SOME NOTES ON THE PHYSIOGRAPHY OF THE LAKE GEORGE REGION, WITH SPECIAL REFERENCE TO THE ORIGIN OF LAKE GEORGE.

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(With one text-figure.)

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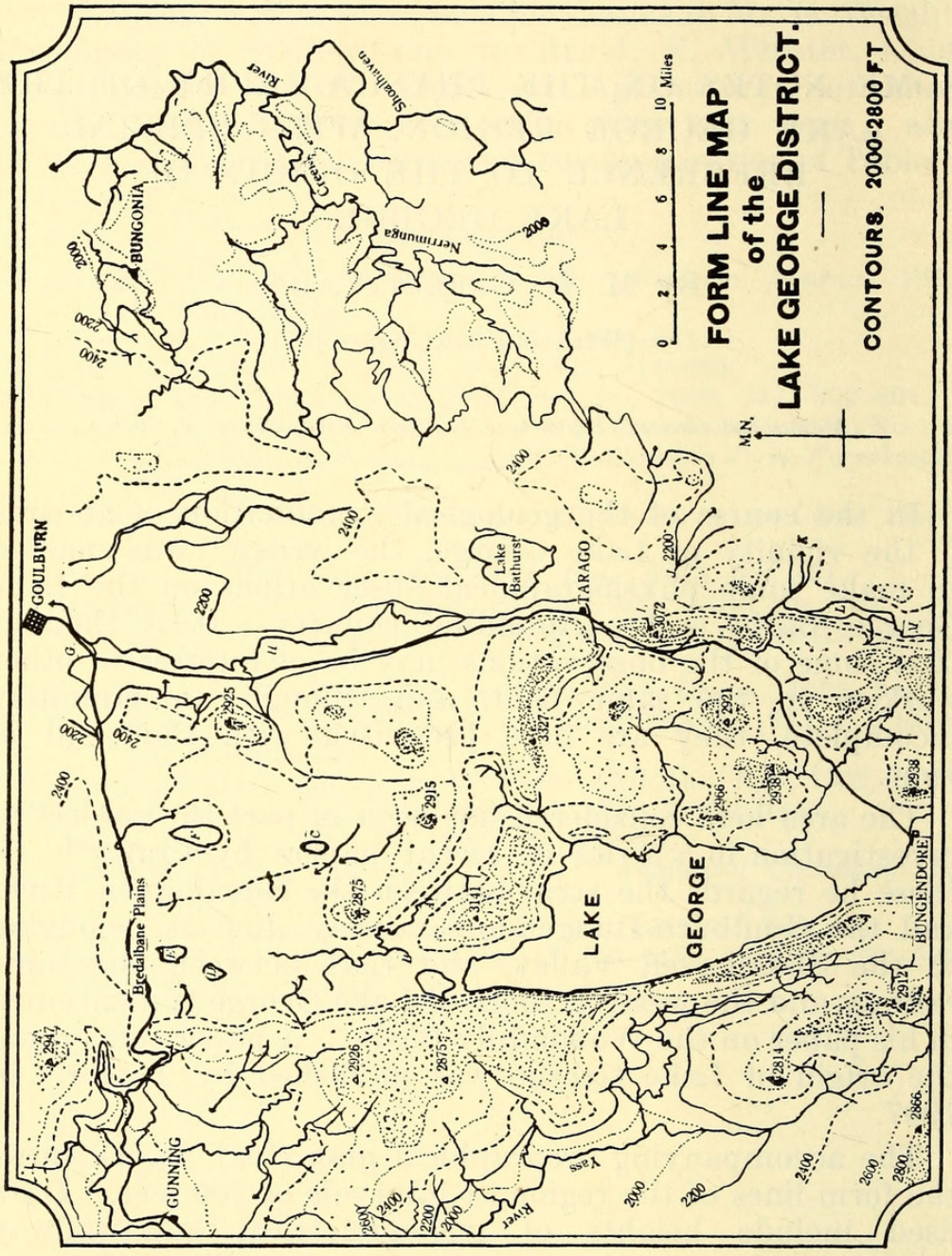
In the course of the geological examination of an area in the vicinity of Lake George, the writer[1] was enabled to make some physiographical observations on the Lake George Basin and surrounding country. It is thought that some of the observations may be of interest to other workers in the same field, and, though unfortunately incomplete, they are here presented with that end in view.

The area here considered has been in part the subject of investigation in a series of recent papers by Craft.[2] In these he regards the strip between the Shoalhaven River and the Goulburn-Bungendore railway line as belonging to the Shoalhaven Valley, and that between the same railway and the western shore of Lake George is mentioned in his paper on the Wollondilly Basin. A paper concerning the origin of Lake George was published by Taylor[3] in 1907.

The accompanying orographical map (text fig. 1) shows the form-lines of the region at intervals of 200 feet. Data used include heights of trigonometrical and railway stations, and aneroid observations by the writer. A paper by Craft has also been drawn upon for part of the area near the Shoalhaven River.

Goulburn-Tarago Railway Line to Shoalhaven River.

This section is dealt with very fully by Craft in Parts II, V, and VI of his Shoalhaven series of papers. The tract is part of what he has termed the " Shoalhaven Plain ",



Text-figure 1.

Map of the Lake George District, showing form-lines from 2,000 feet to 2,800 feet, and chief elevations. Areas between 2,600 feet and 2,800 feet are lightly stippled. Areas above 2,800 feet heavily stippled. Reference letters : Boro Ck.=J, Collector Ck.=B, Currawang Ck.=A, Dry Lagoon=D, Long Swamp=L, Mulloon Ck.=M, Mulwaree Ck.=H, Reedy Ck.=K, Run of Waters=G, Wet Lagoon=E, Wologorong Lagoon=F, Woolowolar Trig.=I, Tarago Lagoon=C.

cut at an elevation of approximately 2,200 feet (modern), mostly in pre-canyon times.

Mention must be made of the lineament of Mulloon, Upper Boro, and Mulwaree Creeks. These have been considered by Craft (V, pp. 204, 209), and he regards the whole valley as having been formerly occupied by an ancestral Mulloon Creek flowing northwards into the Mulwaree, along the strike of the country. On the entrenchment of the Shoalhaven, Boro and Reedy Creeks cut back and captured sections of it (see text figure 6 in Craft's paper). The writer has noted several facts in accordance with this. High level gravels occur on the eastern shoulders of Woolowolar Ridge, and may also be seen on the opposite side of the valley. The actual " divide " between Reedy and Boro Creeks in this valley was found to be of gravel, implying former stream continuity. Finally, the former presence of basalt in the valley, inferred from the presence of ironstone and laterite, has been proved by the finding of a patch of it still remaining[1] and of overlying gravels to the east of Woolowolar trig. station.

Woolowolar Ridge and its prolongations are regarded by the writer as being purely erosional features, and unconnected with any such faulting as was postulated by Craft (1928, p. 637), although he has, by implication, repudiated this hypothesis in a later paper. The ridge is formed of very resistant quartzites and quartz conglomerates for the most part, and is thus in striking contrast with the shale and granite zones to the east and west. At first sight the escarpment from which Sandhills Creek emerges on to the Long Swamp Plain appears to be a fault scarp, but critical examination shows that this is not the case. At this particular point it certainly is impressive, but the effect is not continued to north and south. Probably the excessively canyon-like appearance of the mouth of Sandhills Creek is due to the arrival of the steeply graded Reedy Creek.

The remaining unit of the section under consideration is Mulwaree Creek proper, which flows north to Goulburn, and is part of the Wollondilly system. This stream has eaten its way into the land surface during prolonged stability of grade and base level, and, as seen from the map, has carved out an extensive low-lying area south of Goulburn. From Tarago to Goulburn it has become so

sluggish that it well merits its name of " Mulwaree Ponds ". Further mention is made of this feature below.

Country West of Lake George Plains.

This is quite imperfectly known physiographically as well as geologically. The Lachlan and Yass Rivers and their tributaries, flowing somewhat west of north, have cut into the tableland in such fashion as might be expected in an area possessing alternate belts of hard and soft rocks, striking more or less meridionally. Both rivers show rather steep eastern banks where they run parallel with hard belts, while their western slopes are much more gentle.

Lake George Plains Area.

For the purposes of the discussion this will be taken as including all the country between the Lake George western escarpment and the Goulburn-Bungendore railway. Only brief mention has been made of it by Craft in his Wollondilly paper, but the block-diagram in that paper is useful (see text figure 7). Although the writer is not in agreement with the mode of origin of Lake George assumed in Craft's paper, the salient topographical facts are given therein, and need not be repeated here. A few points may, however, be mentioned, as being of importance.

The Breadalbane Plains represent the confluence of three drainage systems, and divides between them are difficult to indicate. First there is the Fish River, a headwater of the Lachlan ; secondly, there is a gradual slope to the north-east to Run of Waters, draining into the Wollondilly ; thirdly, there is a series of marshy pools draining south into Wologorong Lagoon, which has no outlet.

It is of interest to consider the relations of the streams and lagoons of the Lake George Plains. The principal stream is Collector Creek, pursuing a north-to-south course into Murray's Lagoon, just north of the lake. This receives a number of tributaries, such as the much more active Currawang Creek, all of which meet it in boathook bends. This latter fact may be of significance, though it has come to be regarded with some disfavour as a criterion of river capture or reversal of flow (e.g. Browne[4]). Collector Creek is sluggish ; there is a rise of not more than about 40 feet up this valley from the Lake to the divide between

it and the Breadalbane Plains. This divide itself is marked by the presence of two lagoons, Wet Lagoon and Dry Lagoon. Wologorong Lagoon is mentioned above as having connection to the north with Breadalbane Plains. Tarago Lagoon has an outlet over a low bank of gravel into a tributary flowing north to Collector Creek.

To sum up, the impression given is that the drainage between Lake George and Breadalbane Plains is a meridional one which has lapsed into senility, and is marked by lagoons and marshes.

Area North of Breadalbane Plains.

North of the Goulburn to Gunning railway line there is an area of distinctly higher country, in which the Upper Wollondilly has incised a valley which has barely reached maturity. A fault has been postulated between this area (not shown on the map) and the Lake George Plains—the Norwood Fault—by Craft (1928) on physiographical grounds. A break here is clearly seen by the traveller along the main southern line who compares the country to his north and south in the vicinity of Breadalbane.

The Problem of Lake George.

The Lake has been explained by Taylor[3] as due to the geologically recent formation of a fault throwing to the east along the western margin of the present lake, and the consequent damming of the westerly flowing streams. The evidence he adduces need not be repeated here, but a few points will be noted.

An examination of the map will show (text fig. 1) that consideration of either the general level, or that of the summit plane, on each side of the supposed fault-line does not suggest faulting. Bias may be caused by the large area above 2,800 feet to the north-west of the Lake, but in this area few data are to hand ; the area shown on the map is certainly a maximum, and should perhaps be really much smaller. Again, the actual peaks indicate a much greater height (up to 3,327 feet) to the east of the line than to the west. This effect of continuity of surface would have been even better portrayed by an extension of the map further southwards.

The map also shows that characteristic valley systems occur in uninterrupted fashion in the Yass and Lachlan basins on the west, and the Wollondilly basin on the east

(Mulwaree Creek). The Lake George western escarpment and its less imposing meridional extensions appear to play the rôle of a normal headwater ridge between two river systems. The contrasts drawn by Taylor between the degree of development and grade of streams on the eastern and western sides of the escarpment were found on examination by the writer to be of doubtful strength.

With regard to the so-called antecedent Molonglo and Fish Rivers, the latter near Cullerin has been described by Craft (1928) as entrenched by the uprising of the Cullerin scarp, but it seems to the writer to be no more youthful in appearance here than are parts of such normal streams as Sandhills Creek (headwaters of Reedy Creek), and to demand no special explanation. The case of the Molonglo seems to have been rather exaggerated by Taylor. Certainly it has a fairly wide headwater valley, and a rather restricted middle valley, but so also have other streams which cut through resistant ridges but expand in softer rocks upstream. A topical example is Merigan Creek (headwaters of Mulwaree Creek), with flood-plains half a mile wide, but lower down narrowing greatly in the vicinity of the more resistant ridge near Tarago. Contortions in the sections of the so-called scarp in the Molonglo district were thought by Taylor to constitute evidence of crushing near the fault. Such contortions have also been noted by the writer about two miles west of Bungendore, but he thinks that they must all be much older than Tertiary. In fact the formation of such folding, in preference to brecciation, so near the surface in late Tertiary time seems quite unlikely.

The importance of the high-level gravels south-west of Geary's Gap is difficult to assess. The facts as given by Taylor seem undoubtedly to point to a former north-westerly flow of a stream, of fairly steep grade, across their position on the present escarpment. An examination in the field confirms this view. The question arises, however, as to the antiquity of such a stream (the idea of lacustrine origin seems untenable for various reasons, including slope of the base of the formation). Little importance can be attached to the unconsolidated nature of the gravels from the point of view of age, since gravels may persist in this way to an amazing extent. A case in point is that of the pre-canyon gravels and clays of the Shoalhaven Valley ; thicknesses of these up to 80 or 100 feet have been seen sawn through by the gorges of such

streams as Nerrimunga Creek. On the latter, near Jasper's Gully, such a truncated deposit stands literally on the edge of a gorge 1,200 feet deep, and seems stable. Again, as shown in the very section given by Taylor, dissection of the postulated stream channel in a crosswise direction has been considerable—and that accomplished by mature streams. It thus seems quite feasible that the gravels could be relics of a long extinct cycle of erosion in which the local base-level was at (about) the relative height of the present ridges. An objection to this view may be based on the presence, on the lake floor, in the same line as the gravels, of what is apparently a silicified gravel or "grey billy". This differs, however, in the important respect of silicification, and could easily be due, in its present position, to an outpouring of basalt, now removed, on to the low-lying area of the lake floor. This explanation would indeed tend to suggest the pre-Pliocene existence of the present low-lying lake area.

It should be mentioned that the suggestion by Taylor of the lake silt's being about 200 feet thick is merely an expression of opinion. The writer is not aware of any evidence for a depth greater than thirty feet—that reached by wells sunk into the lake. The contouring of the bedrock of the lake would perhaps form a fit subject for investigation along geophysical lines.

Tentative Suggestion as to the Origin of Lake George.

Although sufficient work has not been done to justify a definite conclusion on the matter, one is emboldened to suggest an alternative mode of origin for Lake George and its associated escarpment.

The features of drainage mentioned above make it clear that a small northward tilt of the Lake George Plains area would convert it into a normal stream system passing into either the Fish or the Wollondilly system. The suggestion is made that down-warping of the area relative to the country to the north took place along the Norwood Fault—or Warp. Instead, however, of a clean break at this point, a kind of ramp was formed, by a general tilt to the south, or by a series of small warps. Precedent for this is found in the block to the north of the Norwood Fault in that there is a gradual rise or tilt upwards from Tarlo to Taralga. There seems no reason why this should not also have been the case to the south. Such tilting would cause stagnation

of the Lake George River system, and cause the formation of the lake itself as well as the numerous lagoons. It may also have played its part in the stagnation of Mulwaree Ponds. Local irregularities in the tilting, perhaps a sagging, or local faulting, would be competent to cause the formation of transient base-levels, or pene-base-levels, along the stream and its tributaries, at which would be deposited alluvial fans and gravel beds. Failing these tectonic irregularities, even antecedent irregularities in the stream gradient, due to such causes as differential hardness, would be empowered by a regional lowering of the gradient to cause such deposits. Perhaps to these causes the gravel barriers of Tarago Lagoon and others, and even that between Lake George and Murray's Lagoon, are due. This latter conspicuous gravel bank is by its very size grossly out of keeping with the storm hypothesis of Taylor.

On this view the western escarpment of Lake George must depend for explanation on differential erosion. Although the argument in this paper has been directed at discounting the presence of a fault scarp of late Tertiary or post-Tertiary age, it does not exclude the existence of older faulting, of Silurian age, for example, but the evidence for such an uncovered fracture, or fault-line scarp, is entirely wanting at present. In any case the present explanation of differential erosion would not be thereby affected. Escarpments just as impressive and due to differential erosion are to be found at Michelago and other places between Cooma and the Federal Capital Territory. Examination of the geology of the Lake George escarpment reveals evidence in favour of an erosional origin. It is composed in large part of relatively hard felsite and porphyry bands, outcrops of shales, as at Geary's Gap, resulting in a notable lowering of the ridge. Numerous instances of meridional ridges in the region shown on the map have been verified as consisting of resistant rock-types. The fact that the strike of the rocks is parallel to the old Lake George River system would considerably aid the formation of the ridge. Of great significance also is the fact that in the actual escarpment the dip of the rocks is to the west, resulting in accentuation of the slope on the east, and its modification on the west. The fact that the escarpment supports rock *débris* and alluvium, with stable vegetation on them, points to its own stability, and discounts the statement that it is being " actively eroded ".

Summary.

The region considered is comprised of several distinct sections : (i) The Shoalhaven Plain, from Tarago to the Shoalhaven ; (ii) the headwater districts of Lachlan and Yass Rivers ; (iii) Lake George Plains, with lagoons and senile drainage ; (iv) the Norwood Warp. The significant features of each are discussed where pertinent to the origin of Lake George. The evidence for Taylor's fault hypothesis is examined from a number of aspects, and the tectonic origin of the western escarpment questioned. An alternative explanation based on stream development and gentle warping is tentatively submitted.

References.

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(4) Browne, W. R. : Note on the Relation of Streams to Geological Structure, with Special Reference to Boathook Bends, *Jour. Roy. Soc. N.S.W.*, 1921, *55*, 52.