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Geology of the Country around Waddamana, Central Tasmania

By

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(Communicated by Professor S. W. Carey)

PLATES V-IX, FIGS 1-8

I. INTRODUCTION

This survey covers an area of about 17 by 23 miles in Central Tasmania, with Waddamana rather to the north of centre, and including Lake Echo in the west and the Lagoon of Islands in the north-east. The boundaries of this block on the Australian Military Grid are 450,000 to 490,000 yards E. and 790,000 to 820,000 yards N. These correspond very approximately to latitudes 42° 19′ S. and 42° 04′ S. and to longitudes 146° 33′ E. and 147° 00′ E.

The area was surveyed on behalf of the Hydro-Electric Commission of Tasmania during January and February of 1947. This was only a rapid reconnaissance survey, but it was based largely on air photos supplemented by field work on important sections in many parts of the area. In this way we present the first detailed geological map (on a scale of four inches to the mile) of a fairly large block of Central Tasmania. Nevertheless, its limitations must be emphasised and a great deal more field work could be done with value in this area.

It is not known who was the first geologist to visit this region about Waddamana; possibly it was Strzelecki who carried out important traverses in this part of Tasmania more than a century ago. In his classical work (1845) he described briefly the Permian section in Serpentine Creek (Marlborough) which lies a short distance off the north-west edge of our map area (see Prider, 1948). He did not, however, describe, any section in the Waddamana area. Jukes (1847) only outlined the general sequence found in this part of Tasmania.

R. M. Johnston, in his general geological work on Tasmania (1888), also failed to describe any section throughout this large area, but on his map he indicated very roughly the presence of 'diabase' or 'greenstone' over three-quarters of the map area in the north, north-west and west, with 'Permo-Carboniferous' reaching up to 'Ebrington' (Hermitage) in the south-eastern part, a general areal distribution which has been borne out by the present survey. Stephens (1898) reported that the only area of older Palaeozoic and pre-Cambrian in Central Tasmania lay between Lake Echo and the River Nive, but this appears to have been an error, possibly mistaking locally metamorphosed Trias for these.

David's Geological Map of Australia (1931) included an inset of Tasmania, which showed, in addition, some patches of Tertiary basalt in this area, while the latest map to depict the geology of Tasmania, appearing in the State Atlas of Tasmania (1947), indicates no further details in our region. The area was included in a broad physiographic reconnaissance of the Central Plateau by Lewis

(1933), while Edwards has examined its basalts (1939) and its dolerites (1942). No work at all has been done on the Permian or Trias sequences, though a valuable regional survey of the Tasmanian Permian has been made by Voisey (1938). To date, therefore, it appears that only generalized accounts of rapid traverses in this area have been published.

The following work breaks a good deal of new ground, but, at the same time, must only be regarded as the report of a general reconnaissance, to which has been added a discussion on the broader implications in the regional geology.

Justification for the latter was obtained by means of a study of the literature, coupled with regional reconnaissances over Central Tasmania, and, in addition, the West Coast, the Northern and North-western Tiers, the Midlands, Hobart area and Derwent Valley. The friendly and stimulating company of Professor S. W. Carey and Dr. R. T. Prider on several of these trips was particularly appreciated. Valuable help in the field was contributed by student assistants, especially W. K. Sneddon, and later B. Motten and A. A. Northey.

Acknowledgments must be made herewith to the Hydro-Electric Commission of Tasmania, which has kindly given permission for the publication of this report, and whose officers facilitated the survey in every possible way; to Professor S. W. Carey, their geological consultant, and to Dr. R. T. Prider, my colleague, who carried out a similar survey in the region immediately to the west. The use of Dr. Prider's map covering the Dee area in the extreme south-west of the present block is gratefully acknowledged. Dr. Austin Edwards has been kind enough to check carefully through the Ms.; Dr. C. Teichert and Dr. A. Voisey have also read it and assisted me with their comments. Mr. H. O. Fletcher, of the Australian Museum, Sydney, has kindly examined and identified the fossils.

II. Physiography

The Waddamana map area may be divided, physiographically, roughly into four equal parts. In the south-west, north-west and north-east there is a high plateau underlain by dolerite rocks, sloping in a more or less southerly direction from elevations of about 3100 feet in the north down to about 2000 feet in the south. The north-west segment includes Lake Echo, east of which broad areas of basalt form a cover over the dolerite (e.g., Bashan Plains). The north-eastern segment includes the Lagoon of Islands and a smaller amount of basalt on the upper part of the Shannon. The south-western part includes lower slopes and plateaux of dolerite and, again, some areas of basalt east of the Dee. In the south-east segment there are more gentle rolling hills and valleys conditioned by the occurrence of sediments (sandstones and mudstones) of Permian and Trias age: the elevation varies from about 2000 to 1500 feet.

There are no true mountain ranges or peaks in this regionally elevated area, but a few hills rising above the plateau are referred to as ' Sugar Loaf '. In this way there are Fisher's Sugar Loaf, south-west of Waddamana (over 2800 feet), Goldie's Sugar Loaf, south of the Lagoon of Islands (over 2700 feet), and Synnot's Sugar Loaf, north of Hermitage (about 2200 feet).

The entire region is drained by three major rivers which flow roughly from north to south: the Ouse which flows almost directly down the centre of the map area, the Dee which drains Lake Echo in the south-west, and the Shannon which comes down from the Great Lake and also drains the Lagoon of Islands through a tributary in the east (Blackman's Rivulet) and joins the Ouse in the extreme southern part of the sheet. Only in the extreme south-east corner of the sheet are there a few small tributaries of the Clyde.

All the main rivers and their tributaries are deeply incised in the southern part of the sheet, but towards the north the valleys become shallower and the streams flow in only slight depressions in the surface of the high plateau. The two lakes, Lake Echo and the Lagoon of Islands, appear to be structurally controlled (see below, under Sections IV—Structure, and V—Geomorphology) and probably represent complex graben collapse structures. In general, the streams are flowing southwards over this southerly tilted plateau and must, therefore, be regarded as originally consequent streams. Deep incision, however, has revealed older structures by superposition and with younger structures antecedent features result. The detailed channels are, furthermore, in many cases considerably influenced by the structural lines of the country, almost every bend reflecting a joint, shear or fault line in the underlying geology. No river terraces of any dimensions have been recognised along their valleys.

Hydro-electric operations have produced an important diversion of the upper part of the Shannon, via a canal and the 'Penstock Lagoon', being carried by pipe-line over 1000 feet down into the Ouse Valley where is situated Waddamana, one of the principal hydro-electric power stations in Tasmania. High-tension power lines radiate from Waddamana to Hobart, Launceston and Shannon. A former line connecting with Tarraleah has now been dismantled and only the telephone line is maintained.

Rainfall in the area varies between 25 and 40 inches, but a good deal of the precipitation falls as snow in the winter-time. A good review of the climate and vegetation of the high plain region, as exemplified at Great Lake, may be found in Legge (1905). The vegetation is mostly of the native eucalypts, and relatively little has been cleared. In the south-east, however, the sedimentary sub-stratum permits a good development of the soil and more extensive pastures are cultivated. This south-eastern section coincides also rather closely with part of the less humid and slightly warmer climatic region of Eastern Tasmania, as recognised by Dr. J. Gentilli (see Map No. 25 in the Regional Planning Atlas of Tasmania, 1947). In the south-east there are the old established estates of Hunterston, Hermitage, Southern Field, Dungrove and Cluny.

The Waddamana region is serviced by a number of moderate all-weather roads, including the Lake Highway in the east and the Lyell Highway in the south-west, together with a number of very rough secondary roads and tracks. However, owing to the backwardness of the agricultural and general development of the area, there are rather large sections without any roads at all and these should best be visited on foot or horseback.

III. General Geology

1. Permian

The Permian rocks of Central Tasmania have been known for over a century. They consist largely of mudstones, conglomerates and sandstones, in places containing large accumulations of fossil remains, indicating shallow water marine conditions. At certain horizons there is a variety of medium-sized exotic boulders of Western Tasmanian origin, consisting mostly of early Palaeozoic and pre-Cambrian quartzites, schists and various igneous rocks. These have long been considered to be of glacial origin and certainly suggest the rafting and melting of ice-floes and ice-bergs. No true (continental) tillites have been found in this area. In the mudstones, sandstones and conglomerates there are many horizons containing sharp, angular fragments of various minerals, such as unweathered felspars, which also suggest a rapid sedimentation.

The Permian of Tasmania has long been recognised as being similar in many respects to that of New South Wales and an exact correlation with that State has been attempted with 'Upper and Lower Marine' series, 'Greta' and 'Tomago' series, and so on. Weaknesses in this correlation have been apparent for some time, and both Voisey (1938) and Lewis (1946) introduced local formation names. Some confusion, however, existed between the two, and R. T. Prider (1948), after consultation with Dr. Voisey and Professor S. W. Carey, proposed a general classification for the Permian of Central Tasmania, which appears to be fairly generally applicable. Briefly, the sequence is as follows:—

3. *Ferntree Formation* (of Lewis, 1946).—White unfossiliferous mudstone without pebbles, in places including a sandstone member consisting normally of equal amounts of angular quartz and fresh plagioclase grains (named 'Risdon sandstone' in an unpublished Ms. by Carey and Henderson, 1945, see Carey, 1947). This group is equivalent to the Lindisfarne 'stage' of Voisey (1938).

2. *Woodbridge Formation* (of Voisey, 1938).—Unfossiliferous, pebbly mudstone with small glacial erratics locally intercalated by a pebbly sandstone. This sequence is equivalent to the Lindisfarne formation of Lewis (1946).

1. *Marlborough Group** (of Prider, 1948.—A somewhat variable group of highly fossiliferous sandstones and mudstones. (This is more or less equivalent to the Cascades 'stage' of Lewis, 1946. See Hills and Carey, 1949.) In it three facies are recognised:—

   (a) Bronte Facies (of Prider, 1948).—A silty sandstone (rich in quartz and fresh felspars) with marine fossils. Locally it passes to mudstones. Prider interprets the material to be fluvio-glacial in origin.

   (b) Grange Facies (of Lewis, 1946).—A yellow mudstone characterised by the fossil *Fenestella* and casts of shelly forms.

   (c) Granton Facies (of Lewis, 1946).—Blue-grey calcareous mudstones with calcareous fossils.

In the present map area, Permian has been identified in a small inlier in the Ouse Valley at Waddamana, where it is partly exposed by faulting and partly by the very deep incision of the Ouse itself. It is overlain on the east by dolerite and on the west by basalt flows. The individual horizons in it are somewhat lenticular and inconstant, but the following section may be taken as a typical representative of the Waddamana sequence:—

7. Grey, sandy mudstone, with blue-grey to olive-brown sandy shales; lenticles of siliceous sandstones occur in places, and angular quartz fragments are common in the mudstones .... 30 ft.

6. Yellow, silty felspathic sandstone, passing laterally into sandy shale and mudstone, with lenticular conglomerate and quartz grit bands, locally with shelly fossils .... 20-50 ft.

5. Yellow, sandy mudstones, with bryozoan 'reef' facies (*Fenestella*, and many other fossils). This facies may interfinger and be intercalated in the overlying sequence of silty sandstones .... 20-70 ft.

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* I am following as closely as possible the proposed Code of Australian Stratigraphic Nomenclature, which was adopted in principle by the Australian and New Zealand Association for the Advancement of Science in 1947 (see Glaessner, Raggatt, *et al.*, 1948). As regards the Marlborough 'series' of Prider, it seems best to regard this as a lithologic group rather than as a time-rock 'series'; in this case the smaller subdivisions may be 'formations', 'members', 'lenses' or 'tongues', but as their status and relationships are as yet undetermined, I am retaining Dr. Prider's suggestion in referring to them as 'facies'.

4. Conglomeratic to sandy mudstone, yellow to reddish-brown in colour. Pebbles are mainly quartzite, but with some granite and schist. Richly fossiliferous in places, especially species of *Spirifer*, *Productus*, *Stenopora*, etc. .... 20-40 ft.
3. Yellow, sandy to gritty mudstone, locally very felspathic, with some quartzite, granite, gneiss, schist and blue crystalline limestone pebbles, passing to a true felspathic sandstone .... 50-60 ft.
2. Creamy-white to greyish mudstones, well-bedded and blocky; unfossiliferous at the top, but with many shelly forms lower down. Thin shaley partings; rare pebbles and angular quartz grains .... 60-70 ft.
1. Blue-grey, block mudstones, with very hard limestone concretions (up to three feet long), mostly unfossiliferous .... 25 ft. (plus)

Total average thickness, 255 ft.

Nowhere is the base of the sequence seen, since it disappears into the bed of the River Ouse. Even outside the Waddamana area, the base is nowhere seen in Central Tasmania.

Pebbles found in these beds range up to about six inches long as a rule; none were found to be glacially striated. Lithologically and faunistically, the Waddamana sequence corresponds fairly well to Prider's Marlborough group, with its Granton facies (our beds 1 and 2), its Grange facies (our beds 3 to 5), and its Bronte facies (our beds 6 and 7).

Fossils found in the Grange facies, in the Waddamana-Ouse Valley area (kindly identified by Mr. H. O. Fletcher, of the Australian Museum, Sydney), include—

Coelenterata

Stenopora crinita Lonsdale.
S. tasmaniensis Lonsdale.
Euryphyllum gregoriana (de Kon.).

Bryozoa

Polypora internata (Lonsdale).
P. woodsi (Etheridge).
Protoretepora ampla (Lonsdale).
Fenestrellina propinqua (de Kon.).

Brachiopoda

Strophalosia clarkei (Etheridge).
S. gerardi King.
S. jukesi Etheridge.
Terrakea fragile (Dana).
T. brachythaera (Sowerby).
Linoproductus cora var. *farleyensis* Eth.
Linoproductus sp. (Large form.)
Spirifer stokesi Konig.
S. duodecimcostata McCoy.
S. tasmaniensis Morris.
S. vespertilio Sowerby.
S. oviformis McCoy.
S. glaber Dana (non Martin).
Martiniopsis darwinii (Morris).
M. subradiata (Sowerby).
M. subradiata var. *branxtonensis* Eth.

Pelecypoda

Aviculopecten sprenti Johnston.
A. multicostata Fletcher.
A. engelhardti Eth. & Dun.
A. tenuicollis (Dana).
Deltopecten fittoni (Morris).
D. subquinquelineatus (McCoy).
Maeonia carinata (Morris).
Stutchburia compressa (Morris).
S. costata (Morris).
Modiola sp.

Gastropoda

Platyschisma ocula Sowerby.
Ptychomphalina morrisiana (McCoy).
Conularia inornata Dana.

Further downstream along the Ouse Valley, about six miles below Waddamana, the Permian reappears at the locality known as Nelson's Bend on this river. Here the mudstones outcrop in the bed of the river and up to 100 feet or so around the west and south-west sides of the valley, where they are overlain by a very massive pebbly grit horizon and succeeded by about 300 feet of sandstones. The structure at Nelson's Bend is extremely complex, for there are a series of north-north-west, north-west, west-north-west, north-east and east-north-east faults which reduce the outcrops here to a mosaic of displaced blocks. The dip is, for the most part, between 10 degrees and 20 degrees to the west and north-west. Fossils were not found in the mudstone, and it would seem that the outcrop is probably near the top of the Permian and that the overlying sandstones are possibly the lowermost Trias.

Following the Ouse Valley further south still, in the vicinity of the old road from Hermitage to Victoria Valley via Triangle Marsh (around the side of the former Butler's Bridge), a fossiliferous Permian mudstone is found dipping gently westwards with dolerite abutting it along a faulted intrusive contact on the east. This intrusive contact may be followed for about five miles in a southerly direction along the Ouse Valley, passing just to the east of McGuire's Marsh Farm and near the junction of the River Ouse and the River Shannon. Above this fossiliferous mudstone follows a series of sandstones. The character of the fossiliferous mudstone suggests the Grange facies of the Marlborough Group, and the overlying sandstones appear to be a local variation of the Woodbridge and Ferntree mudstone formations, or possibly Trias, assuming an erosional gap. It seems probable that this intrusive contact is also faulted, since no mudstone was found to the east of it, but additional sandstones were found which possess more of a Trias character, and these may be followed up the River Shannon, and, unless displaced by further faulting, would lead naturally into the sandstones overlying the Permian in the region between Hermitage and Dungrove.

The third and largest Permian outcrop appears in an asymetric dome-like structure around Hunterston. It is transgressed by dolerites on all sides, and complicated by faulting. It is only here in the north-west that northerly and easterly dips are encountered and everywhere else the dip is away to the south-west from Hunterston towards Hermitage and Dungrove. The successive horizons of the Permian follow one another in uninterrupted sequence, dipping between two degrees and five degrees in the general way towards the south-west, where they disappear beneath sandstones which may be Trias, and eventually are transgressively overlapped by dolerite.

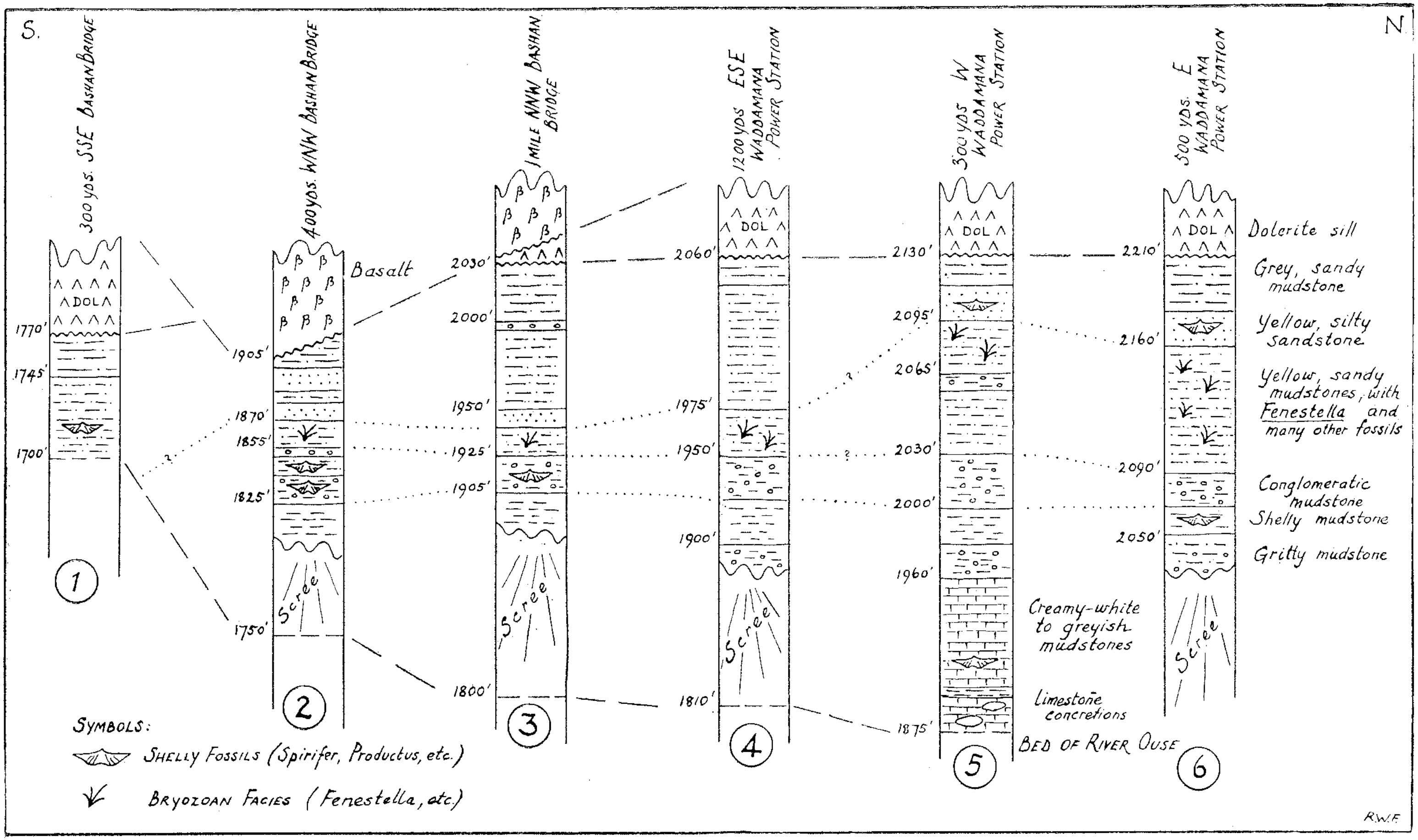

FIG. 1.—Permian stratigraphic columns in the Waddamana area.

The crest of this dome lies in the valley of the Hunterston River, about two miles east-north-east of Hunterston Homestead, where massive blue-grey mudstones outcrop, dipping three degrees north-east on the north side of the stream and three degrees or four degrees south-west on the south side. They are succeeded by about 50 feet of coarse gritty and pebbly sandstone which extends along the strike to the north-west paralleling the Lake Highway near milepost D67, where, however, it appears to wedge out and is replaced by a very fossiliferous band of yellow mudstones with *Fenestella* and various shelly fossils, *Spirifer*, *Productus*, etc.

Just below this mudstone horizon there is a thin sill of dolerite up to about 12 feet in thickness, which has had the effect of baking the overlying fossiliferous mudstones to a thickness of about 10 feet, with the result that the fossils are beautifully preserved in a very hard and resistant rock. This sill may be followed for over a mile around the northern end of the Hunterston Basin. When this same horizon is followed to the east in its sandstone phase, it is found to thicken considerably, so that at a distance of three miles due east of Hunterston Homestead, where it is overlapped by the dolerites of Front Tier, it is found to be dipping at about six degrees to the east and measures more than 200 feet in thickness.

By analogy with the lithology of the Permian in South-eastern Tasmania, we may perhaps correlate the sandstone, the *Fenestella* mudstones, and the blue-grey mudstones below, with Prider's Marlborough Group. It is overlain to the south by a thick sequence of white to creamy mudstones containing scattered pebbles and occasionally erratics of igneous and metamorphic rocks of Western Tasmanian appearance. Fossils in it are rare, but an occasional *Spirifer* was found. This formation shows an immediate analogy with the Woodbridge Glacial formation (of Voisey) and may be followed westwards along the strike, forming hills south of Hunterston Homestead and the range running north-west of Brazendale. The dip here is fairly uniformly about five degrees south-west. To the south-east of the Lake Highway the same mudstones may be followed, forming the hills east of the road and exposed by the northern tributaries of Weasel Plains Creek. Further to the south it forms an amphitheatre all round the west and south of Weasel Plains Homestead. The thickness of this mudstone (probably Woodbridge Formation) varies from 200 to 300 feet.

Overlying the probable Woodbridge mudstones, almost along the line indicated by the Hydro-Electric Commission high-tension transmission line (Waddamana-Hobart), there is a thick sequence of alternating sandstones and mudstones. At the base there is a coarse pebbly grit succeeded by yellow and white siliceous sandstones with one or two further grit horizons. This is overlaid in turn by a mudstone which is white, unfossiliferous and, in the general way, does not have the pebbles characteristic of the Woodbridge mudstones. The mudstone is succeeded by two further horizons of sandstone and mudstone respectively, each about 20 feet thick, making a total of about 150 feet.

These mudstones and sandstones are best exposed in the valleys north of Dungrove and between here and Hermitage and in the valley of the River Shannon between Hermitage and Brazendale. They also form the hillsides west of the Shannon at Brazendale. This alternating sequence in the Dungrove-Hermitage region corresponds, lithologically, with the Ferntree mudstones (and 'Risdon sandstones') recognised elsewhere in South-eastern and Central Tasmania, but it appears that the repetition of the sandstone members is peculiar to this local section to the extent that sandstones are here more important than the mudstones, whereas at Hobart the reverse is the case. No fossils were found in this upper formation. This entire sequence is conformably overlain to the south-west, roughly on a line

Hermitage to Dungrove to Cluny Park, by a massive quartzitic grit band overlain by several hundred feet of sandstones, grits and sandy shales. By analogy with the Hobart and Midlands areas, this may best be regarded as Trias *(q.v.)*.

It may be seen from the above that we have here in the region between Dungrove, Hermitage and Hunterston an extremely well-developed and relatively undisturbed sequence of Permian rocks, and this section may well repay careful examination, since in so many other localities in Tasmania inter-relationships between the different formations are obscured by faulting and by dolerite intrusions. On the contrary, in this area, apart from a few thin sills, dolerite is restricted to the margins, and there is a region about six by ten miles of well-exposed and gently dipping Permian sediments. No other outcrops of Permian are known in this area and the nearest connections are found to the north-west (Marlborough-Bronte region), to the south (Osterley-Ouse region), and to the south-east (Bothwell, Oatlands and the 'Midlands').

In broad terms it may be seen that this general sequence of Permian is to be compared with the Hobart area, or southern division of Voisey (1938). It has no coals, tasmanite oil shales or obvious freshwater intercalations; thus clearly it has less in common with the northern and western divisions of Voisey, though admittedly the absence of the basal beds prevents a complete appraisal.

2. Trias

Trias follows Permian more or less conformably, but in many places in the Hobart-Midlands area there is evidence of a hiatus and a slight disconformity (Nye, 1921, 1924), and a basal conglomerate of Permian mudstone pebbles is known. It consists mainly of unfossiliferous sandstones which are generally taken to be of freshwater origin. The sandstones are often similar to those of the Permian, although certain lithological characteristics may be found useful for field distinctions.

The generally recognised sequence of the Trias in South-eastern Tasmania is as follows (Loftus Hills and Carey, 1949):—

4. *Felspathic Sandstone Formation* (of Nye, 1921).—Felspathic sandstones of tuffaceous type, and compare closely with those of Wonthaggi in the Victorian Jurassic.
3. *New Town Formation* (of Lewis, 1946).—Felspathic sandstones, sandy mudstones, shales and coal measures (plants indicate Upper Triassic age—Walkom, 1925-26).
2. *Knocklofty Formation* (of Lewis, 1946).—Often micaceous 'sparkling' quartz sandstones, locally passing to chocolate shales, sometimes with clay-pellet (intraformational) conglomerates, the so-called Hamilton Formation.
1. *Ross Sandstone Formation* (of Nye, 1924).—Believed equivalent to Springs Formation of Lewis (1946). Massive quartz sandstones often micaceous with a rather constant basal conglomeratic grit.

It is apparent that unless a very well developed sequence of Trias is found in any one place, including the various fossiliferous shale horizons, it is sometimes difficult to distinguish its uniform sandstone formations from one another on the basis of lithology alone, although the felspathic horizons are distinctive.

Within the area of this survey, there are a number of small isolated patches of sandstones which may be classified as Trias, but a thick sequence is found only in the south-east, in the beds which overlie Permian rocks outcropping south of

Hermitage and Dungrove and along the Lower Shannon. Here, in a line running from Hermitage to Dungrove to Cluny Park, a massive quartzitic grit horizon initiates a sequence of about 300 feet of sandstones locally intercalated by sandy shales and further grit horizons. The sandstones are mainly quartzitic and are generally cross-bedded. Measurements indicate that the sediment probably came from the west or north-west.

Along the road half-a-mile north-west of Hermitage, it appears that the same grit rests on the Permian marine sequence, and associated with the cross-bedding in the overlying sandstones there are some excellent examples of subaqueous penecontemporaneous slumping over a band about one to two feet in thickness. The direction of this slumping also indicates a slope from the north-west. It is overlain by sandstones of similar character so there is no question of any external pushing force (such as glaciers) and it is explained as gravity slides on the sea floor under conditions of rapid accumulation with resultant overloading (see Fairbridge, 1946, 1947). The top of this sandstone sequence is transgressed by dolerites west of Hermitage, and even two miles south-west of Dungrove there is no indication of any passage into the chocolate or pink shales which are so widley exposed about ten miles to the south of here in the Hamilton region. This formation, therefore, we correlate provisionally with the Ross Sandstone of the Hobart region.

As mentioned above, there are numerous other small outcrops of sandstones in the present map area. Many of these are simply small inclusions in the intruding dolerites, representing a variety of xenoliths and roof pendants. In places, thin bands are intercalated between thick sills of dolerite. This is particularly so to the west of Dungrove and Southern Field (south of Hermitage) and along the valley of the River Shannon towards its junction with the Ouse. On the northern bank of the Shannon here, about one mile above its junction, there is a small outcrop of flat-lying micaceous sandy shales with flecks of graphite.

Additional small patches of sandstones, presumable Trias, occur at Jean Banks Farm and in several places on either side of the River Ouse about two miles south and south-east of Waddamana. A continuous belt of sandstones is found along the eastern border of Lake Echo and is up to 200 feet in thickness. In the north these sandstones are yellow to pink and felspathic in character, while in the south, near Echo Lodge, they are more quartzitic and have a sparkling character. This sparkling look Prider has shown is due to the euhedral character of the secondary quartz crystallised around the original rounded sand grains, and it is characteristic of the Ross sandstones.

The felspathic sandstones reappear about three miles south of Echo Lodge at Glenmark Farm, while about four miles to the south-west, along Seven Mile Creek, there is a development of sparkling quartzitic sandstones, about 200 feet in thickness. Here they are considerably broken up by both vertical and horizontal intrusions of dolerite. Patches of these sandstones are also found on the surface of the dolerite plateau west of Lake Echo and along the eastern side of Brown's Marsh Creek. In the south, sandstones appear below Victoria Valley beneath the dolerite and extend for a considerable distance up Boggy Marsh Rivulet and in patches up Bashan Plains Rivulet. They are all mainly of quartzitic character.

It is interesting that there are no intercalations of coal measures in our Trias such as are found elsewhere in Tasmania, but since these facies are generally associated with the middle or 'Felspathic Sandstone' beds and the main dolerite sill is generally found between this and the underlying Ross Sandstone (Lewis, 1933, etc.), its absence is hardly surprising, for the former sedimentary cover of the sill is almost entirely stripped off.

3. Jurassic

Following upon the sedimentation of the Trias, there seems to be a complete hiatus in the stratigraphic succession of Central Tasmania, until late Tertiary times. Igneous intrusives, however, in the form of dolerite sills, dykes, laccoliths and even lopoliths, are found intruding the Trias, Permian, and even older rocks. There is no direct evidence as to their age here, except that they must be Mesozoic, but closely analogous dolerites occur in the Karroo System of South Africa which are correlated by du Toit (1920, 1926) with the earliest Jurassic. The most recent and comprehensive study of these dolerites is by Edwards (1942), who made collections through these sills in different parts of Tasmania, showing that not only was the original magma completely uniform and liquid when intruded, but also that it underwent *in situ* differentiation in a remarkably uniform manner.

In the Central Plateau of Tasmania generally, one may readily confirm the observations of earlier authors as to the general characteristics of these intrusions. Here they are normally in the form of vast, more or less continuous sheets or sills, generally of the order of 1000 feet or more in thickness. This aspect may be seen to advantage at many points along the gorge of the Upper Ouse, which, in places, is cut down well over 1000 feet. The bulk of the area is occupied by the exposed surface of only one or two sills. Vertical dyke-like contacts occur in places, but not nearly to the extent found in the Midlands area to the east, where the sill form is less usual. Commonly in Central Tasmania, the intrusion comes up along a vertical (faulted) plane as a dyke, and at a certain horizon spreads out assymetrically to one side in an enormous sill, as noted elsewhere by Lewis (1927) and by Loftus Hills and Carey (1949). An excellent example is seen coming in along a north-south fault from Nelson's Bend down to the junction of the Ouse and Shannon, and spreading horizontally for many miles to the east.

Thinner sills may also be seen in certain places, particularly in the Permian sedimentary area north of Hunterston and just east of Hermitage church. These vary from only 10 to 20 feet in thickness. An equally narrow dyke may be observed cutting Permian mudstones, quarter-of-a-mile north of Brazendale on the banks of the Shannon.

Various authors have discussed in the past whether there were only horizontal and purely vertical contacts, or whether there were irregular and oblique transgressive contacts in places. Both varieties were found on this survey, but certainly the horizontal and rectangular contacts are most common.

Widespread occurrence of chilled margins has already been observed in the region by Nye, Lewis, Edwards, Prider, and others, and they are particularly useful in our area. Edwards (1942) notes that the base of the sill is often chilled to a thickness of 30 feet. Chilling of this order may be observed well along the east side of the Ouse at Waddamana, where dolerite rests on Permian sandy mudstones. The upper margin, as Edwards also observed, is naturally less often preserved, but in the broad plateau east of Waddamana and between Steppes and Interlaken there are numerous flat 'pavements' of very fine-grained dolerite, which are more often horizontally laminated than elsewhere (where vertical jointing is predominant). These 'pavements' are restricted to the higher levels of the plateau and I take them to represent nearly the surface of the intrusion. In places there is even a little baked shale preserved with it, e.g., about three miles north-east of Hunterston, or one mile east of Echo Lodge.

The dolerite sills may intrude Permo-Trias rocks at practically every horizon it appears, but a marked preference is shown for certain levels. At Waddamana it is in the middle of the Permian sequence, between the Marlborough and Woodbridge formations. In the sections between Victoria Valley, McGuire's Marsh, Nelson's Bend, Hermitage and Dungrove, it is a Trias horizon (apparently the top of the Ross Sandstone, as found so often in the Midlands-Hobart region, see Nye, 1921; Lewis, 1933; and others). In the region east of Hunterston and Weasel Plains it appears to be obliquely transgressive, rising from the Permian up into the Trias southwards. A thin segment of Trias, a few hundred feet thick, is caught up between two thick sills of dolerite in the lower Shannon-Butler's Bridge area and again at Lake Echo and east of Brown's Marsh Creek.

The sediments were often tilted to 5, 10 or even 15 degrees during the intrusion, but rarely are they folded. As Lewis (1927) and others noted, there is no evidence of violence associated with these intrusions, apart from the tensional features.

Large xenoliths of sandstone and more rarely shale are often found caught up in the dolerite. They may be an indication of what the former 'roof' material of the sill consisted. Many are found around Victoria Valley, where they are up to 100 yards in lengths, lying at every angle. Here they are almost certainly Trias, since the sandstones of that age underly the sill here and thus presumably also overlay it originally. Another group of sandstone xenoliths occurs south-east of Waddamana, but since they are found in a sill resting on a sedimentary horizon fairly low in the Permian sequence, they may be from one of the mid-Permian sandstones of the type which are so widespread in the Hunterston region.

The sediments in contact with the chilled margins of the dolerite are somewhat metamorphosed, so that the sandstones become quartzites, while the shales and mudstones are 'baked' dark-grey to black, or converted to hornfels or chert. The degree of metamorphism is slight, surprisingly so in view of the statement by Edwards (1942), that the intrusion must have come in at a temperature of about 1000 degrees Centigrade. All authors, however, agree on this (Nye, Lewis, Edwards, Prider, etc.), but there is certainly more alteration at the upper contact than the lower. At the latter contact two-three feet may suffice to carry one down into unaltered sediment, but above I have seen 15-20 feet of baking and silicification; this is true even for some of the quite thin sills, e.g., the ten-foot sill, one-and-a-half miles north of Hunterston Homestead, has so hardened the *Fenestella* beds of the overlying Permian, that these normally rather soft and poorly preserved fossils are very easily collected.

4. Tertiary

As noted above, an extraordinary long phase of emergence followed the close of Trias sedimentation, and it was not until late Tertiary that traces are generally found of lacustrine sediments (see especially Johnston, 1888, 1921; Lewis, 1946). In the Waddamana map-area, probable Tertiary beds were found in only one spot, on the side of the Waddamana-Hermitage road near the head of Black Creek, half-a-mile north-west of Synnot's Sugar Loaf. They rest in a shallow depression in the Jurassic dolerite and amount to no more than ten feet of soft, unfossiliferous yellow-red sandy clays and gravel. The deposit is exposed over a distance of less than 20 yards and is overlain by basalt.

Basalt lava-flows are intimately associated with and overlie the late Tertiary sediments in other parts of Tasmania, and may be compared to some extent with the Newer Volcanic Series of the mainland (Edwards, 1939). Here they cover a fairly large area (56 out of the 391 square miles in the Waddamana map-area). Their existence was recorded in papers by Lewis (1933) and Edwards (1939) between Lake Echo and Waddamana in the Bashan Plains, and north-west of Steppes in St. Patrick's Plains, as well as east of the Dee basalts. These Dee basalts cover some 12 square miles in the region of Duck Creek between the Dee and Victoria Valley. They form some small plateaux and mild rolling country ranging from 2600 down to 1800 feet.

The largest single area, however, is that of Bashan Plains, which extends from north of the region between Waddamana and Lake Echo to McGuire's Marsh near the junction of the Ouse and the Shannon, covering about 35 square miles. It drops gently in altitude from about 3100 feet in the north down to about 1500 feet in the south, the present gradient averaging about 100 feet per mile.

A third area of basalt lies south of Jean Banks between the Ouse and the Shannon, covering about nine square miles. Another small patch north-west of Steppes adjoins the much larger sheet on St. Patrick's Plains, lying mostly north of this map-area. A thin skin of basalt is found in places reaching south of here down the valley of the Shannon.

The basalt occurs in more or less flat, successive flows, each 30-50 feet in thickness and in places up to a dozen or more in number. Owing to differential erosion, these flows weather into a step-like terraced landscape, which often shows up clearly on air photographs as well as on the ground. The basalt quite clearly flowed down over a fairly dissected landscape, for the most part only part-filling the valleys, and only locally crossing the interfluves (see discussion, in Edwards, 1939). Local thicknesses are thus very variable but range to about 600 feet. Prider (1948) found similar thickness in the Tarraleah area. The lava must have been mostly very fluid, for it appears to have travelled down in single flows over the country for distances of 15 miles and more (e.g., in the Bashan Plains lava field).

No craters or vents were located in this area, but the flows appear to have originated in the north and flowed down a pre-existing slope to the south. As noted above there is generally a gradient of about 1 : 100 from north to south to-day, but how much this is due to an initial gradient and how much to subsequent warping is difficult to say; the question is discussed further below.

The basalts are somewhat variable in texture from top to bottom of each flow. At the base they are generally chilled and fine-grained, towards the middle medium-grained, often porphyritic, and towards the top generally filled with gas bubbles and even scoriaceous. These vesciles are sometimes filled by minerals of the zeolite class. The jointing in this area is not well exposed, but when seen it is generally irregular and not columnar.

Petrographically, the basalts belong to the olivine-basalt type. The olivine occurs generally in small phenocrysts against an almost black fine-grained ground mass.

The more precise dating of some of these late Tertiary basalts is indicated in areas outside our own (overlying Miocene lake deposits in the Derwent and Esk basins), which evidence suggests perhaps a Pliocene age. Edwards (1939), however, on physiographic evidence suggests they may well be late Pliocene or even Pleistocene. Lewis (1945*a*) concluded that there was in all probability several phases of basalt eruption, and, in the lack of pronounced evidence of glaciated surfaces on the basalts at Great Lake and elsewhere, the youngest may well be mid-Pleistocene. It may be mentioned, however, that glacial action is not very much in evidence in any case in the Great Lake-Waddamana region, and its features have sometimes escaped notice. The basalt plains around Bashan, etc., appear to bear glacially sculptured valleys. Against this, Lewis states (1945*a*, p. 38) that the Tarraleah-Waddamana basalts are cut by late Miocene-early Pliocene uplifts. So far as I can see at Waddamana, there is no evidence for affixing such an age to the slight post-basalt faulting here: it may just as well be a late Pliocene-Pleistocene uplift. Prider (1948) has indicated that at Tarraleah he has post-Miocene basalt, probably Pliocene, but there is nothing to fix the age more precisely of the youngest faulting.

5. Quaternary

The general region of the Waddamana map-area is extraordinarily bare of soil, alluvium and other superficial deposits, except in the few areas of older sediments. The latter, of course, break down more readily than do the igneous rocks, which cover 70 per cent of the area. The reason for this absence of superficial cover is almost certainly to be correlated with the Pleistocene glaciation which affected Central and Western Tasmania. Lewis (1926) has remarked that some of this Central Plateau is a near 'desert' owing to the soil having been scraped off almost entirely by the ice-sheets. Insufficient time has elapsed since the glaciations to enable the break-down of the two extremely resistent igneous rock types to form new soil.

In the high plateaux of the Waddamana area, like those also to the north and west, there are, however, scattered depressions (mainly along old structurally controlled drainage lines) which are over-deepened, apparently by glacial scour, and these are practically all filled with Quaternary deposits. In places the depths appear to run up to about 200 feet, but generally they are much less. No deep borings have been carried out, and since these deposits are hardly cut into by the present drainage, they are not easily examined. In the Tarraleah area, however, Prider (1948) made a few post-hole bore tests. These proved that the deposits consisted mainly of glacial till. From the indications in our map-area, there must be similar boulder clays here, and in places there are white quartz sands and silt which suggest peri-glacial stream deposits. Glaciated boulders are small and for the most part infrequent.

The surface of these over-deepened glacial basins is now occupied by 'button-grass plains' and peaty swamps, though farmers have succeeded in draining the bulk of them. The bulk of the depressions have clearly recognisable rock floors and rims, and are not to be explained either by purely tectonic means or as boulder-clay dammed lake deposits.

It seems clear that these depressions contain all that is left of the pre-Quaternary soil cover of Central Tasmania. No trace of older lateritized or bauxitized soils *in situ* were found in this map-area, though they are clearly present in the lower, non-glaciated levels beyond the plateaux (Carey, 1947; and others).

Other relics of the ice-sheets are scarce in this map-area. No cirques, U-shaped valleys, roches moutonnées or drumlins were found, nor even striated surfaces. The evidence suggests rather, that if there was indeed an ice-sheet, as it seems, then it was thin and at least partly stagnant. Lewis (1933, p. 31) referring to this general area says: 'The ice-cap was never very thick; perhaps 100 feet was its maximum . . . and all the then existing hills and prominences protruded as nunataks of bare rock'. Certainly the tops of these hills to-day are strewn with scree, which suggests frost action on the well jointed dolerites.

It has been notoriously difficult to correlate the Tasmanian Quaternary glacial deposits with the world time-scale. It is clear that in places they are superimposed on the youngest basalt flows (see also Lewis, 1934), but in the present survey it has not even been possible to recognise any subdivision in the deposits. It appears to have been Lewis' opinion that our region was affected by the ice of his earliest, Malanna stage, which spread out in broad though relatively thin sheet over much of the Central Plateau down to the level of about 2700 feet. In this way ice-lobes would have extended down from the north-west to Lake Echo-Waddamana-Lagoon of Islands (Lewis, 1933).

The topography, which we take to be glacially sculptured, extends however rather further south than this. They are found along the Seven Mile Creek, at Victoria Valley and in isolated cases between Waddamana and Hermitage. Great post-glacial erosion is recognised in the valley of the Ouse and elsewhere, on the south side of the Plateau, so that many of the old traces must certainly have disappeared. If our hypothesis regarding the marsh depressions is correct, however, then the lower limit of the ice in this region should be extended down to a little below 2000 feet.

Already in 1894, Montgomery claimed that 'the great lakes of Central Tasmania are almost *prima facie* evidence of glaciation', but this may not hold good for Lake Echo, which appears to be primarily of structural origin. Lake Echo puzzled Lewis (1933) in that it lay rather to the south of his observed limits of glacial phenomena, but he imagined that beyond the dolerite rim it had been further dammed up by morainal material which is now obscured by vegetation in the valley of the Dee. Exploration here disclosed no evidence of this 'moraine'; the valley following structural lines in the dolerite (see further, Section V). Other swamp basins and lakes beyond his glacial limit (2700 feet) he ascribed to recent earth movements. Victoria Valley, Bashan Plains and the nearly-filled Lagoon of Islands he included here. All, however, have rock rims and appear to lack the necessary younger structural control (lack of air photos of Lagoon of Islands leaves this case still open). They all have smooth well-rounded contours and a plentiful sedimentary filling: the hypothesis of glacial over-deepening seems to be the most satisfactory of the present state of our knowledge.

Besides these Pleistocene glacial beds, there are very meagre superficial deposits in Central Tasmania. In our map-area the bulk of the streams are actively cutting down their beds, so there is very little alluvium. There are a few patches of recent silts along the bed of the River Ouse, notably where it crosses sediments, as at Waddamana, Nelson's Bend and McGuire's Marsh. Elsewhere along the Ouse and in all of the deeper valleys crossing the dolerite, the valley slopes are covered with masses of angular dolerite screes and the beds are choked with enormous dolerite boulders up to 20 feet or so in length. There is a broader expanse of alluvium, on the sediments again, at the junction of the Shannon with Hunterston Rivulet, and lower down there are patches at Brazendale and Hermitage. Similarly on Weasel Plains and around Cluny the sedimentary substratum gives rise to rich alluvium.

The presence of these broad alluvial tracts, high up along the upper courses of these Central Tasmanian streams, at heights of 1500 up to 2000 feet and more, cannot be explained by eustatic changes of sea-level down at the mouths, since they occur *above* bars and nick-points. Nor are they adequately explained as contemporary flood plains, for the rivers are in places well-encised in them, and settlements have been built on them well above flood level. Edwards (personal communication) has indicated that the recession of the bars or nick-points would adequately explain these features.

IV. Structure

The structural picture of the Central Plateau of Tasmania is at first sight perhaps rather simple, but in fact is more complex. The more or less horizontal superficial layers of Permian, Trias and intercalated Mesozoic dolerite, amounting in places to several thousand feet in thickness, rest on a peneplaned basement of older Palaeozoic rocks which had folded and metamorphosed in the Devonian orogeny. Evidence for this phase is, however, outside the present area (see Lewis, 1945*a*; and Loftus Hills, 1922).

Since the Permian marine sediments are all of shallow-water character, in spite of their considerable thickness, a contemporaneous regional subsidence of proportional degree must be assumed. The freshwater character of the Trias suggests regional emergence, but it too possesses a notable thickness which implies relative subsidence between rising marginal blocks.

The next major diastrophic event was a broad warping accompanied by a complex block-faulting which took place at the same time as the dolerite intrusion. Individual fault-blocks thus became tilted to 10-15 degrees, and steeper dips are only found locally in connection with fault drags. Normally, however, the general attitude of the beds remained horizontal and unfolded. Evidence of this 'epi-Trias' faulting is found in many parts of the Midland province, Central Plateau and elsewhere in Tasmania (see Nye, 1921, 1922, 1924, etc,; Lewis, 1927, etc.; Edwards, 1942; Prider, 1948; and others).

With the cooling of the dolerite, a well-developed joint system developed, which is found to be remarkably uniform in character, conforming in some degree to the regional fault pattern. The two thus become difficult to distinguish, unless large displacements occur along the faults. Small displacements, leaving dolerite against dolerite, are hard to identify in the field from simple jointing where there is negligible displacement.

Some minor movements along these already-formed lines of weakness may have occurred subsequently as suggested by movements identified beyond our area. The general evidence here suggests, however, that during the long period from Jurassic to early Tertiary relative quiescence persisted, while the initially uneven, though not tremendously high, relief became gradually reduced by mid-Tertiary times (Lewis, 1945*a*). Lateritized and bauxitized surfaces of this old peneplain are found in a number of places in Tasmania.

Most observers agree that in about middle to late Tertiary and even Pleistocene times there recurred a period of block-faulting, dismembering the pre-Miocene peneplain. These new major displacements produced intense shearing in the dolerite, in places reducing it in a narrow zone to a greyish, puggy clay. In this way it is very easily eroded along these lines, and many of the important structural lines are followed by watercourses to-day. The actual contacts are not often seen in the field, but Prider (1948) has found them on the Nive and Lewis (1933) reports that during the excavation of the foundations of the hydro-electric dam on Great Lake at Miena, some quite wide bands of this vertically weathered dolerite were found. The presence of these weathered shear-zones suggests a movement that occurred long after the initial faulting which accompanied the intrusions. Basing his observations on the restricted area of the Midlands, Nye (1921, 1928, 1938, etc.) considered this post-dolerite faulting as subordinate in character, but on the basis of broader physiographic observations, Lewis (1927, 1933, 1945*a*) concluded that these younger movements were important and actually shaped the present-day relief; it seems that only in late Tertiary-Pleistocene times was the plateau elevated to its present height.

With these conclusions I entirely agree. There is no doubt whatever that the late Tertiary basalts flowed down over a well-dissected youthful surface which could only have been engendered by a recent elevation accompanied by further block faulting.

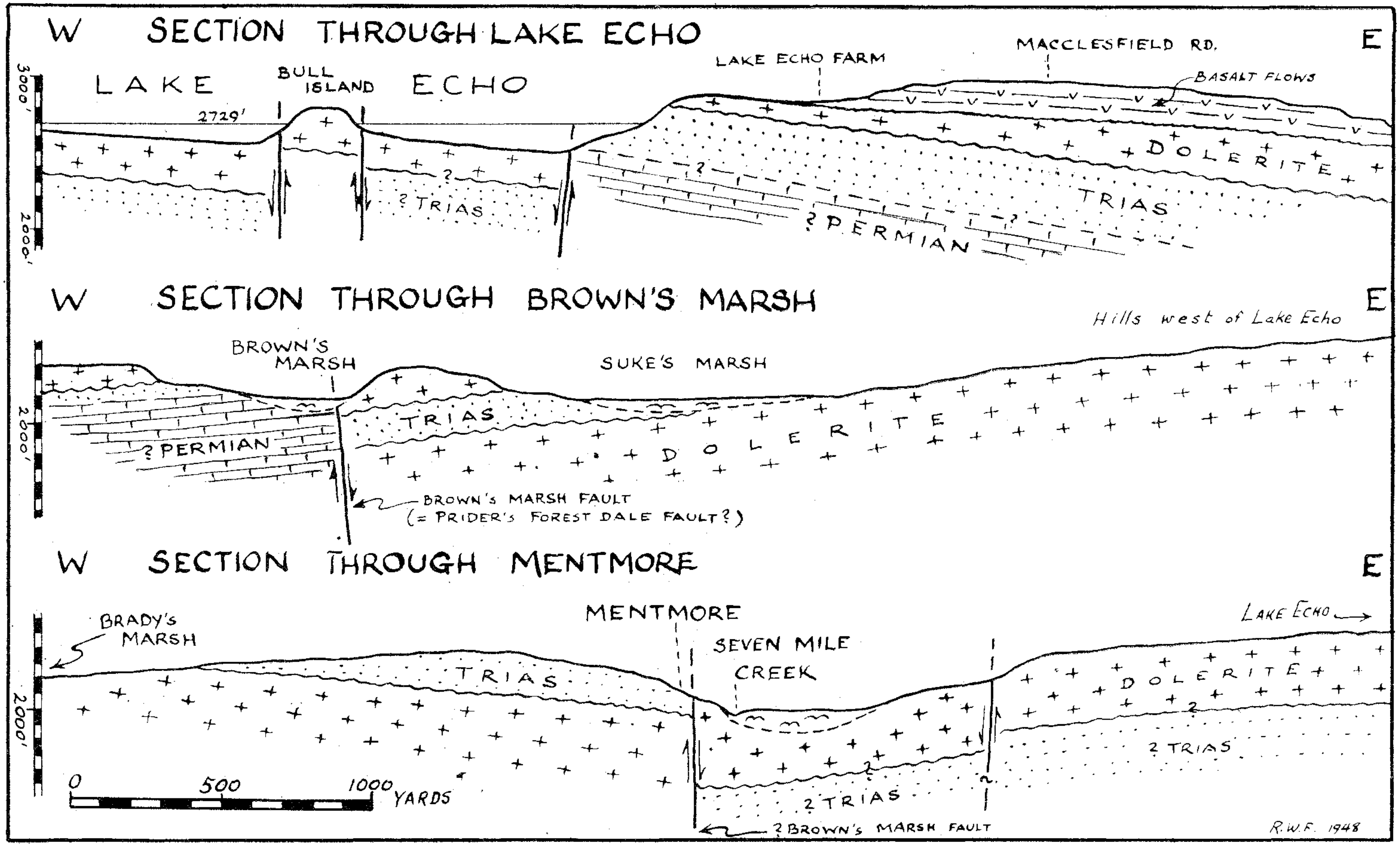

FIG. 2.—Sections through Lake Echo, Brown's Marsh, and Mentmore.

The extrusion of the lavas themselves must have been the outcome of still more taphrogenic disruption, though its traces are not always apparent (Carey, 1947). In the Waddamana map-area the basalts appear to be cut off in a few places by fault-lines, so that if they are glaciated, as they seem to be, then at least in part they would be middle or late Pleistocene in age. Thus at least three distinct periods of displacement have occurred:

(a) Epi-Trias faulting (with dolerite intrusion), displacing—

(i) the peneplaned older Palaeozoic basement.

(ii) the Permian-Trias beds, also originally lying more or less in a horizontal attitude.

This older faulting to-day would not be expected to show physiographic expression (Lewis, 1945*a*, p. 32) unless re-exposed, possibly as fault-line scarps (e.g., Marlborough Fault, Prider, 1948).

The criteria for recognising this epi-Trias faulting are found in correlating across displacements the abovementioned datum-planes or the associated intrusives with true igneous contacts (Lewis, 1945*a*).

(b) Mid-Tertiary faulting, disrupting the Cretaceo-Tertiary Peneplain, but ante-dating the Miocene lake beds and Younger Basalts, which flowed out over youthful topography.

(c) Late-Tertiary to Pleistocene faulting. This disrupted the Miocene, but was associated with Younger Basalt extrusions, which may, according to the evidence of glaciation, have continued into the Pleistocene. Both this movement and the former are well expressed physiographically, but the former is more effaced by erosion and partly obscured by basalt flows.

The final structural pattern of intersecting faults separating a mosaic of jostled and displaced fault-blocks is thus a composite result left by these successive diastrophic phases. It is most probable that repeated movements occurred along old lines. Even the oldest faults are in part parallel to Older Palaeozoic or even pre-Cambrian lines (as noted by Loftus Hills, 1922; Carey, 1947; and others. It is frequently impossible, therefore, to define precisely the age of each fault-line.

Furthermore, owing to the abundance of parallel shears and joints associated with most of the important trends, we may often speak most accurately of 'fault-zones' without being able to define the loci of maximum displacement, sometimes to a width of a mile or so.

In rocks other than dolerite, minor fractures are much less common and are replaced by small warps and flexures. Again, owing to the uniform lithology of both Permian and Trias, just as in the big dolerite sills, even quite large displacements are not always indicated by a change in rock type across the fault.

Consideration of the tectonic patterns indicate thus:

1. Major Joint Pattern

With numerous exceptions, the main dolerite jointing is S.S.W.-N.N.E., W.S.W.-E.N.E. and N.W.-S.E.

2. S.S.W.-N.N.E. Fault Zones

With local deviations, there are about six major fault-zones across the area in a trend varying from N.5°E. to N.40°E. These are, from west to east:

(a) The Echo-Mentmore Zone, a belt of major faults, starting in the south-west near Mentmore, intersecting the south-western shores of Lake Echo, cutting off the two sides of Bull Island and bordering the eastern and western sides of Three Mile Marsh. The throws are partly east and partly west, resulting in a graben at Three Mile Marsh.

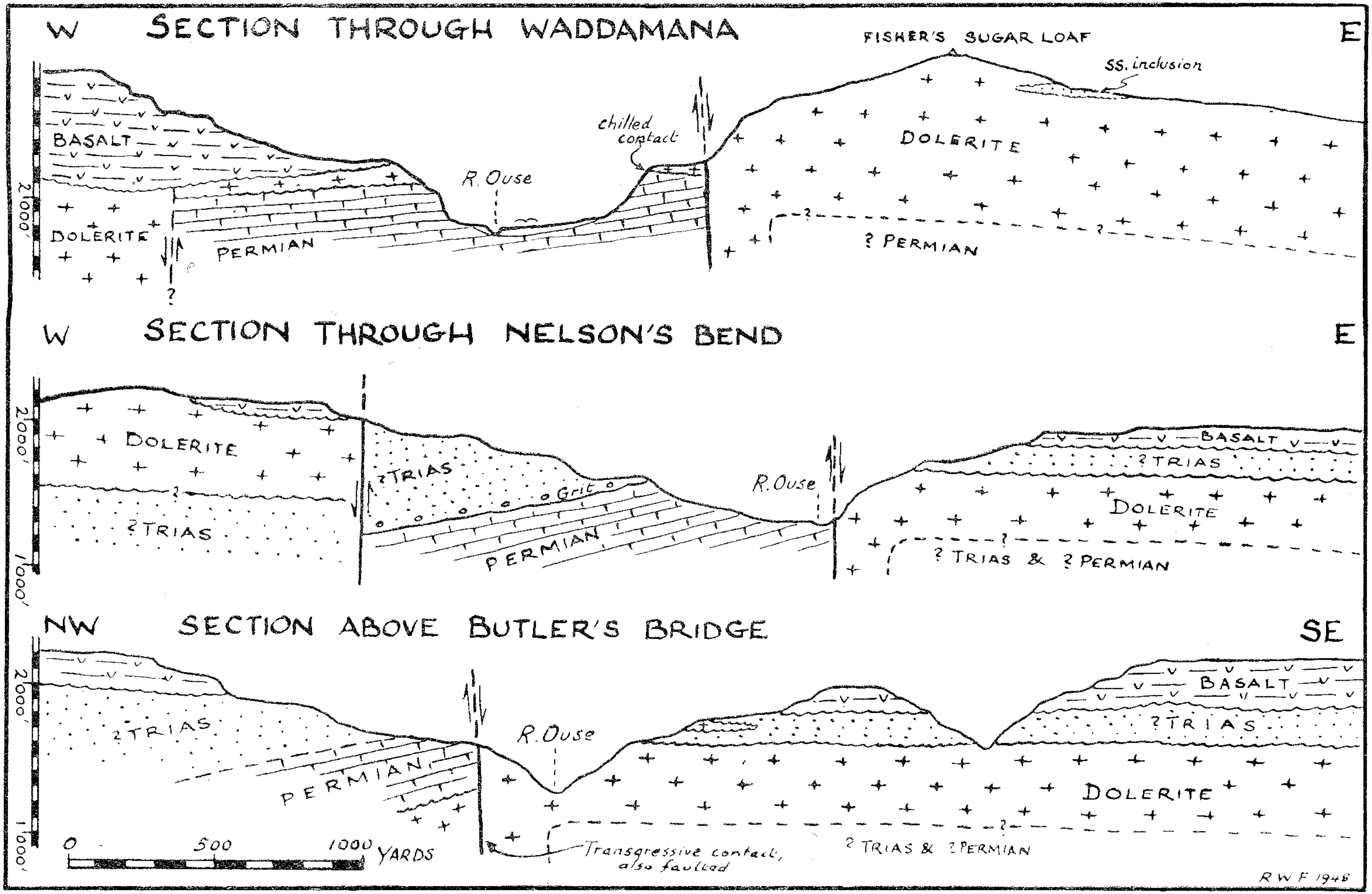

FIG. 3.—Sections through Waddamana, Nelson's Bend, and Butler's Bridge.

Bull Island stands up as a narrow horst on the west side of this zone. The southern and eastern parts of Lake Echo are intersected by this zone (and others, see below) to form a complex 'Senkungsfeld'. Initial movements were probably epi-Trias and mid-Tertiary; latest movements in Pleistocene. Total displacements are probably of the order of a few hundred feet.

(b) *The Echo-Dee Zone,* a narrow zone, followed by the line of the Upper Dee and the eastern side of Lake Echo. Throw appears to be westerly. In the south it has little physiographic expression, although very clearly seen to be scoured out along the River Dee. It is partly responsible for the 2 to 300 foot drop along the east side of Lake Echo, and in this section Pleistocene (post-Basalt) movement is assumed, because broad sheets of basalt extend along the east side of the fault, but nowhere along the west side, which is up to 300 feet lower. Further north and south, however, where it shows no physiographic displacement, it would seem that no movement had occurred since the mid-Tertiary uplift. The total displacement in the centre may reach 500 feet.

(c) *The Victoria Valley-Waddamana Zone* is a broad belt of intense shattering and faulting in which the downthrow is to the west on the west side, and to the east on the east side. At Waddamana itself, the basalt appears to overlap the faults, which, although originating in the epi-Trias movements, seem to have controlled a pre-basalt drainage channel west of Waddamana, down which the basalt has flowed, thus displacing the River Ouse to the east. To the south, however, the basalt crosses to the south-east which suggests that the stream maintained itself across this structural zone during the mid-Tertiary uplift. Displacements would seem to range from 1000 to 1500 feet. Lewis (1933, p. 23) has recognised the direct continuation of this line to the north: 'A major fault appears to traverse the length of the Liffey Gorge and this probably runs southward via Half-Moon Marsh, across the site of the Great Lake and down the Shannon Valley, thence in the direction of the present pipe-line to the Ouse Valley in the vicinity of Waddamana.'. Traces of this trend were found during the excavations for the Miena Dam.

(d) *McGuire's Marsh-Nelson's Bend Zone* in the general way is restricted to a single clear-cut fault line, up which one of the major dolerite intrusions have come, spreading out asymetrically in a sill to the east. In this way, Permian on the west is clearly seen faulted against Trias and intrusive dolerite on the east. The dolerite has baked the Permian at the contact, so the age of the fault is essentially epi-Trias. The line continues for nearly ten miles along the course of the River Ouse, which is superimposed on it, cutting first down into one side and then down into the other regardless of rock hardness. Basalt is seen at rather similar heights on both sides of the valley, and it would seem to have undergone relatively little mid-Tertiary or younger movement. The northern extension of this line disappears beneath the basalt of Jean Banks, but it may control the course of the River Shannon south of its notable right angle bend west of Steppes. The displacement is of the order of 1000 to 1500 feet.

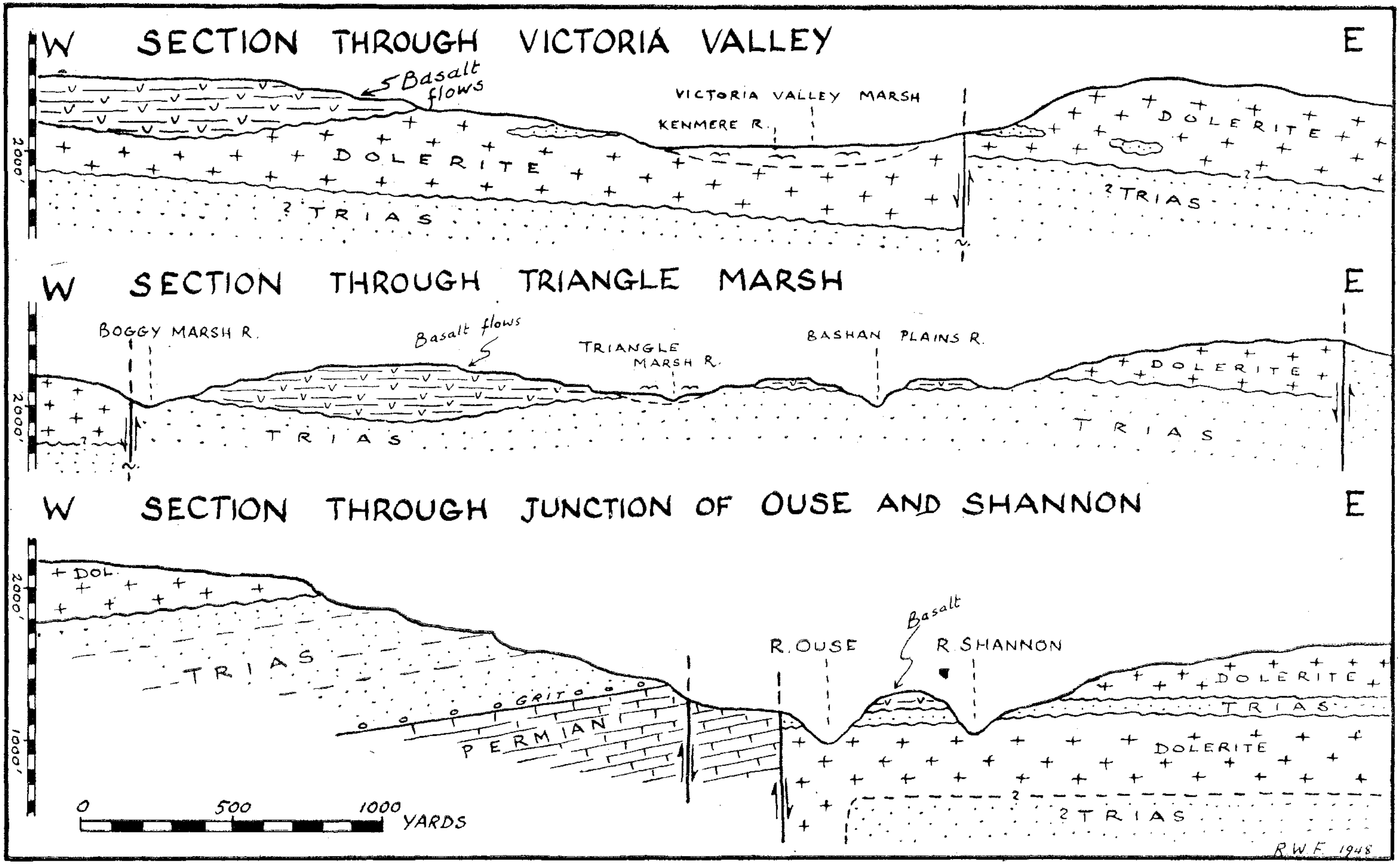

FIG. 4.—Sections through Victoria Valley, Triangle Marsh, and the junction of Ouse and Shannon.

(e) *The Lower Shannon-Steppes Zone.* This is a weakly developed set of lines, which appear to intersect the dolerite south of the Lower Shannon, to control part of the middle course of the Shannon and perhaps pass through Steppes to form the west boundary of the Lagoon of Islands.

(f) *The Cluny-Weasel Plains Zone* is a line which runs out of the east boundary of the map east of Cluny and Weasel Plains and follows the eastern borders of Hunterston and along the Upper Clyde towards Interlaken on the shores of Lake Sorell. It is probably of epi-Trias age for the most part, with an easterly throw and is marked by a fault-line scarp, east of the Hunterston-Cluny sedimentary areas, which, because of their elevation, have lost their dolerite sill capping and are now being eroded out into physiographic basins.

3. N.W.-S.E. and N.N.W.-S.S.E. Fault Zones

The north-westerly trends in this part of Tasmania are the most striking. Faults, shears and joints in this trend cross the map sheet in great sheafs. For this reason they are perhaps least easy to define. They are not so rectilinear as the meridianal to north-north-east trends, and often possess a slightly sigmoidal character, in the sense of a horizontal drag which would suggest a horizontal (transcurrent) movement to the south-east on the east-side (or north-west on the west); this matter will be discussed further below. The general dominance of these lines, may be explained perhaps by the essentially north-west and north-north-west trends in the underlying basement.

From west to east we may recognise:

(a) *The Brown's Marsh-Forest Dale Fault,* a rather exceptional feature, since it is almost definable as a single line. It is recognised north-west of our map-area by Prider (1948) as the Forest Dale Fault east of Marlborough where it appears to throw to the east, cutting off Permian with dolerite. It continues directly in line to the south-south-east with a displacement recognised along Brown's Marsh, where a sandstone of Permian appearance west of the line is brought against dolerite and a sandstone of Triassic type. Further south on this line, at Mentmore and along Seven Mile Creek, a Trias-type sandstone is introduced on the west side of the line against dolerite on the east, probably by cross-faulting. Recent drainage patterns are superimposed on this line, so that its age is probably epi-Trias. Its throw may be 1000 feet or more.

(b) *The Echo-Kenmere Zone* is, unlike the former, an ill-defined belt several miles in width, which crosses Lake Echo from the north-west and reappears along Kenmere Rivulet north of Victoria Valley. It is confused with the north-west to south-east joint patterns and a definite throw is not recognised. Across Lake Echo it appears to have a graben character, and possibly a westerly throw on Kenmere Rivulet. With its present physiographic rôle it may thus have played a part in Pleistocene upheavals, but its origin was probably mid-Tertiary or older. Throws do not appear to exceed a few hundred feet.

(c) *The Ouse-Hermitage Zone* is a pronounced sheaf of fractures along the upper course of the Ouse, crossing into the plateau behind Waddamana to the east and reappearing down the middle course of the Ouse nearly to Nelson's Bend, where it disappears beneath the Newer

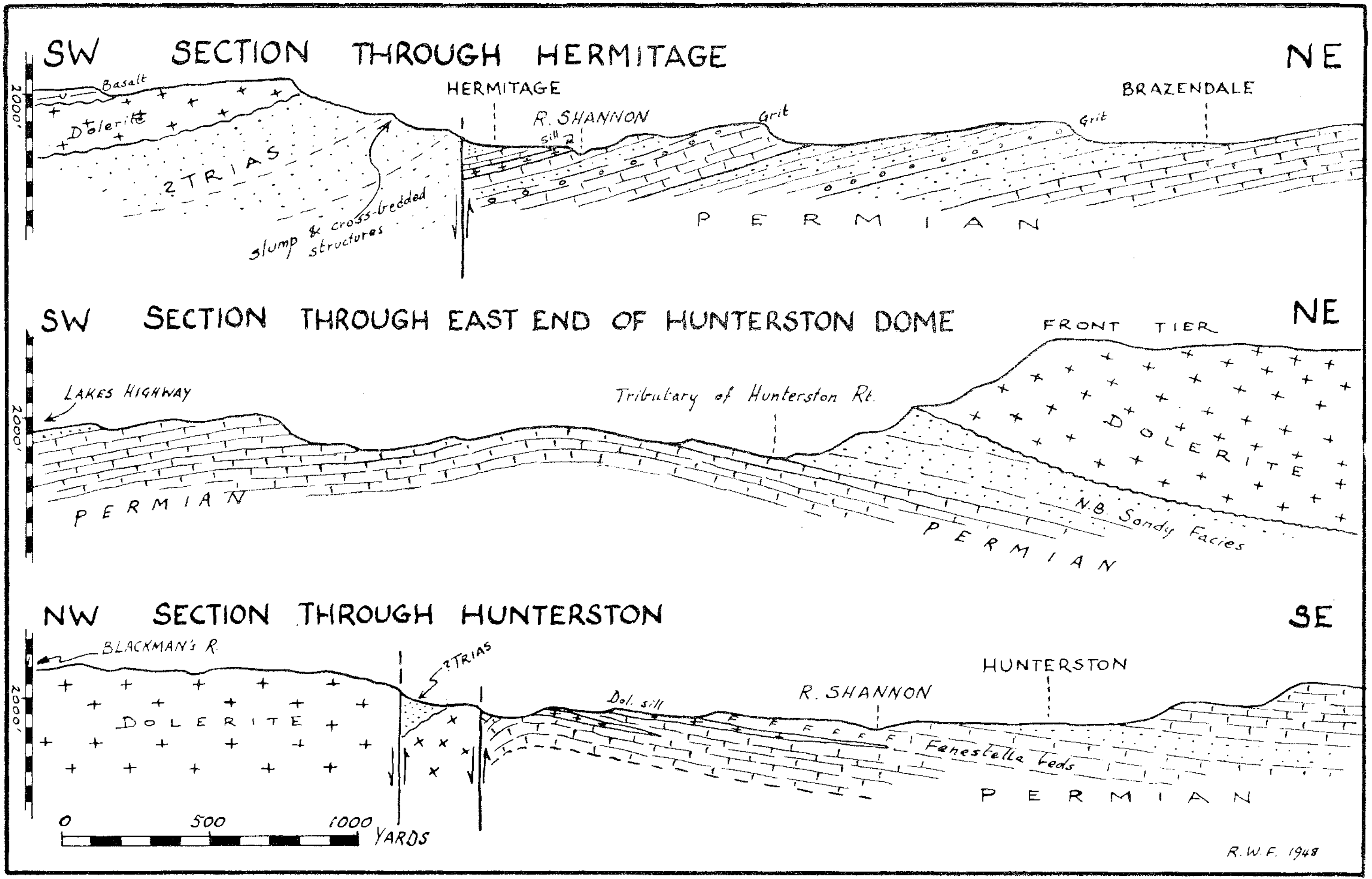

FIG. 5.—Sections through Hermitage and Hunterston.

Basalts in the direction of Hermitage. Between Hermitage, Southern Field and Cluny it seems to reappear in a convergence of various lines from north and north-west. The north-south lines cut off the west side of the Hunterston sedimentary basin and the north-west to south-east lines appear to dive beneath the basalt across the Shannon to reappear along the lower course of Bashan Plains Rivulet. All these faults appear to throw to the south-west. In this way the dolerite hills south of Dungrove (Green Hill, Ware's Sugar Loaf, etc.) are cut off on the south and to the north-west above Nelson's Bend, the west side of the Ouse Valley is generally somewhat lower than the east. In spite of all this physiographic expression, however, the zone is apparently older than the basalts, and probably had its main movements in mid-Tertiary. There is no evidence that it is older than this and none of the individual throws indicates a displacement of more than a few hundred feet. The occurrence of this fault zone along the Ouse Valley has been noted already by Lewis (1933).

4. Folding, Tilting and Regional Warping

As indicated already, there has been no true folding in Central Tasmania since Devonian times, and the general response of the Permo-Trias sediments to subsequent disturbances has been by means of block movements, with vertical displacements, maintaining a horizontal attitude, or with tilting *en bloc* to angles of 10 or at the most 15 degrees. Steeper dips are uncommon and almost invariably associated with fault drag.

An exception is met in the Hunterston-Weasel Plains area, one of the largest outcrops of sediments in Central Tasmania. Here a broad uplifted horst of sediments is surrounded on all sides by faults, throwing down dolerite and the upper parts of the Trias—a Hunterston Fault along the northern margin, a Weasel Plains Fault in the east, a Dungrove Fault in the south-west, and a Hermitage-Southern Field Fault in the west. This elevated block is tilted regionally to the south-west at an average angle of three degrees, but near the faulted margins dips up to 25-30 degrees are recorded. Along the northern and eastern sides there are two gently warped fold structures, giving rise to about one mile of easterly or north-easterly dips. The first is in the eastern part of the Hunterston basin and the second in the basin of Weasel Plains. They are partly separated by a number of small north-west to south-east faults.

These two dome-like structures are anomalous in the general picture of Central Tasmanian tectonics, but hints of intrusive activity are given north of Hunterston and around Weasel Plains by the presence of thin dolerite sills and dykes. It seems quite probable that these domes represent buried laccoliths.

Over the broader area of our map sheet, we may recognise similar areas of regional upwarp or depression, best seen when drawn on a section with an exaggerated vertical scale (x5). Sections drawn to natural scale would emphasise the gentle nature of these broad warps, but it would be difficult to apprehend when reduced to printed size.

Crossing the sheet on this section from east to west we recognise *(a)* the Hunterston elevated block, *(b)* the depressed block between the Shannon and the Ouse, *(c)* the elevated blocks west of the Ouse, rising steadily to Lake Echo, *(d)* the complex graben or senkungsfeld of Lake Echo, *(e)* the tilted block west of Lake Echo to Suke's Marsh, and *(f)* the raised block west of Brown's Marsh.

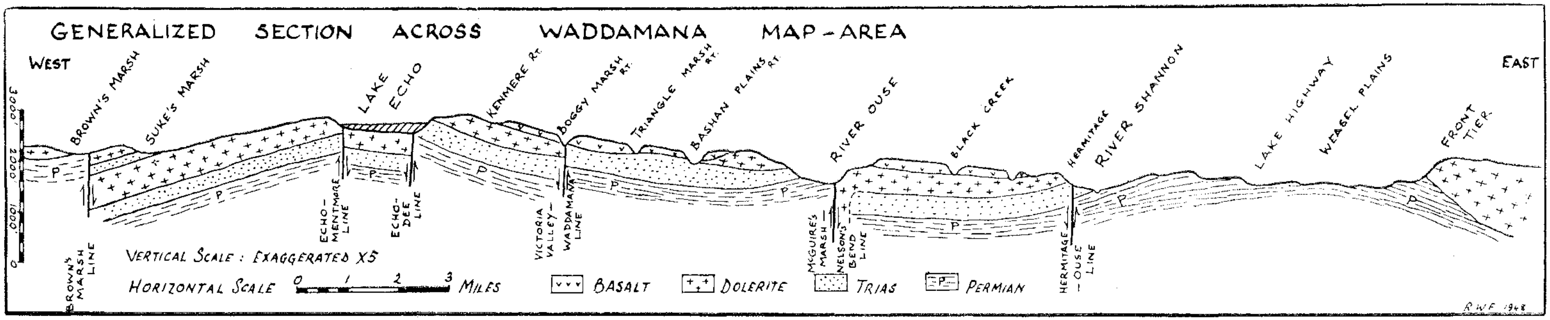

FIG. 6.—Generalised section across Waddamana map area.

Most of these blocks are slightly tilted, some one way and some another. In addition to their east-west tilt factors, most of the blocks are tilted to the south, so that there is a regional uplift towards the north, which averages 1000 feet higher than the southern sides of the blocks. The only exception is the Blue Hill block south of Hermitage and the Range, which has a northerly tilt, down towards the Shannon, rising just off this sheet to 1500 feet above its northern part.

The greatest regional elevations of the north, however, extend to the south in the line of Lake Echo, which stands as a lake-filled graben perched up on the top of one of the upwarps. It has the appearance in miniature of the classical faulted keystone of one of the high rift-valley lakes of Africa. It is the structural opposite from the up-arched horst of Hunterston.

V. Geomorphology

We have, in the Waddamana map sheet, an area where geomorphological considerations have played a major part in unravelling the geological history and structure. Much remains to be done, but some of the broad lines may now be recognised.

In the recognition of lithologic types, the associated land forms may be very helpful. Permian mudstones and sandstones weather in loamy soils of soft, rounded topography, but with cuestas on the hard bands and unmistakeable dip-slopes. Very rapid stream dissection in them produces vertical, blocky cliffs (as for example along parts of the Ouse near Waddamana and McGuire's Marsh, and of the Shannon near Hermitage). The Trias sandstones, and rare shales, weather in a similar manner, but whereas the mudstones are generally cleared for farming purposes, the less productive sandstones, and especially the coarse grit bands, are often left untouched or only partially cleared.

The dolerites weather in the valleys into light red bouldery clays, generally too heavily forested for much clearing; on the plateaux most of this soil is missing and an extremely rocky, though still fairly densely forested terrain exists. The topographic forms developed are essentially scarp and plateau lands, though most of the dolerite plateaux are tilted (to a few degrees only) from the true horizontal, and are found in places to pass along indistinct boundaries beneath other rocks (e.g., between Jean Banks and Hermitage, a southerly tilted dolerite plateau disappears beneath basalts along a quite irregular line). Elsewhere the junctions are mainly abrupt, steep scarps controlled by normal faulting.

The second type of igneous rock in the area, the olivine basalt, weathers into black to dark-red bouldery soils, which may be readily distinguished from those of the dolerite as a rule. Topographically it appears in terraced layers with flat plateau tops reflecting the original lava flows. The terrain is bouldery, though not with jagged rocks like the dolerite, but rather with smaller and more rounded boulders. The rock is fairly pervious and is generally drier, supporting less forest than the others, but furnishes a heavy growth of summer grasses and is thus much favoured by pastoralists. This terraced grassland is unmistakeable on air photographs.

The topography as seen to-day is generally controlled by dolerite sills which are broken up and tilted to form numerous disconnected high plateaux, but more locally by basalt flows which form terraced plateau lands. Again locally, either as 'windows' in the dolerite sills, or more rarely resting on them or sandwiched between them, there are inliers of Permo-Trias sediments which give rise to rounded topographic forms and valley tracts.

This topography is essentially mature in the high plateau lands, but is suffering progressive rejuvenation from the south. The major streams may be seen to be steadily eating back headwards, developing deep clefts in the otherwise mature landscape of the north. In the southern part of the area very little is left of this old surface.

We have thus an immature landscape derived from an older mature landscape. Consideration of the drainage pattern, comparative elevations, the dates of the Pleistocene glaciation, the basalt eruptions and of the successive faulting, as seen in the preceding sections, forces the conclusion that we would expect not one peneplain, but traces of repeatedly revived landscapes, not all of which would have time to be reduced to the near-horizontality of peneplains. In simplest terms we might reasonably seek traces of:

(i) Late Mesozoic—Early Tertiary peneplain,
(ii) Late Tertiary, pre-basalt landscape,
(iii) Post-basalt, pre-glacial landscape,
(iv) Post-glacial landscape, but undissected by post-glacial drainage.

The first we should seek perhaps in the high plateaux, but there is no uniformity in levels here, in spite of claims to the contrary by Johnston, Lewis, and others. Such uniformity would naturally have been broken up by the mid-Tertiary and younger faulting. Relics of older lateritic and bauxitic surfaces are found outside this region (Carey, 1947; and others), but not so far in our map-area. The claim that the tilted surfaces of the plateaux represent the somewhat degraded pre-Miocene peneplain cannot be reconciled with the conclusion that the major faulting was epi-Trias. These tilted dolerite surfaces show a general parallelism in the cross-sections with the bases of the dolerite sills. It might be reasonable to conclude that, since these are infinitely the hardest rock-type in the area, they would be exposed in this manner by the normal processes of differential erosion. Furthermore, in several localities the traces of the chilled upper surface of these sills and even of the baked and contact-metamorphosed roof sediments have been discovered, coinciding with the surface of these tilted blocks. This interpretation is at variance with the one generally accepted so far, but has actually been suggested already by others (e.g., N. F. Giblin, in Nye's discussion, 1928, on Lewis' paper of 1927).

The recognition of stream courses to-day which are superimposed on epi-Trias structures supports Nye's statements (1921, 1928, 1938) that the present system had its inception immediately after the dolerite intrusions. The country was practically reduced to a peneplain (with possibly a few isolated monadnocks) by about mid-Tertiary times. Initially, no doubt, the streams were for the most part structually controlled; they would naturally be located in subsequent patterns down the tilted slopes and along the major fault zones of the epi-Trias disturbances. As this fault-scarp and dip-slope landscape gradually became reduced in relief, so the structure would progressively lose control of the drainage until, finally, peneplanation was achieved. In this way the streams flowing across the peneplain developed meandering courses, but subsequent regional elevation has caused some to be revived, cutting down and developing a superimposed character on the deeper pre-peneplain structures (e.g., along the Ouse between the Shannon junction and Nelson's Bend).

Lewis believed that all physiographic effects of this epi-Trias faulting would have been effaced by mid-Tertiary times, and, therefore, disagreed with Nye's contention about the great age of the drainage system. There was some truth in both ideas, as we shall see, but to some extent these two argued at cross-purposes. We have already concluded, however, that there was really no justification for assuming that the dolerite intrusion caused enormous regional uplifts, and in this we are agreed with Lewis' opinions (1927, 1945*a*, etc.) that the region remained in a state of relatively low relief until after the mid-Tertiary. Later elevations, of course, make the younger drainage developments dominant.

We have seen how regional block-faulting and elevation occurred approximately in mid-Tertiary. Broad upwarps occurred right across the Central Plateau, tilting it to the south-east and south-west and appearing to leave the Midland valley more or less lagging behind (Lewis, 1927, 1933, 1945*a*). Clemes (1924) had already demonstrated three plateau levels, separated by step faults, between Lake St. Clair and Lake Echo, and there are in fact many more attributable to this phase. On this revived landscape an extensive subsequent stream pattern developed, in addition to the older streams which managed to maintain themselves in spite of the structural changes that lead to widespread capture and diversions. The older patterns, of course, became superimposed on the underlying older structures, but the newer streams reflected the new warps and faults. A youthful topography of considerable relief developed. Nye and Blake (1938) suggest that valleys over 1000 feet deep were able to develop before the Newer Basalts appeared.

In our own map-area the pre-basaltic landscape is well illustrated by the course of the basalt flows. The levels of these may be traced down old valley depressions from north-west to south-east. In places the floors of such valleys are found to be more than 300 feet below the dolerite hills on either side. We see that the largest flows in our area converge from Three Mile Marsh and Jean Banks on the Ouse Valley near the Shannon junction. We have already recognised that this section of the river was already in existence (though not as deep, of course, as to-day), and the basalt probably filled its broad meandering valley to a width of about four to six miles. It appears to have been joined here by an ancestral Boggy Marsh Creek on the west and by an ancestral Shannon on the east. These older streams were not coincident with the present, but lay respectively east and west of the present courses. As the basalt flowed down the old valleys it displaced the streams sideways, forming new lateral valleys. The lower part of the Ouse here, being in the centre, may have been blocked altogether, but this could not have been more than temporary, since the main stream has now reasserted itself along very much the same course as before. Higher up, between Waddamana and Bonaparte Creek, it seems that the basalt is thicker and lower about one mile to the west, and therefore the Ouse here may have been displaced to the east. Still higher, between Waddamana and Shannon, there appears to be the old course of the Ouse connecting with the headwaters of the present Shannon. Basalt-filled valleys here indicate displacement to the west, and it seems that the Ouse has captured considerable headwaters south-west of Great Lake, which formerly belonged to the Dee, while the former headwaters of the Ouse are now directed into the River Shannon.

For its part, the Shannon appears to have risen formerly somewhere in the region of Arthur Lakes, to have flowed south through the Lagoon of Islands, Blackman's Rivulet and Black Creek. As we have seen, the Jean Banks basalt flows displaced the lower parts of this course to the east, into the Hunterston region. Meanwhile, a northern tributary from somewhere about St. Patrick's Plains (north-west of Steppes) became displaced to the west by the basalt and captured the headwaters of the old Ouse in the vicinity of Shannon. The course of the Lower Shannon marks, as do other lateral displacements, the junction between the basalts in the west and the non-basalt country in the east; its meanders are thus controlled by structure and relative rock hardness, in notable distinction to the superimposed character of the Lower Ouse.

Similar reconstructions may be visualised for the Dee basalts, where Kenmere Rivulet seems to have been forced to one side and to have beheaded the original valley of Duck Creek, which is now filled with basalt. This basalt area coincides

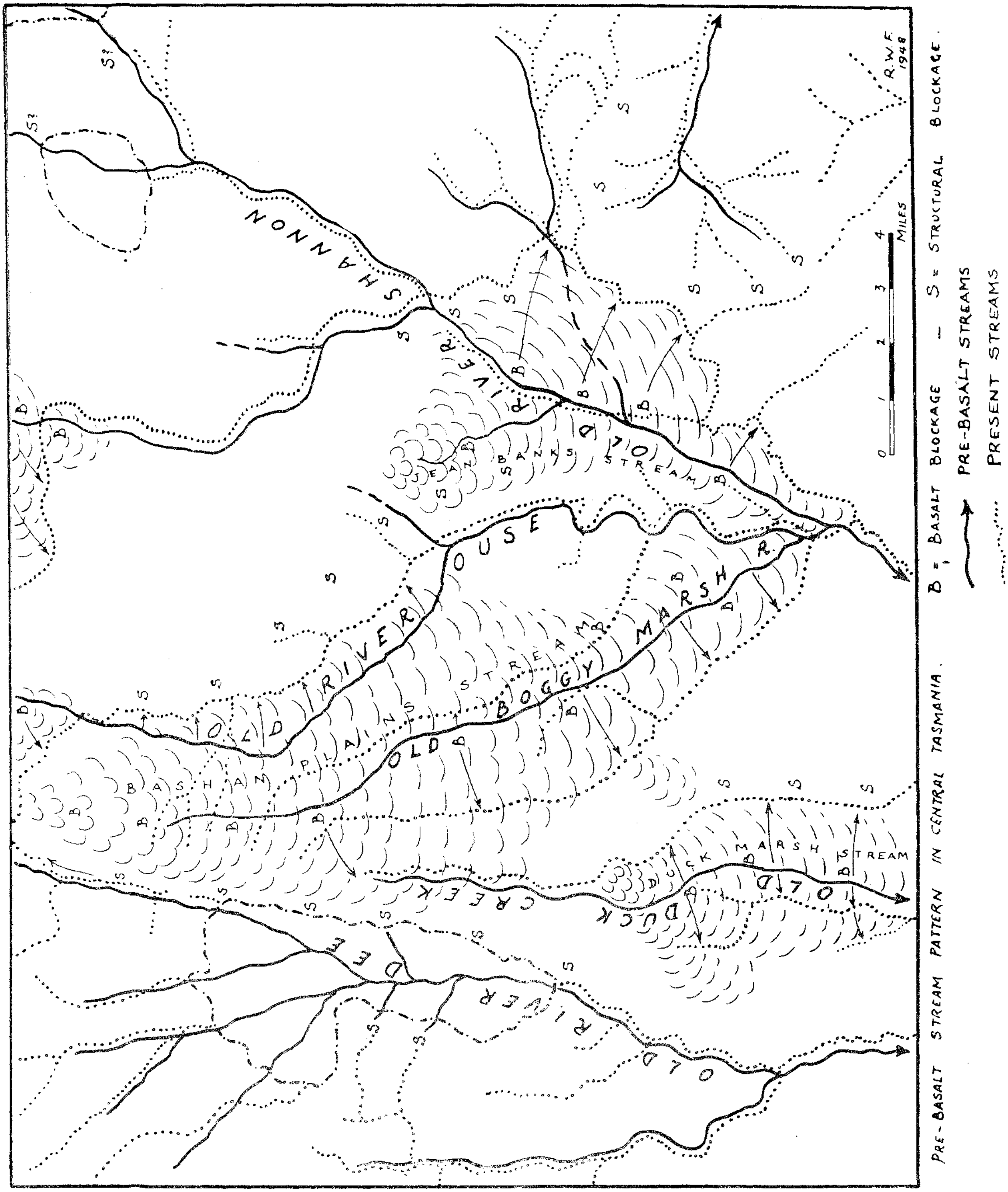

FIG. 7.—Pre-Basalt stream pattern in Central Tasmania.

broadly with the south-eastern (lower) part of our 'Echo-Kenmere' fault zone which is believed to have developed in mid-Tertiary times. Similar sagging may account for the St. Patrick's Plains and Upper Shannon basalts.

The Hunterston horst region became structurally and topographically high at this (pre-basalt) time, while its western edge formed the eastern limits of the Shannon. It became probably tilted to the west at this time and we now see the tributaries, such as Hunterston Rivulet, superimposed on the structures in the Permian sediments, crossing right over the dome east of Hunterston. In the same way Weasel Plains Creek cuts clean across the southern dome in the opposite direction; it certainly must be older that this mid-Tertiary westerly tilt and is clearly older in character than the post-basalt Lower Shannon. The gradual nature of the uplifts, permitting the maintenance of such superimposed patterns has been emphasised especially by Lewis (1927, etc.).

The basalts flowed down over a landscape of high relief which had been elevated most probably in mid-Tertiary times. The post-basalt landscape saw many displaced streams, paralleling the sides of the old valleys now occupied by volcanic flows, as well as captures and beheading (just as in Victoria, see Keble, 1918; Hills, 1940). In addition, it seems almost inevitable that the basalt extrusions must have been the outcome of further deep-seated block-faulting. Since these faults appear to be old lines of weakness revived, they are often difficult to recognise.

In our region, however, there is considerable geomorphological evidence of post-basalt disruption. Elsewhere, Lewis (1927, 1945*a*), Edwards (1939) and others, have noted post-basalt faults, and here at Lake Echo there is evidence of movement. There is no question of such lakes being primary depressions in the dolerite, as postulated by Johnston (1894). Structural observations indicate that Lake Echo is not to be explained solely by glacial erosion, as certain other authors have supposed (Montgomery, 1894); situated as it is near the outer limit of glaciation, its great area alone would render such erosion hardly probable. Nor is there any trace of damming by glacial moraines and boulder clays (supposed by Lewis, 1933) or again by basalts (as suggested by Edwards, 1939). The lake basin is interpreted as a complex 'senkungsfeld', in which the latest movement, especially along the middle part of the Dee-Echo-Three Mile Marsh Line, has possibly been post-basalt in age. The basalt is found extending to within half-a-mile of the lake shore on the plateau east of this line, but west of it, a block depressed at least 300 feet below the plateau, there is no trace of basalt. We may perhaps argue that had this broad depression existed before basalt times, it must have been filled by the lava. The fact that it is not, prompts the conclusion that it is a post-basalt feature.

The foundering of Lake Echo took place at the same time as the elevation and tilt of its marginal blocks. Practically no streams enter Lake Echo on the east; on the plateau here they all flow south and south-eastwards. The south-eastwards flowing streams which enter Lake Echo on the north-west follow structural lines, but may represent former tributaries of the Dee. The River Dee itself is superimposed, and partly antecedent too, along the southern extension of this old line of weakness (the Dee-Echo Line) and the streams in the same trend to the north-north-east along Three Mile Marsh may similarly represent its truncated headwaters. In this case the head of the Ouse probably also once flowed through this system into the Dee.

Regional uplift, however, of the whole of Central Tasmania, with local tilting of blocks, must also have occurred in post-basalt times, for, as Lewis has repeatedly emphasised, the large areas of mature topography still preserved at great elevation, would not have survived an unduly long attack by vigorous young streams.

According to Loftus Hills and Carey (1949), the basalt flows follow even thalwegs from over 3000 feet in Central Tasmania right down to below sea-level in the lower Derwent and Tamar. Substantially this concept appears to be correct, but they admit the possibility of post-basaltic movements, and our geomorphological and structural observations (especially at Lake Echo and north of Waddamana) indicate that slight interruptions of such thalwegs are to be expected. At Lake Echo the post-basalt displacement seems to be about 300 feet. Additional indications of faulting during or after the basalt eruptions are scarce in our area, except in the part three to five miles north-north-west of Waddamana, where smaller disturbances are seen.

The next event to exert further modifications to this Central Tasmanian landscape was, it seems, the Pleistocene glaciation, which, to some extent, it seems, overlapped the period of basalt eruptions. The precise age of the basalts is not fixed. Most authors regard the eruptions as continuing over some time. Both Lewis and Edwards accept most of them as Pliocene to early Pleistocene. Lewis (1945*a*) puts the Tarraleah and Waddamana basalts as Miocene, because they were cut 'by late Miocene-early Pliocene uplifts', an hypothesis for which he produced no evidence at all. Prider (1948) has subsequently demonstrated on fossil evidence that the Tarraleah basalt is post-Miocene. Lewis (1927, 1933, 1934) observed that some of the basalts are glaciated in places, as at Tarraleah and Waddamana, though denies that those at Great Lake are. The former he regarded as Miocene and the latter mid-Pleistocene. Edwards, however, considered them as all fairly young in this part of Tasmania; in fact, regarding most of them as young as mid-Pleistocene. Our own observations are that there is some evidence of glaciation on most of our basalt, though the thinness of the ice and the shortness of the period prevented it from very greatly modifying the landscape, apart from removing much of the soil cover, excavating local basins and gouging small valleys.

Most authors agree that even at their maximum extent the ice-sheets could never have covered more than about half of Tasmania (Montgomery, 1894; Lewis, 1945*b*; etc.). Even then it must have been very thin, for no isostatic compensatory elevation of Tasmania has been noticed in the post-glacial period (Lewis, 1927, 1945*b*). On the other hand, the late Pleistocene and Recent eustatic oscillations of sea-level appear to be faithfully recorded on the shore-lines and rivers of Tasmania (Lewis, 1935, 1945*b*; Edwards, 1941). Nevertheless, insufficient accurate levelling work has been done on this subject to be sure that minor isostatic warping has not taken place. Valleys of the main streams are widely terraced, but these features do not reach up as far as our map-areas, except for a most recent terrace which is probably due simply to normal recession of nick-points.

With the semi-mature post-basalt landscape elevated in places to over 2000 feet, there was also a sudden rejuvenation of all streams peripheral to the Central Plateau. Headward erosion took place on a tremendous scale. Rivers like the Ouse, already a composite of parts of the Lower Shannon and Upper Dee, cut down 1000 feet below the basalt level at Waddamana and further north appears to have captured extensive drainage areas.

The Lower Ouse, it seems, is definitely superimposed along an old epi-Trias structural line, over which it had meandered by the time of the break-up of the post-dolerite peneplain. It maintained itself during this mid-Tertiary elevation, only to have its valley blocked by basalt in late-Tertiary. Nevertheless, it appears to have subsequently re-excavated and further entrenched itself along the old line of weakness in post-basalt times.

To the north-east, vigorous erosion of one of the streams of the Western Tiers, according to Lewis (1933), the Lakes River, led to the capture of the waters of Arthur Lakes and Wood's Lake ('Lake Leacock'), which originally flowed through the Lagoon of Islands and Blackman's Rivulet to the Shannon. As a result of this impoverishment the Shannon has remained for the most part unrevived, in remarkable contrast to its virile neighbour, the Ouse.

The River Dee, long since deprived of its main head-waters by the uplifts about Lake Echo, lost further to the Ouse when river capture took place in the vicinity of Three Mile Marsh, whose clearly southwards directed tributaries are sharply deflected north into the vigorously down-cut Ouse gorge.

Youthful, post-glacial erosion is now advancing steadily up from the southern limits of the plateau. It has not reached the hamlet of the Dee, but very nearly to Victoria Valley in the south-west. The whole of the central part of our area is involved in the rapid down-cutting of the Ouse, and headwards migration of nick-points is to be seen on Boggy Marsh Rivulet, Bashan Plains Rivulet and the Lower Shannon. Not mature section of the Ouse is seen at all in our area, which is in contrast to the Shannon above Hermitage and all its tributaries.

The old post-glacial surfaces are preserved almost intact across the north-eastern, northern and western parts of the map-sheet, except, of course, for the Ouse gorge. Even in the soft sediments of the Hunterston-Cluny area in the south-east there is negligible evidence of revival. Again, it is only in the south within the sphere of the Ouse down-cutting that very active erosion is progressing. Elsewhere we still have semi-mature landscapes, slightly modified by glacial action but much as they were at the close of basalt times.

VI. Discussion

The nature of the Mesozoic-Tertiary diastrophic evolution in Central Tasmania has been discussed before, notably by Lewis (1927, 1945*a*). His main thesis was that deep-seated earth movements of a regional folding character warped the deep crustal basement, resulting in superficial block-faulting dislocation in the relatively thin but brittle surface cover of Permo-Trias sediments and dolerite. With this explanation we may be in general accord, except in his attribution of the gentle basement warps to crustal shortening.

One of his main conclusions (1927, 1945*a*) was that there must have been a period when the country was repeatedly squeezed from the east and south-east against a resistent western buttress or an opposite pressure from the west; this period lasted on and off from Cretaceous to Quaternary. This concept is not altogether in accord with contemporary geotectonic ideas: no large-scale compressive folding or overthrusting is known in this region since the middle-Palaeozoic orogenic phases. The character of the normal block-faulting, associated with warping, fissure volcanics and hypabyssal igneous rocks, quite clearly indicates tensional strains coupled with vertical crustal movements. These points were already made clear by Nye (1921). As Lewis himself often noted, the eruptions and intrusions were not of the violent type; they were not 'squeezed out', however, but rose up on release of pressure along tensional fissures.

We would rather describe the post-Palaeozoic movements as typically epeirogenic, of a type which Stille would call 'undatory' in character; though both broader and more local oscillations are apparent, in dimensions the chief warps would fall into the class of van Bemmelen's 'meso-undations' (1936). By this we mean deep-seated warps of medium size, generally attributed to sub-crustal streaming or convection currents.

An expression of these slow undatory warps, the region has been affected by intense fracturing. In contrast to the slow initial (mainly epeirogenic) movements during Permian and Trias, these episodes of fracturing (taphrogenic phases*) were, it appears, sharp and relatively short, separated by long periods of quiescence.

Broad radius, *vertical* movements are recognised throughout the Eastern Australian Caledonian-Hercynian orogenic belt from Mesozoic through to late Tertiary times, but it is chiefly in Tasmania that the crust is 'fortified' to some degree of rigidity by the presence of the dolerite sills. Thus the reaction to these vertical movements has been in the form of brittle fractures and tilting of fault blocks, unaccompanied, except quite locally, by the usual asymetric folds and monoclines so characteristic of the softer, more ductile cover rocks of the mainland. Striking contrast may thus be seen between the clear, sharp-edged, normal faults of the Tasmanian Permo-Trias-dolerite country and the drag-folded faults and monoclines (overlying basement faults) of the South-eastern Queensland Permian and Trias (see Fairbridge, 1948).

In superficial structures resulting from such deep-seated diastrophic forces, much depends therefore on the thickness and character of the overlying rocks: a thick blanket of soft ductile sediments will react very differently indeed to a relatively thin but brittle crust. One has only to refer to the classical works of Stille in the Saxonian belt of North Germany. Nye (1928) made this point when comparing the tectonics of the Midlands with that of the Central Plateau.

Stille (1943) has re-emphasised that the tectonic evolution of any sedimentary belt takes the following sequence: (i) Initial, embryonic undatory (epeirogenic) warping, with basin and ridge development; (ii) main undulatory (orogenic) folding, with horizontal compression; and (iii) post-orogenic or posthumous undatory warping. Tasmania experienced stage (ii) in the Devonian already, and since then has been involved in both general and local undatory (up and down) movements (stage iii). Stille makes a special point that in this post-orogenic stage, the first tendency is towards a general negative undation (downwarp, i.e., in Permo-Triassic-Jurassic times), followed by a general postive movement (upwarp, i.e., in mid and late Tertiary times) irrespective of the various local undations, which are superimposed on the major warps.

The igneous activity normally associated with such epeirogeny and taphrogeny in a maturing continental region (or 'Kraton' of Stille and Kober) is of well-recognised and definite character. First came the Permian downwarping, culminating at the close of Triassic and beginning of Jurassic times with deep-seated tension and block-faulting, accompanied by quiet hypabyssal intrusion of vast dolerite sills and dykes, in places of laccolithic and even lopolithic nature.

After the elapse of nearly two hundred million years in apparently almost complete quiescence, in mid-Tertiary times further block-faulting ensued, only to be revived once more towards the end of the Tertiary (with elevation and the extensive basalt eruptions of Central and South-east Tasmania).

Like the Newer Basalts of Victoria, these essentially olivine basalts of Tasmania are not the type of the Pacific province, but are intermediate to the tholeiites (according to a personal communication from Dr. Edwards). It is thus likewise incorrect to compare them, with Tyrrell (1937), to the 'Flood Basalts' (Geikie's 'Plateau Basalts').

As Edwards (1938) also remarked, in connection with the Victorian examples, it is significant that the region has suffered no major orogeny since the Devonian, and there is thus a notable absence of the geosynclinal and orogenic type of lavas. The region in short is typically epeirogenic, or better kratogenic, to use Kober's

* This is the term Krenkel first used in his early work on the African rifting and was later broadened by Bucher (1933) and Picard (1939).

term, and exhibits the igneous rocks normally associated with an originally semi-rigid but later deeply fractured and stressed crust. This fracturing seems to have reached greater depths by Tertiary times, since the basalts are presumably more 'abyssal' than the tholeiitic dolerites.

In view of the apparently shallower origin of the dolerites, one might also look for some indications of volcanic eruptions which might represent the surface expression of the Mesozoic lopoliths. On the contrary, however, there is an apparent absence of Mesozoic eruptions, except for certain traces of tuff in the late Trias New Town Beds of Hobart (Lewis and Voisey, 1938), but an examination of the thickness of the sedimentary cover for each period may provide the explanation for this fact. The Mesozoic intrusions invaded a thick and more or less resilient mass of sediments ranging up to several thousands of feet in thickness, while the late Tertiary eruptives appeared in precisely the same region, which, far from having had the addition of any further sediments, had actually been exposed to continuous erosion throughout the odd 200 million years of the Jurassic-Cretaceous-Tertiary periods. Some thickening to the crust had been achieved by the intrusion of the dolerite sills, but these were now well fractured along vertical lines.

An additional reason for the absence of large-scaled Mesozoic extrusives may be sought in the nature of the epeirogenic and taphrogenic movements at the time. Just as Edwards had indicated in Victoria, there had also been a long period of down-sagging across the middle of Tasmania between the older, positive or stationary belts; during this period Permian and Trias shallow water marine and lacustrine sediments several thousands of feet thick had accumulated. It is hardly necessary, however, to postulate at the close of the Trias a sudden up-doming of this tectonically negative belt in order to provide space for dolerite lopoliths as did Nye, and others. On the contrary, Lewis (1927) argued that the elevation of Central Tasmania was post-doleritic. It would seem to be more in harmony with the evidence if the marginal blocks continued to rise, and, though the sagging belt between actually stood above sea-level, it continued to react tectonically as a down-warp. Thus, with the increasing load of sediments on the down-sagged belts, the Permian basement rocks were now less able to bend or stretch and started to fracture: rather like a 'green-stick' fracture of a young bone, or like the fracture of a china plate (the Permian) covered by a layer of porridge (the Trias).

In the case of a down-warp, it is the basement which fractures first, whereas in an up-arched structure, compression may occur in the lower horizons, tension in the upper. For this reason I feel inclined to reject the suggestion (of Nye and earlier authors) that the Mesozoic dolerite intrusion accompanied an up-warp. I do not agree entirely with Edwards who wrote (personal communication) that he imagined 'a state akin to the early stage of a geosyncline in miniature', referring to Bucher (1933, p. 478), a subsiding basin in which the lower horizons were fractured in a state of tension, while the soft, upper beds remained ductile. Tasmania during the Mesozoic should not, I feel, be compared with any stage of a geosyncline (see Stille, above): however, we agree entirely about the state of the intruded rocks: faulting in the hardened basement, with ductility in the overlying cover.

A similar situation exists in South Africa, where the Karroo dolerites exhibit close similarities to those of Central Tasmania, not only in their age, style of injection, etc., but also in that they intrude a continental basin sequence, the borders of which appear to have had a *positive* epeirogenic tendency throughout the periods in question. Du Toit (1920) correlated the injection with regional compressive and warping movements, discounting Schwarz' original idea of tension

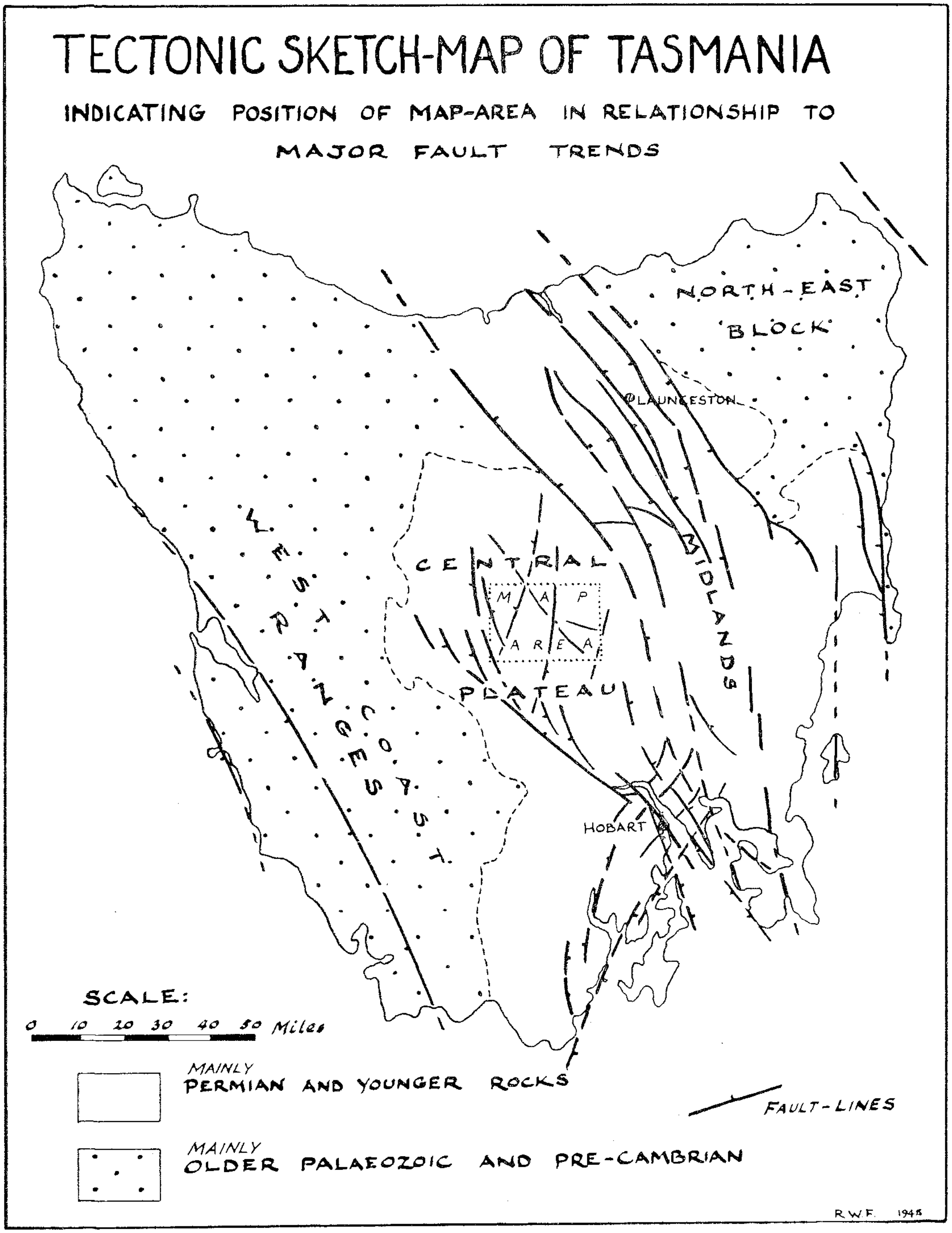

FIG. 8.—Tectonic sketch-map of Tasmania.

at the base of a subsiding trough. The deep-seated vertical fractures, especially in the older consolidated rocks are well-recognised, however, and the spreading out of sills at the junction of any sandstone and thick shale or clay member in the Karroo Beds is commonly found in many areas. Quite recently Jones and Pugh (1948) have confirmed how a wet, clayey horizon is specially effective in blocking the upwards movement of such injections.

It has been sometimes suggested that either, or both, the Mesozoic dolerite and the Tertiary basalt eruptions coincided with the events associated with the disruption of the old Gondwanaland continent, which appears to have existed prior to the Permian. This seems to be correct, for studies elsewhere in the Gondwanaland region also seem to indicate major taphrogenic phases at about the beginning of the Jurassic and towards the end of the Tertiary.

* * * * * *

Turning now to review the fracture pattern found in Central Tasmania, we have recognised first and foremost multitudinous sheafs of north-west to south-east lines crossing our map from end to end. They are best developed naturally in the brittle dolerite and tend to be absorbed in the soft sediments. In character they range from true faults and shears down to massive joint swarms. Their net effect is much the same: they appear to have been formed by series of broad north-west to south-east warps.

In addition to these gentle minor undation axes which trend north-west to south-east, there is a second set of major trends essentially of north-south to north-north-east to south-south-west orientation, which are more associated with major displacement than with warps. It is along these lines that major vertical dolerite intrusions are noted.

The complex, intersecting pattern of faults, shears and joints of the Central Plateau of Tasmania naturally calls for explanation beyond the circumscribed limits of our particular map-area. I have therefore sketched in the dominant patterns of faulting in the younger rocks of Tasmania on a tectonic map, in an endeavour to perceive the broader pattern. For clarity the map depicts only the younger tectonic patterns of the country, and omits the pre-Cambrian and Palaeozoic fault-fold trends.

It will be seen immediately that the younger rocks of Tasmania are crossed by a major series of north-west to south-east to north-north-west to south-south-east faults in a complex graben form which extends from Hobart through the Midlands to Launceston and the north coast. Between this shatter zone and the west coast there are many parallel lines. These major trends are intersected, however, by another series of faults which range from north-south to north-north-east to south-south-west; these are mainly subsidiary to the others but in eastern and south-eastern Tasmania they come to play a major role. In this manner the whole of Tasmania itself is triangular in shape and many of the plateaux and basins reflect this structural form.

It seems likely that, along these north to north-north-east trends, the faults break not only the superficial cover rocks, but also the semi-rigid, early Palaeozoic basement (Hills, 1922). The north-west to south-east trends, in Central Tasmania, on the other hand, we have seen are more in the character of fractured warps, and, although some are severely faulted, their habit is more flexural than that of the north-north-east lines. They parallel the older, pre-Cambrian fold-trends (see Twelvetrees, 1905; Waller, 1905; Carey, 1947). The resultant segmentation of the contrary into tilted and warped, diamond-shaped fault-blocks is thus of considerable complexity.

This pattern is not restricted to Tasmania, however. Lewis (1936) suggested that the major north-west to south-east lines of the Launceston-Midlands Graben, bounded on the east by the Ben Lomond Line and on the west by the Western Tiers Line, actually seem to cut clean across Bass Strait, to reappear in Victoria, again with intersecting north-east to south-west lines, as the boundaries of the Melbourne sunkland. Lewis showed how this rift conditions the presence of the Bassian Trough in the middle of the Strait, an area of subsidence completely enclosed by the 45 fathom contour and almost inexplicable by any but tectonic means.

The age of this depression has been also discussed by Nye and Blake (1938), who considered that the latest features were probably about early Miocene, though its original lines might go back to the Jurassic. One cannot agree with such an ancient date for the 'latest' features. Faulting is known to extend well into the Pleistocene (faulted basalts) and the basin depression of Bass Strait would have become blocked with sediment if it were anything but a very youthful feature.

VII. Summary

An area of the Central Plateau of Tasmania covering 391 square miles has now been mapped geologically for the first time, mainly by use of air photographs coupled with two months' field work. While the work can only be regarded as a preliminary reconnaissance, the broad results indicate that the geology consists of only one or two massive dolerite sills intrusive into the flat-lying Permo-Trias sediments, locally covered by Tertiary basalt flows. Block faulting took place during the dolerite intrusion and again in the Tertiary, before, during and after the basalt eruptions.

It is believed that the region suffered successive down-warpings in Permo-Triassic times culminating in the intrusion, through basement tension fractures, of dolerite in giant sills and even lopolithic structures. The relief was reduced during Mesozoic-early Tertiary times from one of moderate elevation to that of a peneplain, to be faulted and considerably elevated in several phases in mid and late Tertiary, even Pleistocene, during which basalts erupted and flowed down over an already well-dissected and youthful landscape. Streams are mainly superimposed in character.

The present landscape of tilted plateaux separated by fault-scarps is largely the result of differential weathering exposing the surfaces of the major sills, coupled with deep stream dissection owing to the considerable regional elevation (2000-3000 feet). Glaciation during the Pleistocene is believed to have carved out shallow depressions now occupied by boulder clay and marsh deposits, but otherwise little trace of it remains.

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PLATE V

FIG. 1.—Well-bedded, creamy white Permian mudstones, dipping 4° S.S.E., seen on W. bank of R. Ouse, 250 yds. W. of Waddamana Power Station. (Neg. RWF 3855.)

FIG. 2.—Platey cleavage in dolerite on important N.W.-S.E. shear zone, seen N.W. of Waddamana Power House on floor of R. Ouse. (Neg. RWF 3843.)

FIG. 3.—Slumped structure in current bedded sandstone (probably Trias), ½ mile N.N.E. of Hermitage. Direction of currents and slumps is from N.W. to S.E. (Neg. RWF 3825.)

FIG. 4.—Cross-bedding in quartzose sandstones (probably Trias), immediately below dolerite sill 2 miles S.W. of Dungrove Homestead. (Neg. RWF 3888.)

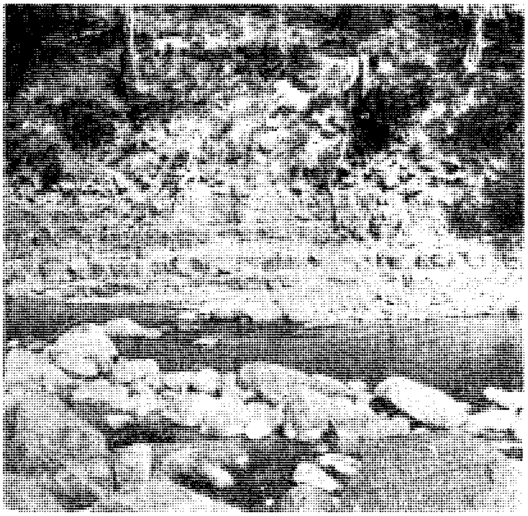

FIG. 1

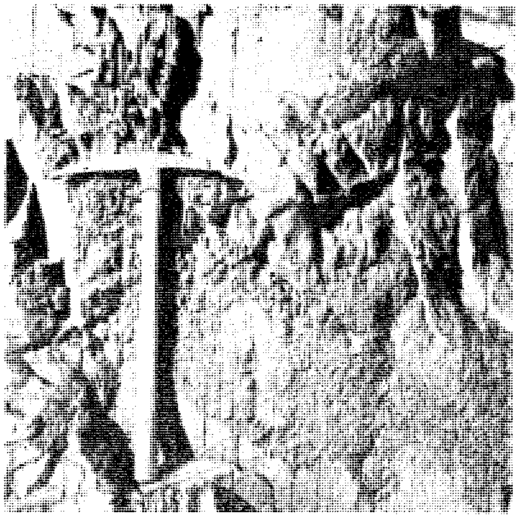

FIG. 2

FIG. 3

FIG. 4

PLATE VI

FIG. 1.—Looking E. across Shannon Valley from 1 mile N. of Hermitage. Alternating Permian mudstones and gritty sandstones dip few degrees S.W. (Neg. RWF 3823.)

FIG. 2.—Looking S. from same spot as fig. 1. Permian mudstones and sandstones dip gently S.W., to be overlain in distance by probable Trias and in turn by overlying hilltops of dolerite (Dungrove Green Hill on left, Ware's Sugar Loaf on right). (Neg. RWF 3822.)

FIG. 3.—Nelson's Bend on R. Ouse, 8 miles S. of Waddamana. W.-dipping Permian mudstone and sandstone, overlain by probable Trias sandstone. (Neg. RWF 3854.)

FIG. 4.—Nelson's Bend, looking E., showing horizontal probable Trias sandstones, overlain by basalt, separated by faulting from Permian mudstone in bed of river and dolerite on right-hand side. (Neg. RWF 3852.)

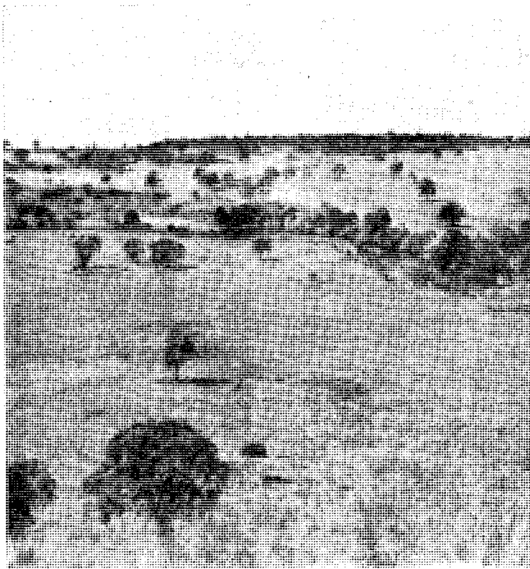

FIG. 1

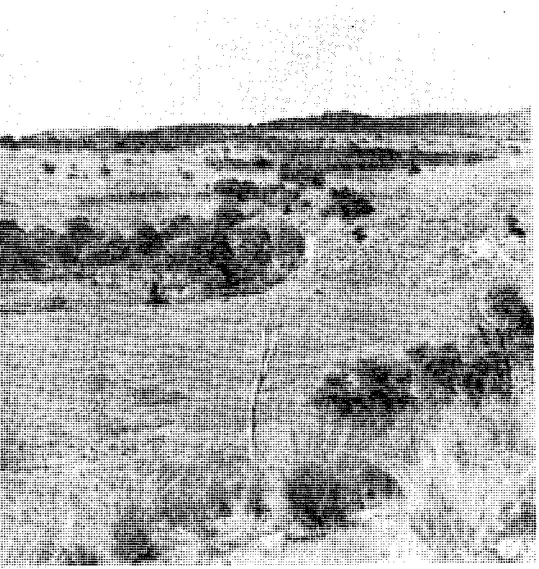

FIG. 2

FIG. 3

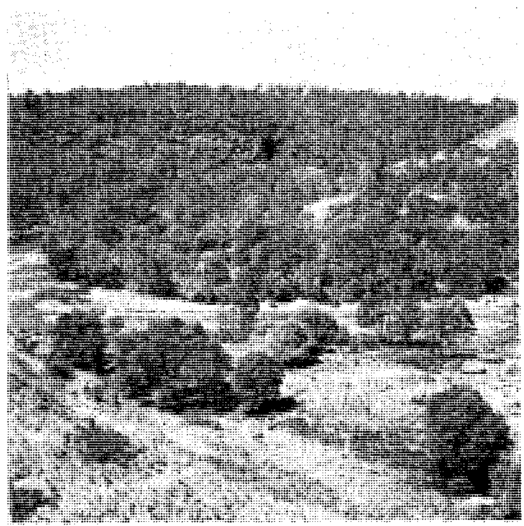

FIG. 4

PLATE VII

FIG. 1.—Looking from the hills W. of Waddamana across the Ouse Valley towards Fisher's Sugar Loaf, typical monadnock near faulted margin of dolerite country. (Neg. RWF 2826.)

FIG. 2.—From same spot as fig. 1, but looking S. down Ouse Valley and showing typical horizontal basalt lava flows resting on Permian mudstones (in the valley). (Neg. RWF 2827.)

FIG. 3.—Lake Echo, N.E. corner. From shore of probable Trias sandstone, looking N.W., past Bull Island to N. shore and dolerite plateau. (Neg. RWF 3861.)

FIG. 4.—Horizontally laminated dolerite, probably chilled top of 1000 foot thick sill, coinciding with flat top of plateau, 1 mile E. of Steppes. (Neg. RWF 3815.)

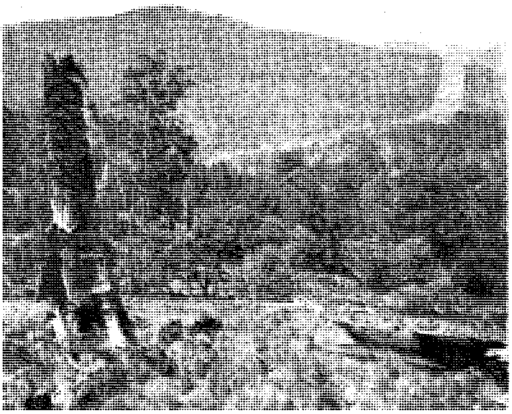

FIG. 1

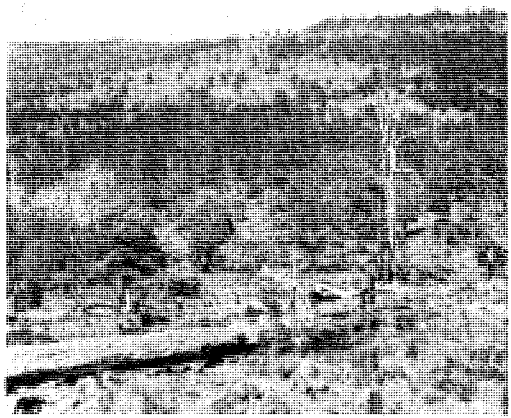

FIG. 2

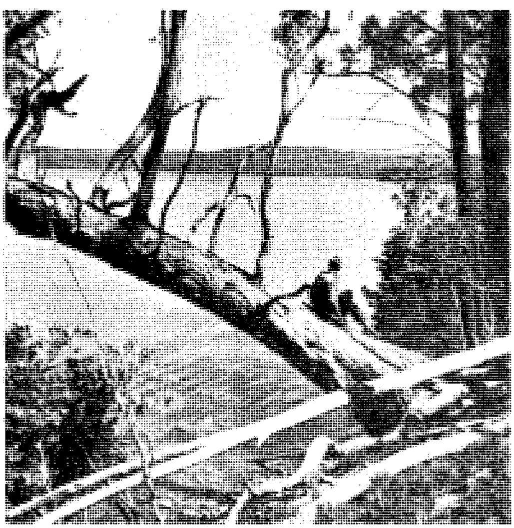

FIG. 3

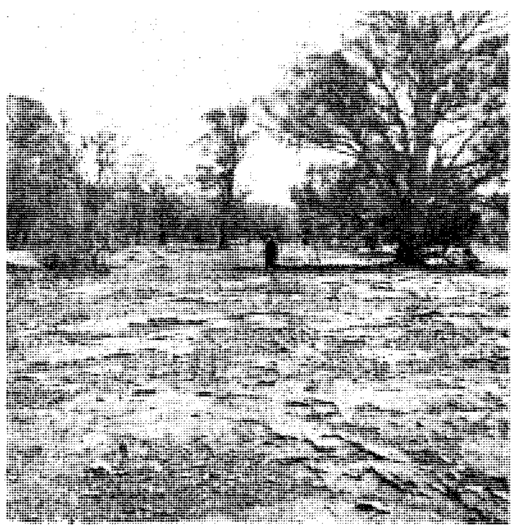

FIG. 4

PLATE VIII

Oblique air photo, looking N.E. over Waddamana, showing pipe-line from Penstock Lagoon, down to Power House in Ouse Valley. Note almost flat dolerite plateau cut off by faulting and deeply incised along the line of the Ouse.