deep and not much wider—which mark the lower portions of the Cotter, Gudgenby, &c. (There may have been up-lift also, and, in fact, another tilt block to the west.)

We have seen that the Divide used to lie where the knot of high mountains intrudes on the Murrumbidgee valley, near Tennent. The Divide is *now* 60 miles to the south, between Berridale and Cooma, but the clashing between the two systems—the Murrumbidgee and the ancient Snowy—has resulted in the interesting "cross-fork" contours of Tharwa.

(c) *Rivers of South-eastern Australia.*

A word or two on the general river evolution in this south-eastern region of Australia may not be out of place. I have not investigated the very rough country in the extreme west of the Territory. The extraordinary valley of the Upper Cotter is quite possibly another parallel fault plane. Indeed, the Goodradigbee, Tumut, and Adelong Rivers, may all have been determined by folding or faulting in accord with the general north-south trend of the rocks in this area (see Figs. 16 and 18). The sudden bend of the Murrumbidgee to the west, near Yass, probably indicates where the river leaves the uneasy crust of the Monaro Highlands for the comparative solidity of the western flanks.

Leaving the Murrumbidgee and Snowy systems, let us look at the coastal streams. Notice the Deua and the Shoalhaven, and, to a less extent, the Wollondilly-Hawkesbury. They flow north along large valleys, and then near the mouth suddenly bend to the east. The Clyde also has this feature reversed (Fig. 17). Evidently the main drainage is north and south, and the east-west mouths are later features. Even the proposed Federal port, Jervis Bay, is probably a relic of one of these north-south valleys; but in the case of this one, most of it has vanished before the waves. The two headlands are more or less isolated from the mainland, being joined by low and narrow isthmuses.

Are there any other phenomena which throw light on this curious distribution of irregular river systems? Why do not the eastern rivers show the normal branching and regular shape of the lower Lachlan and Macquarie—with tributaries uniformly spread over the country so as to carry off the drainage in an orderly and economical manner? See how closely the eastern rivers are packed between Lake George and the Murray (Fig. 18). It is as if every subscriber to a telephone system required a separate trunk line.

(d) *The Seismic Area.*

I think the earthquake map of New South Wales, to which the Commonwealth Meteorologist drew my attention in connexion with the Canberra faults, undoubtedly helps to explain the anomaly (see Fig. 18). Some vast earth-building (tectonic) forces have robbed New South Wales of a great slice of her coast line, quite lately in geological time. The change in the main drainage is evidence enough of this. For instance, observe the way the Nepean River (near Cataract Dam) rises on the very edge of the thousand-foot sea cliff at Bulli. The other slope of its watershed has vanished beneath the waves (see Fig. 18).

It must not be supposed that these earthquake shocks (shown by black dots on Fig. 18) experienced during the last 50 years or so, are of a very violent nature. They merely mark a re-adjustment of crustal stresses. Probably many small shocks, with quiescent intervals, gradually led to the elevation of the Canberra tilt-block. The fact that the Molonglo could cut through the scarp while it was rising proves this.

But the whole of the topography of this corner of New South Wales proves that the history of the area has been a very troubled one in late geological time.

(e) *History of the Topographic Cycle.*

Possibly the history was somewhat as follows:—A continued period of rest led to the production of a peneplain of an advanced type—now represented by the 3,000 feet knobs (monadnocks) extending from the Murrumbidgee to Moss Vale. Owing to an uplift of about 800 feet, this peneplain was cut into by the grade of the rivers being steepened, and all the foregoing level country (except the aforesaid monadnocks) was completely eroded. This cycle continued to a stage of late maturity; and at that period the country consisted of broad rolling valleys, whose chief direction was north and north-west. Then, some 20,000 years ago, as deduced from the Lake George infilling, an age of unrest set in. We know of the huge simple fold which constitutes the Blue Mountains scarp (above Penrith). We know of the wonderful Nepean gorge due also to this movement. The movement extends to Mittagong, and has no doubt influenced the Shoalhaven capture at Tallong. To the south the folding has changed into actual breaks in the strata—faults, in fact—and of these we have evidence at Lake George, along the Murrumbidgee, and further south also. Probably at this period huge areas of the coast subsided—it may be as series of tilt blocks like the one described in Fig. 15.

Thus the late maturity of the topography has been considerably modified, and, owing to the differential character of the movements, the result is that "young" and "mature" features are placed in juxtaposition in a way that makes the path of the investigator difficult, both metaphorically and literally.

The edges of maximum up-lift are notched by powerful streams, which are technically known as "antecedent," because their courses date from pre-uplift dates. Numerous "obsequent" streams* of no great length have scoured gullies down the face of these scarps (*e.g.*, Grove Creek). "Rejuvenation" has affected the mature features of the area to a considerable extent, especially near the junction of the tributaries with the main river.†

---

* Obsequent streams flow in directions quite contrary to the main slope. For instance, down surfaces which are the result of secondary movements such as fault planes. Similarly, reversed streams are obsequent.

† Since this report was written I have read a paper by Mr. C. A. Sussmilch, F.G.S., published last year in the Proc. Roy. Soc. N.S.W. It deals succinctly with the region between Barren Jack and Kosciusko, and is a most valuable and suggestive contribution to our knowledge. He has investigated the region south of the territory in greater detail, and has proved that the main Murrumbidgee Valley is bounded by fault scarps, and confirms my statement that a "wind gap" near Cooma indicates where the Upper Murrumbidgee originally ran into the Snowy River.

PART 4.

Some Economic Aspects.

Since man is to some extent the result of his environment, it follows that the physiography of the territory ought to exercise some influence on the community—present and prospective—in the area.

During my short visit to the territory I was occupied chiefly in gaining a knowledge of the topography, but the following brief notes may serve as an introduction to the economic survey which it is to be hoped will some day include not only the area in question, but the whole of the Commonwealth.

The economic aspects of the physiography may logically be treated under the following headings :—

- (A) Communication (Roads and Railways).
- (B) Vegetation (Timber, Pasture, &c.).
- (C) Mining (Building-stone, &c.).
- (D) Soils (Crops, &c.).
- (E) Meteorology (Rainfall).

It will be seen that the sections are arranged for investigation somewhat after the " Heuristic " method ; *i.e.*, in the the same order as that in which the subjects concerned have interested those practical students—the settlers.

" A."—*Communication.*

Lake George is of interest in the history of Australian Exploration.

" Once the Blue Mountains were crossed the country was opened up slowly but surely by the people themselves, without the aid of needless and expensive exploring expeditions. A squatter's run in those days consisted of just so many square miles of forest or plain as he needed for his cattle to roam over. The next comer pushed out again beyond him in search of fresh country, and so the land became known. In this manner, Hamilton Hume, before he was eighteen, discovered the country round Berrima, and, again, in 1817 he discovered Lake Bathurst and Lake George, thus opening up the way for further exploration of the country round the head-waters of the Murrumbidgee. In 1823 this stream was discovered, adding a third great river to those already known which were flowing away into the unknown west."*

Hume at first thought that Lake George was portion of that inland sea which the early explorers were convinced occupied western New South Wales. But the lake is merely the expression of one of nature's latest adjustments, and is generally dry.

" From 1828 to 1864 the lake was only for one year (1852) more than 10 feet deep, so that indications seem to point rather to a continuance of the present arid conditions, so far as one is able to judge from records not yet extending over a century. The lake bottom is portioned into grazing leases, and fences run nearly across the bed. The local sheep-breeders for the most part much prefer the lake dry, since many extra sheep can be carried on their runs."†

To the west of the lake a barrier in the shape of the Cullarin Range extended for nearly 50 miles square across the path of expansion into the interior. This fault scarp rises in a steep face (often 700 or 800 feet high) above the Lake George and Molonglo Plains. But it is broken by two outlets, one far to the south—the Molonglo defile (*see* Fig. 19)—where the road crosses to Queanbeyan, and the other midway down the west bank of Lake George—Geary's Gap—where the old main western road connected Goulburn, *viâ* Gundaroo, with Yass. Both of these gaps are intimately connected with the uplift, as has been explained previously.

To the west of the Cullarin Range the country is open and was easily occupied—the Molonglo River affording an easy route across to the Murrumbidgee. Here the river valley is constricted at two places, the Tharwa gap (between Tennent and Rob Roy in the south) and the Urayarra gorge (between McDonald and Strom in the north). These were important crossings to the Gudgenby and Cotter areas respectively, and have since been replaced by the two Murrumbidgee bridges in the territory. The Tharwa bridge is determined by the Old Divide forming suitable bluffs at each side of the river. The Urayarra bridge crosses the river where slight rejuvenation has caused a trenching of the main Murrumbidgee valley.

Beyond the valleys of the Gudgenby and Paddy's Rivers are the precipitous valleys of the Cotter and Goodradigbee, separated by the 5,000 feet ranges of Tidbinbilla and Brindabella from the open country to the east. The Upper Cotter valley is still unknown. Only one or two surveyors and an occasional settler have ever been along the valley, which is completely uncharted. There are no roads except that to the few farms at Brindabella, and no settlements until Yarrangobilly is reached on the main road between Tumut and Kiandra.

To the north of the territory the country is open, and good roads lead to Yass (*viâ* Hall) and Gundaroo (*viâ* Sutton).

The Gudgenby area affords an interesting example of the effect of the fault plane on communications. The lower valleys around Naas are naturally served from Tharwa and Queanbeyan. Higher up, the river valleys (Naas, Gudgenby, &c.) become very narrow and rough, until the head-waters are reached. Here they open out again, and there are settlers around Boboyan (Fig. 16). But the communication is south to Cooma, though, from the official maps, one would suppose a high range had to be crossed. The present divide is merely swampy upland, which not long ago was occupied by rivers draining south into the Upper Murrumbidgee ; so that the settlers are unconsciously following the ancient drainage line rather than the present system.

The Cooma Railway has been affected by the two fault planes—once adversely and once favorably. The Cullarin fault scarp has necessitated the steep grades between Bungendore and Queanbeyan. Probably, as Mr. Scrivener has pointed out, with a little tunnelling a better route could be found a few miles north, *viâ* Millpost Creek (on the east) and Weber's Creek to Burbong (on the west). However, to the south the Murrumbidgee fault has formed an excellent route to the Cooma district, and the railway skirts the river the whole way after passing Royalla. The zig-zag at Tuggeranong is necessary to raise the railway over the ancient Divide, for a low-level route, *viâ* the comparatively recent Tharwa gap, would necessitate too many bridges and embankments.

" B."—*Vegetation.*

In the short time at my disposal I was unable to map the vegetation of the territory. The timber line is a fairly well marked feature, and roughly corresponds to the 2,000-ft. contour in the neighbourhood of the site. Below this line the country is open, and indeed almost treeless—partly naturally and partly artificially. The black area in Fig. 10 is, in general, timbered with moderate size eucalypts.

* Gaunt, on Early Explorations (*Picturesque Australasia*, 1890, p. 174).

† Taylor, Lake George. Proc. Linn. Soc. N.S.W., 1907, p. 337.

FIG. 18.—Map correlating the chief seismic area of New South Wales with the anomalous river evolution of the region. Each black dot (copied from a map by the Commonwealth Meteorologist) represents a seismic shock.

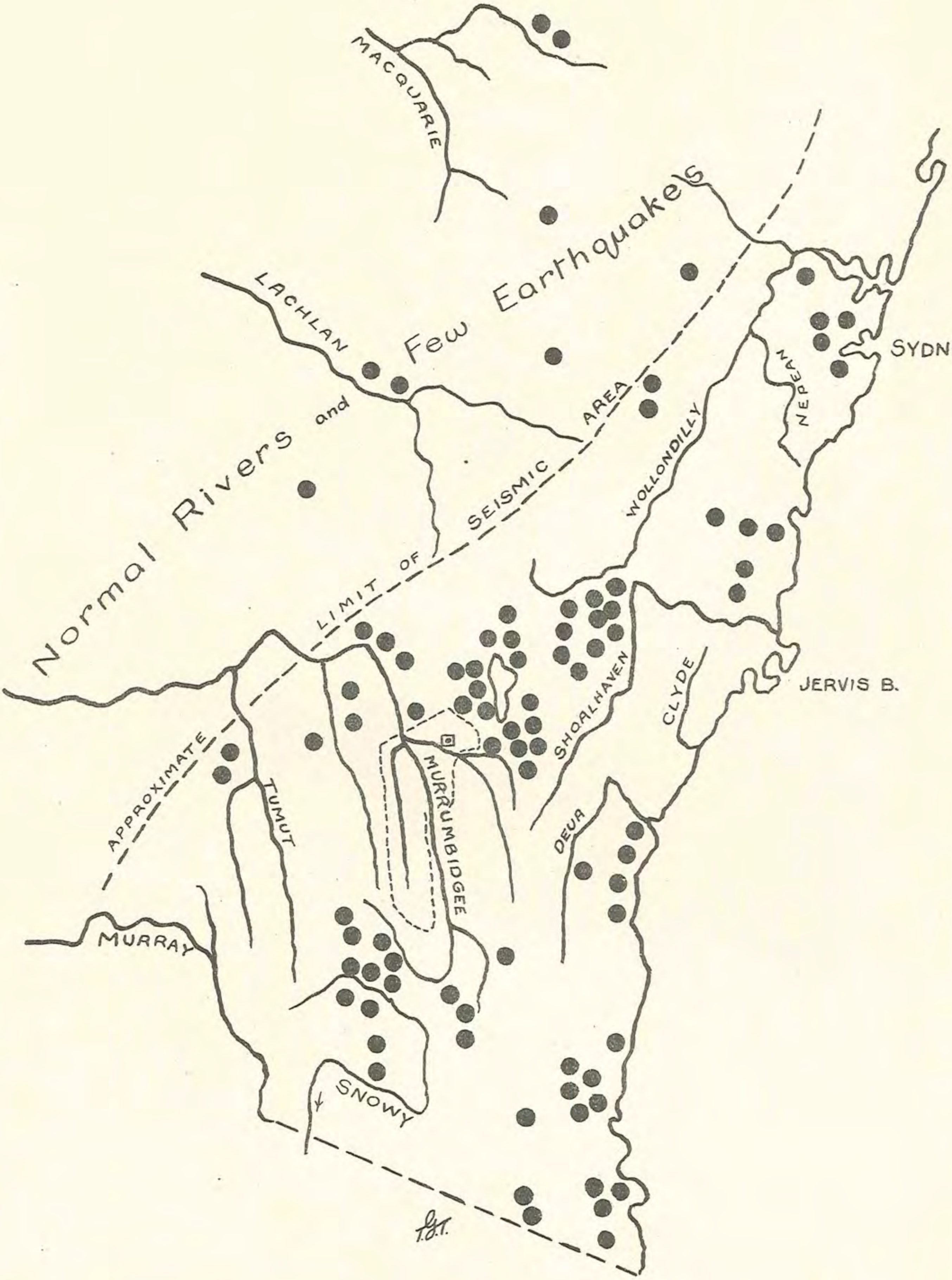


Fig. 19.—Sketch of the Molonglo defile looking South-West, showing a young gorge, where the River leaves the Plains.

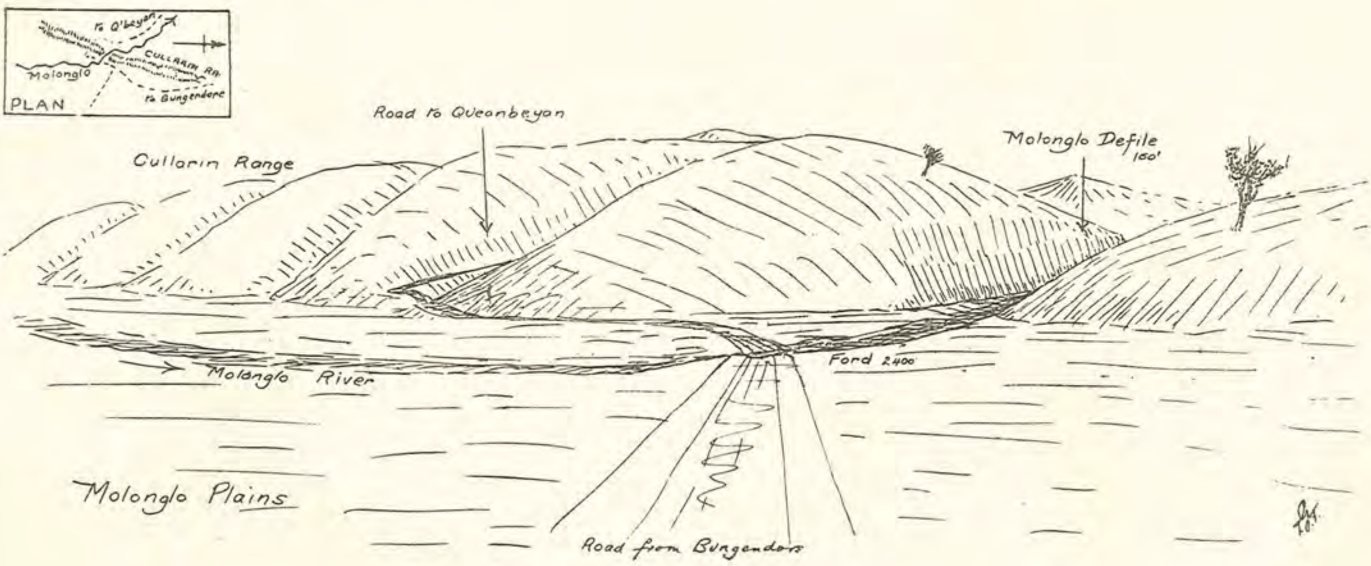


Fig. 20.—Approximate Rainfall Chart of the Great Monaro Valley.

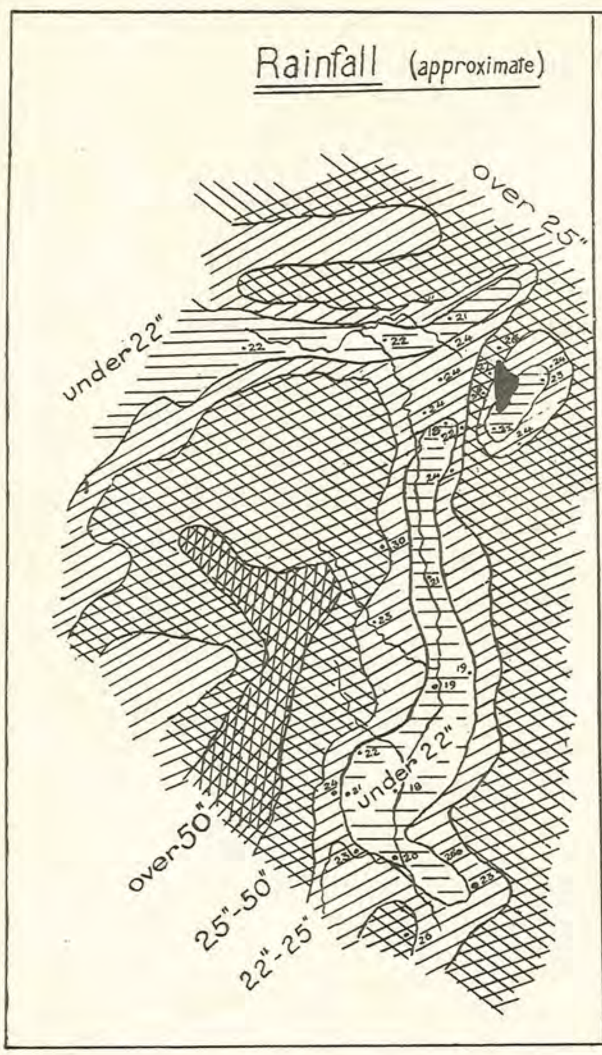
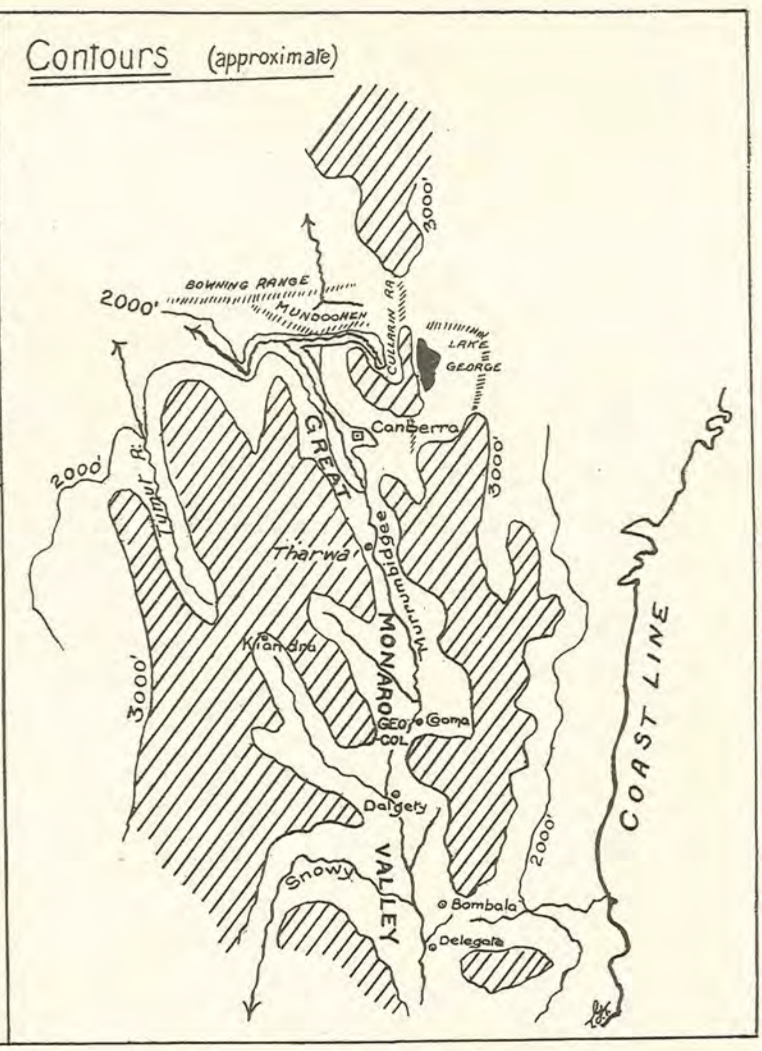


Fig. 21.—Approximate Contour Map of the same area as Fig. 20, showing the position of the Cooma Geocol.



One of the most urgent matters in connexion with the territory is that of forest preservation. The suicidal cutting and clearing of every inch of timber is appalling. The steep slopes of the ridges are covered with loose material composed of a mixture of boulders and soil. This is held together by the tree roots normally, and nourishes not only the trees, but also a certain amount of pasture. After the trees have been cut down the roots decay, and there is nothing to prevent the loose soil washing down into the gullies. The steep face of the fault scarp along the west bank of the Murrumbidgee is a glaring example of this lack of forethought. The soil is washed away too quickly for grasses to grow. The waters rush down rapidly to the creeks and bring about an alternation of floods and dry creeks, instead of more normal conditions. Moreover, in many parts of the State, actual shortage in fuel is being experienced in regions which were covered with forest less than 50 years ago. The question of planting the Capital Site is under consideration, but the destruction of native timber should be stopped immediately on all high stony grounds unsuitable for pasture; and of these there are many in the territory. For the timbered ridges control the climate of the whole area in a marked degree.

"C."—*Mining* (*Building-stone, &c.*)

"D."—*Soils* (*Agriculture*).

Sections "C" and "D" depend essentially on the geological survey of the territory, and this is in other hands. A short summary may not be out of place, however. The rocks consist of sandstones (altered often to quartzites) and limestones. These are of older Paleozoic age, probably Silurian, and their strike is approximately north and south. Of more interest, perhaps, are the extensive eruptive areas. These are of two main types; massive granites in the south, near Tharwa, and less acid and darker Dacites in the region around Canberra. The rocks which usually give rise to the richest soils—shales and basic rocks—are not present in notable quantity. Hence the country is chiefly a pastoral one. Large areas of wheat are grown, however, along the river banks, especially to the south of the Molonglo, and loads of potatoes are brought in from the Paddy's River area.

There is little mining. A copper mine near Bullen has been worked intermittently.

"E."—*Meteorology*.

The relation between the rainfall and the topography is very well marked in the physiographic area of the Upper Murrumbidgee Basin. The rainfall grade is steeper than in any other portion of New South Wales. Within a distance of 40 miles the rainfall has dropped from 64 inches at Kiandra to 19 inches at Cooma (*see* Fig. 20). But the most interesting fact, to which Mr. Hunt called my attention some time ago, is the elongated arid area extending from Bombala northwards to Queanbeyan, with an annual rainfall of less than 22 inches. This appeared to me to be a result of topography, and led me to realize that there was really a large continuous valley extending for 300 miles, from Cowra southwards over the border and practically to Orbost, on Bass Straits. The middle section of this valley I propose to call the *Great Monaro Valley*.

Investigation in the Upper Murrumbidgee Valley practically confirmed this supposition, though it showed the presence of three bars across the Great Monaro Valley, two being of recent date. One of these at Cooma has cut off the Upper Murrumbidgee from the Snowy River. Another at Delegate has cut off the Snowy from the Bemm River. The third is the Old Divide at Tharwa, which has been breached by the fault plane and eroded to a comparatively wide gap by the big river. In Fig. 21 the areas over 3,000 feet are shown as well as they can be plotted with our rudimentary knowledge of the contours in the Alps. It is seen that this region is broken into three large portions, each with an annual rainfall of over 25 inches. The Mundoonen ranges of 2,500 feet (along the north bank of the Yass River) also have a rainfall of about 25 inches. Then the parallel Murrumbidgee-Yass valley forms a drier belt with 21–22 inches. A very interesting isolated arid area is the enclosed basin of Lake George (22–23), separated by a belt of better rainfall (25–27 on the Cullarin fault scarp) from the next area. The lowest rainfall (18–19) occurs in the north of the Great Monaro Valley (near Canberra), and in the south of the valley (near Dalgety). On the flanks of the valley the rainfall very rapidly increases to 50 inches on the west and 30 inches on the east.

Naturally enough, the bounding lines in both maps can only be drawn approximately. Without doubt, when more data are collected, the agreement will be found to be more exact in some regions, and not so close as I have shown in others. Moreover, it must be noted that the direction of the prevalent winds is a factor which is independent of the topography, and may very well lead to a want of concordance between the contours and the rainfall. The question of the physical controls affecting human occupation in the geographic unit of south-east Australia forms the subject of another physiographic study, which will be published shortly.

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COMMONWEALTH METEOROLOGY.

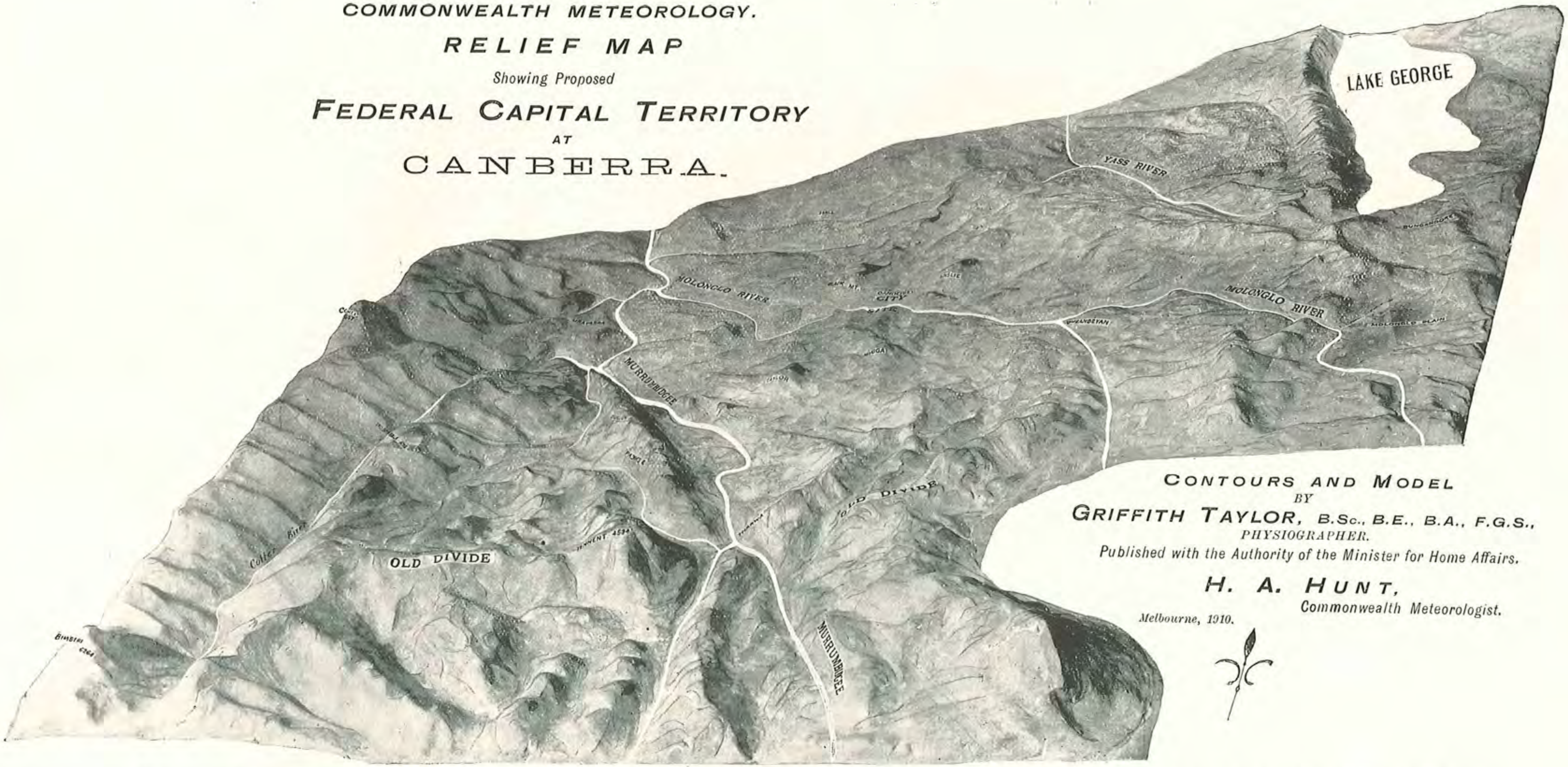
RELIEF MAP

Showing Proposed

FEDERAL CAPITAL TERRITORY

AT

CANBERRA.



CONTOURS AND MODEL

BY

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H. A. HUNT,

Commonwealth Meteorologist.

Melbourne, 1910.

The area is crossed by two fault-planes, one in the east along the Cullarin Range (broken through by the Molonglo Defile) and the other (through Tharwa) immediately west of the Murrumbidgee River. The block between has tilted, the east rising and cutting off the head of Yass River, which originally flowed through Geary's Gap. The west has sunk, and the Murrumbidgee has occupied the depression and captured many streams (Naas, &c.), which used to run into the Snowy River. Thus, Tharwa marks the breach in the ancient divide. The Cotter Gorge (along the left of the photo.) is 2,500 feet deep, and has been cut in an area of late (relative) uplift. It occupies a young valley, and rises near Bimberi, the third highest mountain group in Australia. Around Canberra occur numerous monadnocks (such as Strom), which are relics of an old peneplain 800 feet higher than Canberra.

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