GEOLOGICAL NOTES ON THE COUNTRY BETWEEN THE YASS AND SHOALHAVEN RIVERS.

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(With Plate VIII and one text-figure.)

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The following notes have been compiled as a result of scattered observations and traverses made between 1931 and 1935. The accompanying map is intended to portray the broad relations of the rock-systems and to serve as a guide to future workers. In its preparation cognisance has been taken of the work of Carne and Jones (1919), Craft (1931) and Naylor (1935), in so far as it impinges on the area ; for a detailed map of the Lake George district, see a paper by the writer (1936).

Upper Ordovician.

Of the several belts shown on the map, that on the east is the best known. Slates, phyllites, sandstones, grits and quartz-schists are the rock-types ; in the river gorges they are fresh and resistant, while on the plateau level they are soft and much weathered, and differ considerably from the former in appearance. Graptolites were not found in the area mapped, but numerous occurrences of crustacean carapaces are very similar to carapaces found in association with Upper Ordovician graptolites lower down the Shoalhaven at Badgery's Crossing and Tallowal Gully.

Upper Ordovician graptolites have recently been described (Naylor, 1935) from I.9.* This seems at present to be an isolated occurrence.

Fossils have not been found in the area marked as Upper Ordovician to the west of Lake George. In his paper on the Yass District (1912) A. J. Shearsby notes on his map a belt of shales extending south from Gunning to the Yass River, and he calls them the Gunning Shales ;

* Grid reference to map.

this belt he regards as homotaxial with the Jerrawa Shales, and of Upper Silurian age, on lithological grounds, apparently. The general occurrence of phyllites, slates, schists and schistose grits, as well as strong folding and crumpling such as is found on the Shoalhaven River, has guided the writer in regarding these rocks as Upper Ordovician. The rocks are much more altered than the Silurian to the east—both the Upper Silurian of Mount Fairy and the possible Lower Silurian of Collector. Moreover, in this extensive belt there is a total absence of limestones, which is strong circumstantial evidence in view of the common association of this rock with the known Upper Silurian belts.* What is undoubtedly a remnant of the same belt is found at Cullarin, 9.C.

The evidence is overwhelming that the Ordovician rocks form a closely folded unit. Innumerable sections exposed by the Shoalhaven and its tributary creeks point definitely to isoclinal folding, and the same conclusion is reached from numerous strike and dip determinations on the plateau level; only a few such are shown on the map.

Lower Silurian.

Naylor describes Lower Silurian fossils from near Bungonia (p. 124) in rocks which "appear to dip under a more arenaceous formation of Upper Ordovician age" to the west. This is the only definite Lower Silurian area in the region under discussion, and according to Naylor's section (p. 128) it would seem as if the Lower Silurian may be expected in a narrow zone only. The zone to the east of Lake George marked on the map as being of "doubtful age" should perhaps be mentioned here. No fossils have thus far been found in this belt, other than rain-prints and ripple mark in D.7, and one is reduced again to tentative lithological correlation. While there does not seem sufficient evidence to suggest an Ordovician age, since the rocks do not show the degree of regional metamorphism and folding exhibited to the west of the Lake, there is on the other hand a distinct appearance of greater age when compared with the Mount Fairy (Upper Silurian) Series to the east. Whatever be their age, there seems no doubt

* Since the above was written, Upper Ordovician graptolites have been collected from the Jerrawa shales by Mrs. K. M. Sherrard (*Proc. Linn. Soc. N.S.W.*, 1936, *61*, Abstract of Proceedings, 1).

that the rocks of this belt will be found to have preceded those of the Mount Fairy Series. The writer has in a recent paper (1936) suggested that the amphibolites of the eastern margin of Lake George may be pre-Upper Silurian, which would imply that the associated injected sediments would be at least as old, though no attempt is made in that paper to subdivide the sediments. The boundary between this doubtful zone and the Mount Fairy Series on the accompanying map has been so drawn as to include, (i) the amphibolite-bearing areas, (ii) areas near Lake George which in the field present a rather more ancient appearance than the Mount Fairy Series, including outcrops in E.5, E.4, E.3 and F.4, and (iii) a zone exposed in the Travelling Stock Reserve, F.9-10, just east of Yarra, which is very similar to that in F.4.

Upper Silurian.

The Upper Silurian rocks occur in two belts, very probably the opposite limbs of a large fold structure, and are among the best known strata of the region. The belt running from K.10 south to J.4 was examined mostly in its northern section. The limestones occurring between Bungonia Creek and Bungonia, K.9-10, have been described by Carne and Jones (1919). They are definitely of Upper Silurian age. Further south, an Upper Silurian cyathophylloid form was found in a mass of silicified limestone, and, nearby, shelly fossils in fine sandstone ; these included chonetoid types considered by the late Mr. W. S. Dun to be of Upper Silurian age. This locality is marked on the map as fossiliferous, in the south-western corner of K.8. Further south still, near Windellama, in J.6, occur beds of limestone regarded as Upper Silurian by Carne and Jones ; this age was also confirmed by Mr. Dun after examination of fossils collected by the writer. As at Bungonia (and further north at Marulan), the Windellama limestone consists of two belts (see Fig. 1).

With regard to the age of the belt stretching to the south of Goulburn, we have the northwards continuation through the Upper Silurian limestones of Baw Baw and elsewhere ; to the south we have a belt of definite Upper Silurian limestone extending for about nine miles south of Mount Fairy. Other fossils are not known from this belt. Apart from limestones, the Upper Silurian sediments are chiefly shales and fine sandstones. Occasionally a tendency to slaty or phyllitic forms is noted. As with the older

systems, there is every evidence that close isoclinal folding has taken place ; this is dealt with in detail in the paper on the Lake George District.

Devonian.

There appear to be representatives of both Middle and Upper Devonian in this region, but these are not distinguished on the present map. The writer (1936) has already described the best known of the Middle Devonian occurrences—that near Tarago, G.4. *Favosites* sp. and *Receptaculites australis* were taken as indicating the Middle Devonian age of a group of limestones which appear to underlie a synclinal structure of red-bed conglomerates, sandstones and quartzites, and felsites, some of which are doubtless Upper Devonian. Further north, at Lake Bathurst, the writer has collected numerous fossils from several limestone horizons. This assemblage includes *Receptaculites australis*, and some brachiopods of Devonian aspect. There is also evidence of the red beds again hereabouts. Other narrow limestones and calcareous olive shales occur in creeks to the south-west of Tarago township, and these have been provisionally regarded as also Middle Devonian. But it is not impossible, especially in view of the rather sharp folding of these latter beds, that they are inliers of Upper Silurian exposed by down-cutting through the Devonian. It will be noted that the occurrence is directly on the line of the known Upper Silurian belts in this district.

In the neighbourhood of Tarago the limestones are followed by red conglomerates, and then a group of massive quartzites and felsites, which form prominent peaks and ranges. This is similar to the succession near Goulburn, where red beds of the same type are seen to underlie the quartzite mass of Governor's Hill.

Another belt of Upper Devonian, divided by an elongated granite intrusion, is to be found near Bungonia. The rock types include sandstones, tuffs, slates, and possibly igneous flows. From Bungonia to Windellama, I.6, the rocks are distinctly different in type from those of the Silurian and Ordovician nearby, and moreover, have much shallower dips. Naylor (1935) seems rather inclined to doubt the existence of Upper Devonian (Lambian) rocks in the vicinity of Bungonia. However, fossils have been collected from several localities. In J.9, fossils are rather scarce in the sandstones, but casts of brachiopods and lamelli-

branchs were obtained, and identified by the late Mr. W. S. Dun as of definite Upper Devonian age. Moreover, at a point further south, on Jacqua Hill, J.8, fossils were obtained in ripple-marked sandstone; these include *Lepidodendron australe* and other forms, stated by Mr. Dun to be indubitably of Upper Devonian age. Thus, even were the sandstones on the Bungonia-Goulburn road not Upper Devonian, the structure suggested by Naylor would still have to accommodate the Upper Devonian at Jacqua Hill. Shelly fossils may also be found on Lumley Creek, in central J.9.

Another question raised by Mr. Naylor is that of the age of the limestone on Jerrara Creek, south-western J.10. A Devonian age was suggested by Carne and Jones (1919), but it has been provisionally classed by Naylor as Upper Silurian (p. 126), a conclusion which apparently he did not find to conflict with his conception of the structure, for he states: "These limestones dip to the west along with all the other series in this part of the district. They therefore appear to underlie the Jerrara Series [Lower Silurian], and though the latter has not yet been traced as far north as portion 46, the overlying Upper Ordovician belt has been identified (both lithologically and palæontologically), in portions 270 and 271, ph. Jerrara, a little to the west of the most northerly outcrop of limestone." While the writer also examined the limestone outcrops, and failed to find diagnostic fossils, and would prefer to retain an open mind on the question of their age, it is interesting to consider the implications in each case. The southernmost limestone outcrop lies to the east of the fossiliferous horizon* of the Lower Silurian, and thus dips could take it under the Lower Silurian without difficulty. As, however, on Jerrara Creek the Ordovician occurs a little to the west of the limestone, it leaves scant room for the Lower Silurian, which occupies a quarter of a mile on the road. While the writer is well aware that contour, thinning of beds, and the incidence of isoclinal folding may considerably affect width of outcrop, he has not as yet a clearly defined mental picture of a succession of Upper Silurian limestone, Lower Silurian and Upper Ordovician at this point, especially in view of the variable dips and strikes. The

* Boundaries of Lower Silurian and Ordovician, and the fossil-bearing locality, are transferred from Naylor's map.

line of the limestone outcrops and the strikes of the rocks to the east of them, including the fossiliferous Devonian, are west of north, while the few strikes taken in the Lower Silurian are meridional or somewhat east of north. Should the limestone turn out to be Devonian in age after all, no radical alteration of structure would become necessary, for the writer's conception of the Upper Devonian of the region is that it is only a residual veneer, and that down-faulting need not always be called into play to explain isolated occurrences.

An area, extending from the Goulburn-Bungonia road southwards past Lake Bathurst has been left blank on the present map. This was previously regarded by the writer as of Devonian age. At various localities rocks were observed which seemed most closely related to the Upper Devonian. In particular, for some miles towards Bungonia from Goulburn, tuffs, felsites and shales were observed similar in appearance to the Upper Devonian on Bungonia Creek. However, no palæontological evidence one way or the other is to hand, and since Mr. Naylor regards much of the stretch between Goulburn and Bungonia as Upper Silurian, it has been thought wisest to defer consideration of this zone. Outcrops are poor in this region.

On the maps of the geological survey Devonian rocks are shown as outcropping on the eastern bank of the Shoalhaven in the vicinity of L.8. I have not examined this eastern side of the Shoalhaven in very great detail, but have no doubt that outcrops of Devonian rocks of any size do not occur, Ordovician and Kamilaroi being the only systems found. Their strike, if meridional, would carry them into the belt marked as Devonian on these maps between Yalwal Creek and Badgery's Crossing. These outcrops are not shown on the present map, as the writer believes that they do not exist, since he has found Ordovician rocks continuing downstream, which are unconformably overlain by Devonian only to the east of the Kangaroo River.

Kamilaroi.

Strata of this age occur only in the extreme north-east of the area, forming cliffs at intervals along the eastern bank of the Shoalhaven River.

Tertiary.

Chief among the Tertiary sediments are the high-level gravels and clays occurring in belts parallel to the Shoalhaven (see papers by Craft). Tertiary lacustrine deposits also occur, and include deposits of laterite, and fine sandstones altered by contact metamorphism by later basalt flows. Laterite is found chiefly in I-J.8, K.7 and G.4. Manganese, cobalt and nickel-bearing Tertiary sands are also common in isolated patches for some miles south of Bungonia. Plant fossils are found in the Tertiary beds in K.10, and in contact quartzite near the silicified limestone in south-western K.8. Tertiary basalts are common, in scattered residual patches, as in J.9, I.8, K.8, I.6, G.4 and F.10.

Igneous Rocks.

Amphibolites.

The occurrence of these has been fully dealt with elsewhere by the writer (1936); it is suggested that they probably represent basic intrusives of pre-Upper Silurian age.

Granites.

It is quite certain that granites of at least two ages are present in the region, but the age of the individual bosses is in many cases obscure. Each will be dealt with separately.

All that can be said of the granites west of Lake George is that they apparently cut sediments of Upper Ordovician age; no upper limit of age can be given. The rocks vary from hornblende-biotite-granites to quartz-felspar-porphyries. Strong crushing of the rocks is in evidence. At the contact with the slate tongue near Cullarin, excellent sections of various stages of assimilation of sediment by gneissic granite may be seen in large road-cuttings; all stages of transition are found.

The writer has elsewhere given reasons for assigning an epi-Silurian age to the granite on the eastern shores of Lake George, and the same doubtless applies to the mass just east of Bungendore. Partly digested masses of amphibolite may also be found in the latter. It is probable also that the Wologorong mass, E.7-8-9, is a similar continuation of this epi-Silurian granite northwards. It is chiefly a crushed biotite-hornblende granite, with

abundant microperthite. Amphibolite masses may likewise be found in this granite.

The Boro Ganite, H.1-5, may easily be of later age. Although sheared zones occur, uncrushed hornblende-biotite-granite with no trace of directional structure is quite common. It is considered that this granite may be of epi-Devonian age.

The Bungonia granite, K.8, with which may be linked the Nerrimunga Creek intrusion, L.8, appears to be definitely of epi-Upper Devonian age. Transgressive relations with the Upper Devonian are found on Bungonia Creek. Granite at Bungonia itself grades northwards into porphyries and porphyrites towards Jerrara Creek and to the north-east. Southwards granodiorite is found, and towards the western margin aphanitic types again occur. Biotite is the chief ferromagnesian mineral of the granite. The Nerrimunga Creek intrusion exhibits pronounced differentiation, with formation of hybrids between earlier and later types.

Metamorphism by the Bungonia granite is more pronounced than was observed in the others. The silicified limestone five miles south of Bungonia may be due to the granite intrusion. Nearer the junction, quartz-pyroxene hornfels may be found at the dip arrow about one and a half miles south of Bungonia; the rock also contains titaniferous magnetite. Biotite-cordierite hornfels occurs on the western boundary of the granite in J.8. Altered rocks such as cordierite hornfels are common near the Nerrimunga Creek mass.

Quartz-Dolerite Dykes.

These are very common in the area, especially in the eastern division, and are exposed chiefly as dykes cutting the older Palæozoic rocks in the gorges of the Shoalhaven and its tributaries. The average width is about five feet, and there is a tendency to occur in clusters. Several distinct types are found, which it is hoped to describe more fully later. All that can be definitely stated as to their age is that they are post-Silurian.

Structural Geology.

Sufficient is not known of the structure of the region to justify an attempt to draw sections across the map. It will be sufficient to point out a few significant features which may be found useful in correlating with other areas.

The Ordovician and Lower and Upper Silurian are individually closely-folded units. Regionally, it is probable that some such structure as Naylor has postulated further north may be found to exist. It is suggested that Goulburn-Tarago may be the axis of a major synclinal structure embodying the Ordovician, Silurian and later the Devonian units. While Naylor has found evidence for a continuation of such a structure north from Goulburn, it is probable that it is too simple an explanation for the Lake George region. One outstanding difficulty is the amphibolite series—unless we assume that the basic intrusions were fairly confined, and then we might have a succession Ordovician-? Lower Silurian-Upper Silurian-Devonian eastwards to Tarago. But there is not much evidence to support this, and conditions on the east are not so simple. The dominant westerly dip over the whole area of the older rocks seems to favour a system of major folds having axial planes dipping in this direction also, the bedding and schistosity of the smaller crumples and folds being indicative of the larger structures, and supporting some such interpretation as Naylor has given west from Bungonia. An examination of the Upper Silurian limestone occurrences is of interest (see Fig. 1). In each of the four cases given, Mount Fairy, Windellama, Bungonia and Marulan, there is a main belt and a subsidiary belt (which may divide as at Bungonia). If we assume a correlation of the main belts, it is seen that there is an overturned relationship between the Windellama and Marulan-Bungonia deposits. At Bungonia the main belt is on the very east, near the Ordovician ; at Windellama it is shown as being on the very west, though the field relations here are not so clear. We thus have features which, although of an unknown degree of reliability, are not opposed to the interpretation that at Bungonia and Windellama we have the main (nearly basal) limestone outcropping on the eastern and western limbs respectively of the asymmetrical syncline shown on the right of Naylor's section. Should the Jerrara Creek limestone be Silurian, it would correspond in position with the Windellama limestone. The Mount Fairy limestones (normal sequence) would appear to represent the western limb of the overfold as it descends again to earth.

It is likely that the Upper Devonian does not share the large-scale overfolds of the earlier systems, which were

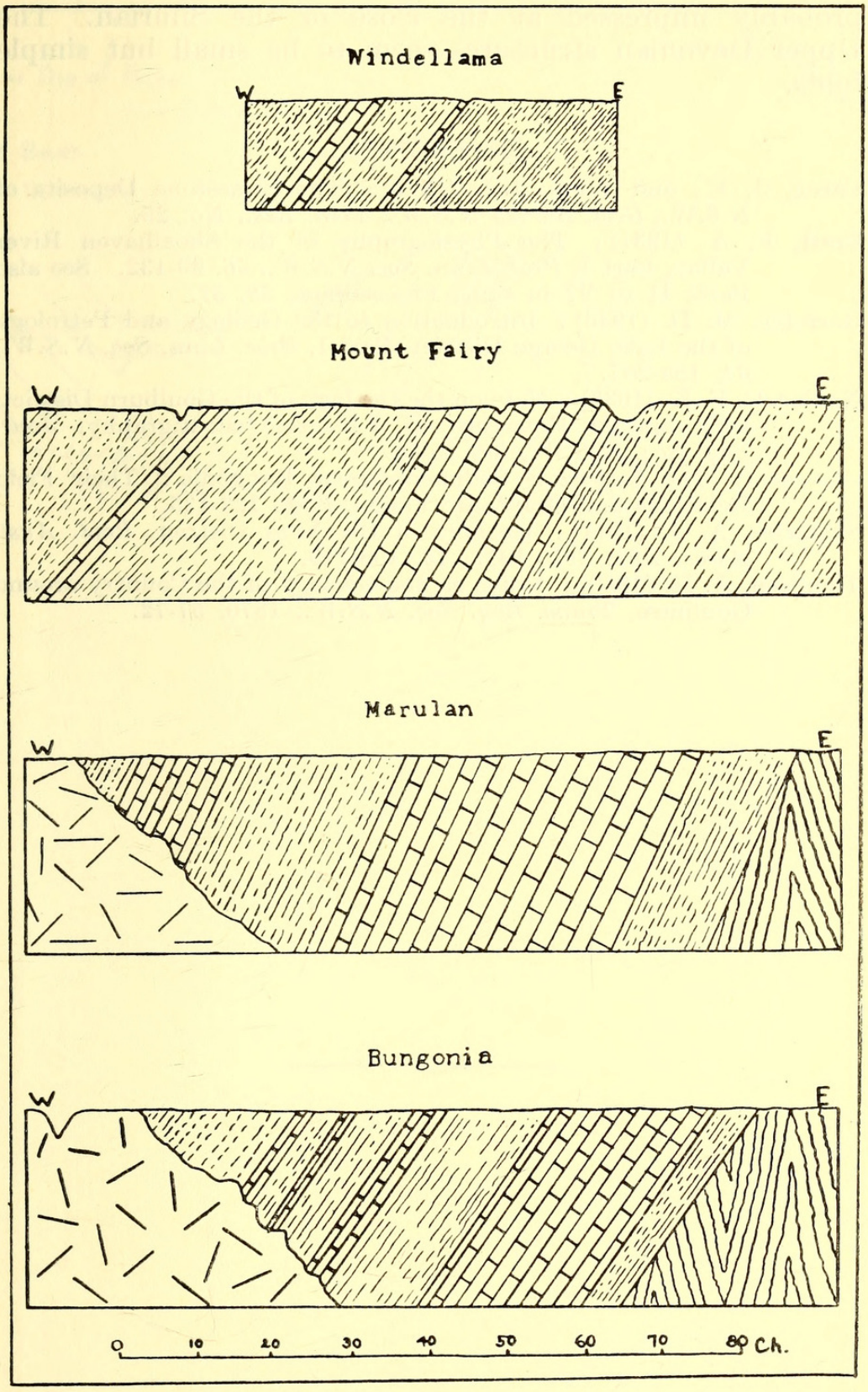

Fig. 1.

Sections illustrating the size and sequence of limestone deposits at Windellama, Mount Fairy, Marulan and Bungonia, the last two after Carne and Jones (1919).

probably impressed at the close of the Silurian. The Upper Devonian structures seem to be small but simple folds.

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