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ART. X.—*On the Evidence of the Origin, Age, and Alteration of the Rocks near Heathcote, Victoria.*

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(With Plates XIV.-XVIII.).

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1.—Introduction.

Victorian geology abounds with problems for the solution of which conflicting hypotheses have been proposed by different observers. Among these controverted questions none is of greater interest and importance than the one with which this paper is concerned, and few present greater difficulties in the way of a completely satisfactory solution.

The problem may be stated briefly to be the origin and age of certain basic and acid igneous rocks, their relations to cherty and jasperoid series, which generally accompany them, and the relations of all the above to the Silurian and to the Ordovician rocks of the district.

The work of mapping the area presents considerable difficulty, as over a considerable part of the district rock-junctions are hard to find, and when found the relations of the rocks to one another are not easy to interpret. Furthermore both igneous and sedimentary rocks have in places been so altered that it is not surprising that different observers have interpreted the geology in different ways. Microscopic examination of the rocks helps considerably in following the interesting series of metamorphic and metasomatic changes which the rocks have undergone, but partly as a consequence of these changes some of the questions which ordinarily an appeal to the microscope would have settled, remain to some extent unsolved.

Heathcote lies about 74 miles north of Melbourne, on the Bendigo road, and within the valley of the McIvor Creek. The field observations in this paper are the outcome of several visits to the district. I have been assisted in my observations by my assistants, Mr. H. J. Grayson and Mr. H. S. Summers, M.Sc., and during one visit of four days by the members of the Geological class of the University of Melbourne. The area visited extends from Photograph Knob, in S. Heathcote, on the south, to a little beyond Lady's Pass, in Dargile, on the north. The junctions of the Ordovician rocks with the cherts and with the igneous rocks in this area, have been carefully examined in the field, collections of the rocks have been made, and about 80 rock sections have been examined. Both in the field and in the laboratory the hypotheses and evidence of previous workers have been examined in conjunction with my own observations. Further work, over a more extended area is necessary before all the obscure questions in Heathcote geology can be resolved. In this communication certain questions raised in previous papers are reviewed, a number of hitherto unrecorded observations are set out, and their bearing on earlier evidence and hypotheses is considered. I hope at a later date to deal with the evidence from the Northern and the Southern extensions of these rocks, and meanwhile offer this paper as a contribution of facts and of tentative conclusions from them, which it is hoped will be of some service towards the solution of the problems of the district.

2.—Previous Literature.

1. Geol, Sketch Map of Victoria, by Selwyn, 1866. The rocks of the Heathcote district, apart from Lower and U. Silurian, were marked as trap and described (p. 172) as dykes.

2. Descriptive Catalogue of the Rock Specimens and Minerals in the National Museum, Melbourne, by Selwyn, 1868. On page 16 the rock from Mt. Camel was described as diabase, but in the list of errata the name was changed to diorite, as the ferro-magnesian mineral was identified as hornblende, and not pyroxene. On p. 18 the substance named "Selwynite," then regarded as a mineral, was described as " in a vein in the U. Silurian rocks," indicating Selwyn's view that the basic rocks were intruded in post Silurian times.

3. *Dunn, E. J.* "Notes on the Geological Features of Heathcote and Neighbouring Parishes." Quarterly Rep. Min. Dep. Victoria, Dec. 31st, 1888, pp. 76-77. In this paper Mr. Dunn briefly described the rock series. The granitic-like rocks he regarded as syenite . . . "schistose beds, in part serpentinous, are exposed in the railway cutting south of the town. Decomposed intrusive rock is abundantly represented in them. . . . A boss of intrusive rock (greenstone) occurs on the south side of the creek, and about a mile west of the post office." Mr. Dunn stated that carbonate of magnesia is abundant in botryoidal masses in the older Silurian (Ordovician) rocks. A reef worked 1 mile S. 20 deg. W. of Tooboorac, according to Mr. Dunn, is in highly altered Silurian (Ordovician) rocks (micaceous sandstones).

4. In a letter sent to the Mines Department on July 6th, 1891, but only recently published (Records Geol. Surv. Victoria, Vol. II., Part I., 1907), Mr. Dunn asserted the pre-Silurian (pre-Ordovician) age of some of the Heathcote rocks. He says: "The formation is of pre-Silurian age, and the beds of which it consists comprise highly silicious and jaspideous rocks, very talcose splintery schists, tufaceous deposits, quartzite and ancient vesicular basalts, once surface flows but now intercalated with other strata." Mr. Dunn then suggested that these rocks have marked resemblances to the rocks of the Te Anau series in New Zealand.

5. *Lidgey, E.* "Notes on Quarter Sheet, No. 80, N.W.—Parishes of Dargile, Heathcote, Costerfield and Knowsley." Prog. Rep. Geol. Surv. Victoria, No. VIII., 1894, pp. 44-46. Mr. Lidgey described the Metamorphic rocks as consisting of "basic lavas and amygdaloidal rocks, tuffs, agglomerates, varieties of jasper, cherty rocks, and talcose, and chloritic schists." In the description of the Lower Silurian (Ordovician) rocks he recorded the finding of trilobite fragments in a micaceous mudstone from a paddock marked 3N., T. Blake, in the parish map of Knowsley East. He further noted that some of the Silurian conglomerates contained pebbles of the metamorphic rocks.

6. *Etheridge, R., Junr.* "Evidence of the existence of a Cambrian Fauna in Victoria." Proc. Roy. Soc. Victoria, new ser., Vol. VIII., 1896, pp. 52-56, pl. 1. Mr. Etheridge examined the trilobite fragments collected from Knowsley East, described

a form by the name of *Dinesus ida*, and referred it to the Cambrian series.

7. The above paper is also referred to in Mon. Prog. Rep. Geol. Surv. Victoria, No. 11, 1900, p. 26.

8. *Howitt, A. W.* "Notes on Diabase and adjacent formations of the Heathcote District." Special Rep. Dep. Mines, Victoria, 1896; 16 pp., 3 pl. and maps [with appendix by E. Lidgey, p. 15].

Mr. Howitt described the more acid igneous rocks as plagioclase aplites and felspar porphyrites, and the more basic rocks as hornblende diorites, and varieties of diabasic rocks, including diabase porphyrites, compact diabase, diabase schists, breccias and extremely altered rocks. To some of these altered rocks he applied the term spilite, and he noted that in the "regenerated rocks" the original structure of the rock has been more or less completely lost, and replaced by calcite, quartz and epidote, and in other cases the rock now consists entirely of actinolite. The cherty rocks were regarded by Mr. Howitt as having been produced by the alteration of Lower Silurian (Ordovician) shales by the intrusion first of the diabase, and later of the granitic rocks. The general characters of these cherty rocks reminded Mr. Howitt of adinoles, although he pointed out that an analysis made of one of the cherty rocks showed a much higher silica and a much lower soda percentage than is characteristic of the typical adinoles. Mr. Howitt suggested by analogy with other areas in Victoria, that the probable age of the intrusion of the igneous rocks was the close of the Silurian or the earlier part of the Devonian period.

Mr. Lidgey, in an appendix to Mr. Howitt's paper, withdrew his previous opinion that the diabases were lava flows interbedded with the Ordovician series, and agrees with Mr. Howitt that they were intrusive, and have altered the Ordovician sediments for a distance of 2 to 15 chains from the diabase contact. With Mr. Howitt's paper are included a general geological map of the area on a scale of 2 miles to an inch, and four smaller maps of parts of the area on the scale of 2 inches to a mile. The names of the Geological surveyors are not given, but I gather that Mr. O. A. L. Whitelaw mapped the small area, including the parish of Heathcote, and that Mr. Lidgey was responsible for the general map and the remaining three smaller areas.

9. *Ferguson, W. H.* "Report on an area of Cambrian rocks at Heathcote." Monthly Prog. Rep. Geol. Surv. Victoria, No. 2, 1899, pp. 23-25, 1 pl. Mr. Ferguson defined on a sketch geological map the boundaries of the beds containing the Dinesus fauna, adopting as their upper and western boundary with the Ordovician a thin bed of "brecciated-conglomerate." Ferguson stated that the trilobites were found in block 3.I., parish of Knowsley East.

10. *T. S. Hall.* "Supposed Graptolites from Heathcote." Mon. Prog. Rep. Geol. Surv. Victoria, No. 11, 1900, p. 26. Mr. Hall was unable to identify with certainty any of the remains submitted to him. He stated that graptolites of the Bryograptus type were probably present.

11. *Gregory, J. W.* "The Heathcotian, a Pre-Ordovician Series, and its Distribution in Victoria." Proc. Roy. Soc. Victoria, Vol. XV. (New Series), Pt. II., 1903, pl. 4. Professor Gregory discussed the previous literature, examined further trilobite remains from Knowsley East, and showed that the original *Dinesus* described contained two genera. The new genus he named *Notasaphus*, and suggested that the *Dinesus* beds be included in the Ordovician, as its lowest representative along the Heathcote line. He agreed with Mr. Howitt in the determination of most of the rocks, but Mr. Howitt's "adinoles" he described as black cherts and the aplite of Mr. Howitt he regarded as fine-grained grano-diorite. He recorded fragments of diabase from the Silurian quartzites near the "Copper mine," and hence regarded the diabases as pre-Silurian. The relations of the cherts, schists and diabase with the Ordovician rocks are discussed, and he regarded the series as of pre-Ordovician age. This view was based partly upon his field observations and petrographic work, but also largely on the evidence of the geological mapping of the district, and on the absence of dykes intrusive into the Ordovician series.

Prof. Gregory claimed that "Heathcotian rocks" of pre-Ordovician age occur also at Dookie, under the Silurian rocks of Rushworth, W. and N.W. of Geelong in the valleys of the Barwon and the Moorabool, at Mt. Stavely in W. Victoria, probably also at Waratah Bay, C. Liptrap, and possibly on the Howqua River. He explained the distribution of the Ordovician and Silurian rocks of Victoria in relation to an old Heathcotian land surface stretching across Victoria, and in conclusion suggested a subdivision of the Silurian rocks of Victoria into an upper, or Yeringian, and a lower, or Melbournian, series.

The following papers do not deal with the Heathcote district, but the authors correlate or contrast some of the rocks described with the typical " Heathcote " series.

12. *Stirling, James.* "Report on Examination of Reefs at Howqua Valley." Quarterly Rep. Min. Registrar, Victoria, June 30th, 1888, p. 70. In this brief report Mr. Stirling states that Malcolm's reef is situated at Malcolm's Creek, about one mile above its junction with Lick-hole Creek. It occurs in a dense blue crystalline rock, like certain massive diorites.

13. *Stirling, James.* "Preliminary report on the Geology of Dookie District," with map and two sketch sections, ibid. pp. 76-77. Mr. Stirling described the structure as follows:—"The rocks are mainly U. Silurian sediments, intruded upon by certain diorites, gabbros, etc.; the latter have in most cases effected induration or hardening of the former along the contacts, and in some places have caused segregations of iron ore, chiefly carbonates and oxides. . . . Near Dookie College, ascending the S.W. slopes of Mount Major, the sediments are indurated, the sandstones become flinty and converted into hornfels. . . . Towards the summit of the hill outcrops of hard silicious rocks are seen to be commingled with irregular bands of ironstone."

14. *Ferguson, W. H.* "Report on Sketch Survey of Eastern Portion of County of Moira." Monthly Prog. Rep. Geol. Surv. Victoria, No. 10, Jan., 1900, p. 10. The altered rocks of Dookie are regarded by Mr. Ferguson as quite distinct from the Silurian rocks or their metamorphosed representatives. They consist of cherts, quartzites, talcose schists, and ironstone and quartz rocks. Diorites and other eruptive rocks cover large areas. The district is traversed by a great number of dykes.

15. *E. J. Dunn.* The Settlers' Guide, Victoria, 1905, p. 60. To a pre-Ordovician (Heathcotian) age Mr. Dunn refers the rocks of Heathcote and Mansfield, and says minor outcrops occur in several other areas. Black slates on the Divide west of the

Macallister River, and the "black slates" of Hedi are, according to Mr. Dunn, probably referable to the pre-Ordovician. On the map, besides the Heathcote and Mt. Stavely areas, a narrow strip east of Walhalla is included in the Heathcotian series.

16. *Howitt, A. M.* "Report on the Edi-Myrrhee Turquoise Belt and the Chert and Jasper Beds near Tatong, County of Delatite, with Plan." Rec. Geol, Surv. Victoria, Vol. I., Pt. 4, 1906, p. 239. Mr. Howitt described the series of cherts, jaspers, etc., occurring in the district, and on lithological grounds classed them as Heathcotian.

17. *Howitt, A. M.* "Reports on the Phosphate of Alumina Beds near Mansfield, County of Delatite," with plan (Plate xxvii.), ibid. pp. 245-247. On p. 246 Mr. Howitt states: "In allotment 16A and 16B, parish of Loyala, phosphatic beds are associated with black and green cherts containing fragments of trilobites and brachiopods." Mr. Howitt compared these with the Heathcotian series.

18. *Dunn, E. J.* "The Iron Mask Ferro-Manganese Mine, near Buchan, E. Gippsland." Rec. Geol, Surv. Victoria, Vol. II., Part 2, 1907, p. 49. Mr. Dunn stated that Heathcotian rocks are probably represented near this locality. Further on he said: "Five miles on a road east of south from Buchan is a ridge running northerly from a portion of the Mt. Tara Range. . . . Here occur ferruginous, highly siliceous beds approaching jasper, in cherts, probably Heathcotian."

19. *Dunn, E. J.* "The Mt. Tara Goldfield, E. Gippsland." ibid. p. 46. Cherty rocks which occur at the Taedato Creek gold workings are claimed by Mr. Dunn as being of Heathcotian age.

20. *Dunn, E. J.* "Red Jasper in the Heathcotian rocks of Tooleen." ibid. p. 81. These are met with on the main road to Rushworth, and have been traced over an outcrop of half a mile in length and one chain in width, and are associated with an ancient igneous rock.

21. *Dunn, E. J.* "General Geological notes on the country between Omeo and Limestone Creek, County of Benambra." ibid. p. 131. Two and a-half miles W. 30 deg. N. of the hut on Limestone Creek, silicified schists permeated with quartz veins were met with, and striking N. 30 deg. E. They present a strong

resemblance to the Heathcotian series. About four miles N. 20 deg. W. from the hut on the Limestone Creek, near the head of Horseyard Creek, occurs a band of red jasper rocks interbedded with green schists.

22. *Dunn, E. J.* "On Mt. Wellington Corundum." "Mining Standard," October 16th, 1907. Mr. Dunn briefly describes the relations of the corundum to the serpentine area and the relations of the serpentine with the U. Ordovician shales.

23. *Hall, T. S.* "Excursion to Mt. William, Lancefield." "Victorian Naturalist," Vol. XXV., No. 1, May, 1908, pp. 9-11. In this account Dr. Hall records the silicification of the shales of the Lancefield beds near the disused Mt. William railway station, and states that the shales high up on the flanks of Mt. William are much indurated, and are succeeded by diabase or greenstone. He says: "There can be but little doubt that the Ordovician is older than the diabase, and has been silicified by its intrusion."

24. *Summers, H. S.* "On the Cherts and Diabases of Tatong." Read at Roy. Soc. Victoria, April, 1908, and published in this volume. Mr. Summers discussed the relations of the cherts and diabases in this area, which had been previously partially described by Mr. A. M. Howitt, of the Geological Survey of Victoria. He showed that the cherts were in places clearly interbedded with unaltered sediments mapped by Mr. Howitt as Ordovician on lithological grounds.

25. *Thiele, E. O.* Read at Roy. Soc. Victoria, May, 1908, and published in this volume. Mr. Thiele in a previous paper (Vic. Nat., vol. xxii., 1905, p. 24) had recorded the finding of U. Ordovician graptolites in black shales closely associated with the Serpentine area, near Mt. Wellington. In this paper he discusses fully the relations of the Serpentine to the sedimentary rocks of the district, and demonstrates that some of the black cherts which occur near the Serpentine contain recognisable U. Ordovician graptolites. The silicification of the shales is thus shown to be of post U. Ordovician age.

3.—Discussion of Previous Literature.

The foregoing list of papers shows that the literature on the Heathcote and apparently related districts is a lengthy one. My first visit to Heathcote for various reasons was deferred till February, 1908, but during the last three years I have made myself familiar with the most important papers on the district, and their perusal left me in doubt as to the balance of evidence adduced in favour of the pre-Ordovician and post-Ordovician hypotheses respectively of the age of the cherts, diabases and granite rocks of the district. At the same time various points of criticism suggested themselves as to which special examination in the field and with the microscope might be expected to be fruitful in results.

The age of the older sediments has been the subject of debate, as Mr. Etheridge described the *Dinesus* as a Cambrian form, while Prof. Gregory has shown reasons for including the beds containing the trilobites with the Ordovician as its basal member. The age of the normal older sediments is recorded as Ordovician on lithological grounds, as no fossils had been found in them. No real objection can be taken to this view, because at various points in the field they are recorded as succeeding the *Dinesus* beds, show similar dips and strikes, and are only separated from them by a narrow brecciated conglomerate a few inches in thickness.

The great stratigraphical problem is, of course, the relations of the cherts, jasperoids, diabases, and granitic rocks to one another and to the normal Ordovician sediments, and apart from the geological mapping the most important contributions are the paper by Mr. Howitt, in which the post-Ordovician age of the diabases and granitic rocks is asserted, and those of Mr. Dunn and Professor Gregory, in which a pre-Ordovician age is claimed for the igneous rocks and cherts. Mr. Dunn's first paper in 1888 is purely descriptive, and does not deal with the relative ages of the rocks. In his letter to the Mines Department, in 1891, however, he definitely states the pre-Silurian (pre-Ordovician) age of the cherty and igneous series. It is difficult to discuss Mr. Dunn's communication, because he does not present the evidence on which he based his claim for the pre-Ordovician age of the rocks, but his view was evidently based on considerable work in the district, since he states (Rec. Geol, Surv. Victoria, Vol. II., Part II., 1907, p. 81), that he had mapped the rocks of the area and sent the map to the Mines Department in 1892, but that the map had been lost.

Mr. Howitt's paper bears evidence of most careful petrological examination of the rocks, and his examination led him to the conviction that many of the rocks were of an intrusive character. This view he tested in the field. Mr. Lidgey was then mapping the area, and had come to the conclusion that the diabase was interbedded with metamorphosed Silurian (Ordovician) sediments. Mr. Howitt got Mr. Lidgey to re-examine the evidence in the field, and as a result of this he found evidence of alteration in the Ordovicians. The nature of the alteration of the Ordovician relied on by Mr. Howitt was first a bleaching of the sediments by the elimination of organic matter, then molecular rearrangement, and in extreme cases silicification to "adinoles" with over 90 per cent. of Silica.

While the intrusive character of some of the igneous rocks was placed beyond a doubt by Mr. Howitt's petrological work, I think the evidence given of contact alteration by the diabase was of a less convincing character. For instance, he does not discuss the evidence of the maps published with his paper, in which, while cherts are shown between the diabase and Ordivician in some places, in others unaltered Ordovician is shown on the maps in contact with diabase, regarded by Mr. Howitt as intrusive. Further, the silicification of sediments to cherts, as the result of intrusions of diabase, is a distinctly unusual type of purely contact metamorphism, which would seem to merit some discussion, especially as among the altered diabases he records silicified rocks. However, the feature noticed by Mr. Howitt south of Mt. Camel that the Ordovician rocks which are silicified become less so away from the contact, is certainly significant.

Mr. Howitt's view that the intrusion of the igneous rocks occurred probably in Devonian times appears to have been based upon analogy with the age of other intrusive masses, and not upon definite field evidence. Less weight, therefore, attaches to this view than to his conclusions as to the relations of the igneous rocks to the Ordovician series, especially as Lidgey reported the occurrence of metamorphic rocks in the Silurian conglomerates of Mt. Ida. Professor Gregory's paper, in which he supports Mr. Dunn's view of the pre-Ordovician age of the cherts and igneous rocks, is of a very suggestive and far-reaching character.

In discussing the relations of the Heathcote rocks to the Silurian, Prof. Gregory records fragments of diabase in the matrix of the basal Silurian rocks of the Copper mine. This, together with Lidgey's record of pebbles of metamorphic rock in the Silurians, certainly indicates a pre-Silurian age for the diabase and cherts.

The evidence which Prof. Gregory quotes of the relations of the diabase to the Ordovician is of a less direct character. He states that in places he found no evidence of alteration at the contact. At Red Hill, where schistose rocks occur between the diabase and unaltered Ordovician, he was unable to find either a sharp junction or a passage from schists to Ordovician, but on microscopic examination was always able to say whether a rock belonged to the schistose or to the Ordovician series. It seems to me that these determinations under the microscope should be interpreted very cautiously where the field evidence is not clear, inasmuch as two sections cut from rocks of the same series might easily present very different microscopic characters if one were unaltered and the other highly altered.

On p. 161 Prof. Gregory refers to Craven's paddock, in Knowsley parish, allotment 32, where he says: "The two rocks can be well seen in contact close along the eastern fence. Here, as elsewhere, the junction between the hard cherts of the metamorphic series and the normal slates and sandstones of the Ordovician series can be clearly recognised." The statement of locality is almost certainly a misprint for Knowsley East, as the diabase series does not occur in Knowsley. The name of Craven does not appear on the map, and allotment 32 does not occur along the line of the metamorphic or diabasic rocks. The number of the allotment is probably wrongly stated, and this is unfortunate, as Professor Gregory's statement implies the occurrence of a discontinuity at this point between the cherts and the normal Ordovician.

Professor Gregory comments on the absence of dykes from the igneous rocks intruding the Ordovician and Silurian rocks, and regards this as important negative evidence of the pre-Ordovician age of the igneous rocks. He lays great stress on the evidence afforded by the geological maps, which he claims is inconsistent with the view of Mr. Howitt that the igneous series is post Ordovician, and proves that the Ordovicians are resting unconformably upon the cherts and diabases. In several of the cases mentioned by Prof. Gregory he did not verify the mapping. From among a number two cases may be cited. From the northern boundary of the Heathcote parish diabase is shown in contact with the Ordovician for two and a-half miles to the west of the northern end of the township, and along the whole of this line no metamorphic rocks are shown between the Ordovician and diabase series.

In S. Heathcote, again, a patch of metamorphic rocks is shown in allotments Nos. 15 and 16, where a bay represented on the map as unaltered Ordovician runs up between the diabase on the north and an intrusion of Felspar porphyrite on the south-east.

It must be admitted that the simplest explanation of the mapping at the latter point is, as Prof. Gregory stated, that the Ordovician rests unconformably upon the cherts and diabases. It seemed to me to be a case where the field evidence should be closely examined. All the other cases mentioned by Prof. Gregory seem to me to be susceptible of an alternative, if less simple, explanation. It is admitted that in the areas mapped as diabase there occur intrusive rocks, lava flows and fragmental rocks (agglomerates, etc.). Apart from the question of the mapping accurately representing the relations of the rocks, we have then the possibility that the apparently capricious distribution of cherty rocks might stand in relation to the proximity of intrusive rocks, and that the appearances claimed by Prof. Gregory of the unaltered Ordovician resting unconformably on the diabase might be explained by the overlapping of lava flows of diabase or diabase tuffs over different members of the Ordovician series. In this way it would be possible to explain the absence of alteration in certain parts, as recorded on the map. Mr. Howitt's evidence, and especially the variability of silicification of the Ordovicians with the distance from the diabase, was in apparent conflict with that adduced by Prof. Gregory. Much of the latter is, as he notes, of a negative character, and the positive evidence is possibly susceptible of another interpretation.

I felt that neither view was so firmly based but that further evidence, especially of a positive character, if available, would serve to strengthen one or other of the rival views. I therefore entered on field work in the district with the intention of examining the field evidence as closely as the time at my disposal would permit. My attention was largely directed to the relations of the igneous rocks to the Ordovicians, and to the black cherts, and I paid particular attention to the areas above cited, and notably the occurrences at S. Heathcote, just north of Photograph Knob, and now present the results of my investigations.

4.—Relations of the Igneous Rocks to the Silurian Series.

S. Heathcote.—Behind and for some distance to the north-west of the S. Heathcote Hotel, silicified and chertified diabase, and in places a mixed selwynite and carbonate rock occurs, forming the western boundary of the McIvor Creek. The Silurian rocks, mainly sandstones and quartzites, outcrop on the opposite side of the creek, and just below the hotel are seen in section in the stream, near where scheelite was found some years ago. No actual contact, howver, could be seen.

Heathcote.—Within the limits of the township the relations between the two series are everywhere obscured by the recent alluvium deposited by the McIvor Creek.

Near the "selwynite" Outcrop.—This occurs about 2½ miles north of the township, on the Murray Road, on the west side, and just north of the junction of the road running N.W. towards Derrinal. Selwyn described this substance as "in a vein in the Silurian." There can, however, be no doubt that it is within the diabase area, although very close to the junction, as diabase in situ occurs in a small gully on the east side of the road. The selwynite appears to be a peculiar modification of the diabase. Near here Prof. Gregory states that sections of the basal Silurian rocks contained fragments of diabase. I have had sections of some of these rocks made, and there occurs in some of them small iron-stained areas which may very likely be decomposed diabase fragments, although I am unable, owing to their iron-stained character, to be certain of their nature.

About 3 Miles N. of selwynite Outcrop.—A road joining the Murray road and running between paddocks 3m and 3j towards the isolated diabase mass in Tranter's paddock, Knowsley East, crosses a small creek by a bridge within 20 yards of the Murray road. The Silurian is mapped as being "in situ" on the east side of the Murray road, and beneath the bridge in the bed of the creek are large blocks of Silurian quartzite and conglomerate not "in situ," but evidently derived from rocks near at hand. These blocks in several instances contained pebbles and angular fragments of black cherts. Microscopic examination of these chert fragments shows that they are petrologically indistinguishable from the black cherts of Lady's Pass, and near Red Hill. This corroborates Lidgey's evidence, and shows Professor Gregory was right in claiming the cherts, and presumably the diabase, as of pre-Silurian age.

5.—Relations of the Igneous Rocks and Black Cherts to the Ordovician Series.

This problem is the most obscure of all those which arise in the Heathcote district, and, as the previous literature shows, Professor Gregory and Mr. Howitt have given explanations of the relations of the two series which are mutually conflicting. Mr. Howitt claimed that the diabase has everywhere altered the Ordovician rocks for some distance from the contact, the nature of the alteration in places being bleaching and the formation of secondary micas in the shales, and in other cases the silicification of the shales ultimately to black cherts. Professor Gregory has not dealt with this aspect of the question except to state that in several localities, some of which he cited, the Ordovician at the contact with the diabase was quite unaltered.

I have followed the line of contact of these two series from Photograph Knob in the S.E., almost continuously to three miles north of the selwynite outcrop in the northern part of the area, and without at this stage discussing the origin of the alteration wherever I have examined them. I have found the Ordovician rocks silicified near the junction with the diabase to a greater or lesser extent. On the accompanying sketch Geological map (Pl. XVIII.) I have indicated this by a series of dots added to the horizontal shading, which represents the Ordovician rocks. The map is based upon those published in Mr. Howitt's report by Messrs. Lidgey and O. A. L. Whitelaw. The boundaries of the

Silurian, Pliocene and Alluvial deposits I have accepted without confirmation, as the problems discussed in this paper are not materially concerned with these rocks. The boundaries of the igneous rocks and of the diabase Ordovician junction I have examined fairly closely, and while not claiming that the revised boundaries I have laid down are absolutely accurate in every detail, I feel confident they represent a sufficiently close approximation to the true relations for the purposes of a sketch map and for this discussion. In that part of the map dealing with the junctions of diabase and Ordovician I have made some important modifications. The marginal silicification of the Ordovicians is represented by dotted lines. The interesting relations near Photograph Knob have been closely examined (see Sketch Section), and I have come to the conclusion that the bay of unaltered Ordovician represented on the map in Mr. Howitt's report just north of the felspar porphyrite, is in reality diabase tuff and silicified diabase approaching a chert, while the patch marked metamorphic has no defined boundaries, and is really highly silicified diabase and diabase tuff. Probably a dense bluish grey rock which is represented here was accepted by the author of the map, and apparently by Prof. Gregory, as a blue Ordovician shale. It shows, however, no sign of bedding, and in section under the microscope (Sect. 614) differs from the shales (Sect. 574) by showing an absence of bedding and of micaceous flakes. It appears to consist almost wholly of chloritic or serpentinous alterations of a basic rock, probably a tuff. A foliated bluish grey rock of somewhat similar character is seen in section in a small gully immediately south of Photograph Knob, and a similar rock (Sect. 597), splitting readily into long semi-prismatic masses, occurs in paddock 17c, about a quarter of a mile S.E. of Photograph Knob, and within the boundary mapped as diabase. The same rock has then in one place been mapped as unaltered Ordovician, and a little further to the S.E. as diabase. There can be little doubt that both outcrops are related to the igneous series, and probably represent fine-grained consolidated diabase tuffs. This is supported by the fact that at the S. end of Red Hill, in the shaly diabase, occurs an indurated rock (Sect. 633), agreeing closely in hand specimen and under the microscope with the rock N. of the Felspar Porphyrite. The rock in the gully S. of Photo. Knob is a rather coarser type in which the fragmental character can be made out (Sect. 582), while the Knob itself represents coarse consolidated agglomerate, probably occupying the neck of a vent. This interpretation would remove the evidence of unconformable overlap of the Ordovicians N. of the felspar porphyrite claimed by Professor Gregory at this point. It is to be noted that the Felspar Porphyrite occupies a considerably smaller outcrop than is shown on the earlier map. West of the diabase and felspar porphyrite partially chertified Ordovician was seen at several points, but no good exposures were visible. The marginal Ordovician continues cherty to the gully south of the small Diorite Knob shown on the map. Here again I have altered the geological boundaries. The black cherts and very silicified rocks extend round the E. and S.E. sides of the diorite, and also in a somewhat less silicified form for about 20 yards on the west and south-west sides. A trench about 40 yards west of the diorite shows Ordovician shales, in places indurated and containing sporadic nodular lumps of cherty carbonates. The rocks here are vertical, and strike N. 40 deg. W. The same strike is noticed in a creek about 150 yards W. of diorite, and in much silicified shales 20 yards N.W. of the diorite, and also in the black cherts seen a few yards further north. Rock exposures are so limited that the relations between the black cherts and slightly cherty Ordovicians are not seen, but the evidence of dip and strike discloses no discontinuity. The black cherts extend much further to the N.W. than was shown on the earlier map, and have been traced beyond the next gully to the N., and then N.E. to within a few hundred yards S. of Crossing No. 45, where they come in contact with the granitic series. The marginal Ordovician continues to show evidence of silicification northerly as far as the gully at the S. end of Red Hill.

Between the diabase of Red Hill and the normal Ordovician occurs a narrow strip of rocks marked as metamorphic, and described as schistose beds by Prof. Gregory, which extend further both to S. and N. than is shown on the earlier map, and whose relations to both series are not very clear. At the S. end of Red Hill they are fragmental beds apparently made of diabasic material. A small gully running S.W. from here across the strike of the beds gives an almost continuous exposure of these rocks, which pass into what is mapped as normal Ordovician. Strike and dip were observed at several points along the section, and were found to remain practically constant. The rocks plainly here form a continuous series without stratigraphical break, and the inference is that the schistose fragmental diabase rocks form the lowest representatives of the Ordovician series at this point (Plate XVII., Fig. 2). Following them northwards is a puckered shaly rock with surface outcrops of an alteration to ironstone, and to ferruginous cherts. At the beacon marking the summit of Red Hill the dump from an old mining shaft shows silky shales almost completely altered to chert. On the northern slopes of the hill not far north of the Beacon these give place to very decomposed, greasy-feeling shales, and N. and N.W. of these black cherts are again seen, and form the most northerly of these beds on Red Hill. West of Red Hill the ground slopes to a gully, and the very limited exposures do not permit a close examination of the relations of this series to the normal Ordovicians. Dips and strikes, however, in the two series, whenever they could be observed, were fairly concordant. At the S. end of the hill strikes E. and W. were noticed; further north both series showed W.N.W. strikes. No break in the succession was seen, and no conglomerates were noticed. The field evidence points strongly to the ironstones and grey and black cherts being simply highly altered representatives of the schistose fragmental diabasic bedded rocks at the S. end of Red Hill, and all these types should be included not with the pre-Ordovician, as Prof. Gregory maintains, but as the oldest representatives in this locality of the Ordovician series. Beyond the gully, running S.W. at the W. end of Red Hill, cherty Ordovician extends along the contact up to the small patch of Pliocene shown on the map. Beyond this the contact for about a mile has not been examined by me. A hill composed of black finely-bedded and folded cherts occurs about 250 yards W. of the Derrinal road, and about 300 yards N.W. of junction of the Derrinal and Murray roads. The hill is about 150 yards S. of crossing 51 on the railway. The dip is 90 deg., and strike W.S.W. It is shown on the early map as diabase, and it is indeed in contact with diabase. It appears at first sight to be a normal shale silicified to a black chert. Closer investigation, however, showed that on the E. and N.E. sides, especially in a shallow railway cutting S. of Gate 51, less silicified portions of the same bedded series are represented, and pass gradually into a bedded fragmental diabasic rock, apparently a bedded diabase tuff. The evidence seems clear, then, that here the bedded black cherts, with associated ironstones, are simply silicified, probably submarine, basic tuffs, or rocks made up of diabase fragments. A few hundred yards beyond this hill the Ordovician diabase junction crosses the Derrinal road near a road cutting. The Ordovicians are soft brown shales containing numerous Magnesite concretions, strike N. 10 deg. W. about, and are nearly vertical. On the east side of the road cutting a few yards from the road, silicified shale was seen, and in the bed of the Mt. Ida Creek is an outcrop of a dense silicious rock, with Pyrite abundantly scattered through it. The rock looks at first like a quartzite, but under the microscope is clearly seen to be an igneous rock, consisting mainly of lath-shaped plagioclase, chloritised biotite and some Pyrite (Sec. 648). A few yards down stream the diabase was seen in situ, and is partly fragmental in character. Massive silicified diabase was seen a little N.E. of the road cutting, and again in a cliff section on the E. bank of the Mt. Ida Creek, north of the outcrop of silicious diabase. I have also examined the junction between diabase and Ordovician, at *several points further north*, notably W. and S.W. of the Selwynite outcrop, north of paddock A_6, Knowsley East, near the southern end of the Dinesus beds, in paddocks 3 and 3q, and also in paddocks 3m and 3j, Knowsley East. In all these places the Ordovician was more or less cherty in character, and in several places the Dinesus beds were distinctly cherty. Whatever explanation may be offered of this feature, Dr. Howitt's claim for the marginal alteration of the Ordovician near the diabase contact is one that can be generally substantiated in the field. It should be noticed that on Lidgey's map (Quarter Sheet No. 80), the diabase is not represented as outcropping anywhere in allotments 3q and 3m, Knowsley East, a gap of nearly a mile. In its place a thin outcrop of "Metamorphic" rocks is shown. Professor Gregory (op cit) refers to this locality as follows:—"Moreover the metamorphic rocks occur in places where there are no igneous rocks exposed in the immediate vicinity. Thus an exposure of the typical cherts of the metamorphic series occurs along the eastern edge of allotment 3q in Knowsley East. The cherts occur between the Silurian rocks on one side, and unaltered Ordovician on the west. There are some diabases a little south of this allotment, but none occur in it." I am unable to reconcile the mapping and Professor Gregory's statements with my own observations at this point. At the S. end of allotment 3q, near the Murray road, is a limited outcrop of a bedded rock in hand specimen like a quartzite, and associated with it is a dark, dense cherty rock. Microscopic examination shows that the latter (Sect. 651) is a diabasic rock, probably fragmental, which has been almost completely silicified. I am less positive about the origin of the former (Sect. 588); it may be a quartzite, but it presents appearances which suggest that it may represent an extreme stage of replacement of a diabasic rock by silica. Just W. of this outcrop foliated or platy diabase occurs, similar to that on Red Hill, and, indeed, fragments occur fairly abundantly on the surface going northwards along allotment 3q, between tho road and the outcrop of the Dinesus beds, which here, as elsewhere, are frequently chertified.

This evidence is of importance, as from the assumed absence of diabase in this locality, Professor Gregory inferred that the Ordovician overlaps and rests unconformably on the metamorphic cherty series.

An isolated area of diabase is shown on the map, occupying an allotment with the letters M of W, and indicated on the Parish Map of Knowsley East as Tranter's Paddock. It is represented as surrounded by normal Ordovician. It consists mainly of a platy variety of diabase similar to that on Red Hill, and probably representing an altered tuff. Near the margin it is highly silicified, and in places is converted into a black dense chert. The rock mapped as Ordovician, with which it comes in contact, is well bedded, generally considerably silicified, and cavernous, owing to the removal of crystals by solution from the rock. In general appearance under the microscope it strongly resembles a submarine bedded tuff.

An almost identical rock occurs just W. of S. Heathcote railway station, in what is mapped as Diabase; some of the

Dinesus material is also similar, and the cherts of Lady's Pass appear to differ from it only in a more complete silicification.

6.—Relations of the Dinesus Beds to the Ordovician and to the Diabase.

On Quarter Sheet 80 these beds are shown in the Parish of Knowsley East as a narrow band up to a quarter of a mile in breadth, stretching northwards from the northern end of allotment 3 to the middle of 3k. Their eastern boundary is the diabase series, and the bedded silicified fragmental diabase recorded as "Metamorphic." Their western boundary is with the Ordovician shales, and the boundary taken by Mr. Ferguson was a thin bed of a "brecciated-conglomerate." Along the road running west from the Murray road, and separating allotments 3m and 3j, a small section is to be seen in which the strike of the rocks is almost N. and S., and the dip about 70 deg. to the W. The section shows from E. to W. a few feet of the upper beds of the *Dinesus* series, consisting of brown shales and mudstones partially silicified. These are succeeded by the brecciated-conglomerate about 2 inches in thickness, consisting of subangular fragments of shaly material, and cherty fragments set in a fine groundmass. Succeeding these are mudstones with smaller fragments forming, according to Mr. Ferguson, the lowest beds of the normal Ordovician series here. A specimen taken about 20 feet W. of the brecciated-conglomerate consists of a bedded, rather dense, light-coloured, somewhat cherty rock containing little black specks, which were at first thought to be small fragments of an older black chert. Under the microscope, however (Sec. 634) (Pl. XVI., Fig. 4), these show as quite colourless areas, with no defined boundary, but passing gradually into the groundmass of the rock. There can be no doubt that they are secondary in origin, and represent local segregations of chalcedonic silica in a less siliceous matrix.

The brecciated-conglomerate also contains fragments of what in the hand specimen look like a black chert. Under the microscope (Sec. 618) (Pl. XIV., Fig. 1), it is seen to consist of fragments of altered diabase, and of a fine-grained rock, possibly diabase tuff. All of the fragments are more or less silicified, but the bedded fragments are more completely replaced than the others, and some approach in character the black cherts. Secondary quartz as well as chalcedony occurs, and it is probable that all the silicification was effected after the formation of the conglomerate. In one fragment a circular cross-section in chalcedony may represent a section of an organism. From the appearance of the rock under the microscope, it may be either a local shoreline detrital conglomerate, or a rather coarse submarine tuff. In any case it is clearly interbedded, and cannot be regarded as representing a stratigraphical break between two separate formations.

The relations of the *Dinesus* Beds to the Diabase have not been clearly seen. The diabase for at any rate some distance along its outcrop east of the *Dinesus* Beds is either the platy type as occurs at Red Hill, or the highly silicified jasperoid, and I have not anywhere seen an exposure showing the relation of the two series. The abrupt junction shown on the Quarter Sheet between the two at the S. end of the *Dinesus* Beds I have been unable to confirm. Cherty tuff-like rock fragments occur in the paddock both to the N. and S. of the junction, as mapped, but no exposures are seen. The field and microscopic evidence would admit of two explanations. On the one hand the diabase may be an older series and the *Dinesus* beds may represent bedded detrital rocks from the old diabase land area. On the other hand, the diabase may be practically contemporaneous and represent submarine lavas and tuffs passing westward into more finely-bedded tuffs, the *Dinesus* series.

7.—Nature and Origin of the Igneous Rocks.

The Basic Igneous Series.—As pointed out by previous workers, the basic igneous rocks comprise intrusive masses, lava flows, and fragmental (pyroclastic rocks).

Dr. Howitt and Professor Gregory maintain that most of the rocks are intrusive, while Mr. Dunn, from field evidence, regarded them as mainly surface rocks. Within the limits of the area I have observed—viz., from Photograph Knob on the south, to Lady's Pass on the north—I find both field evidence and microscopic evidence in support of the view that the bulk of the rocks consist of lavas, tuffs and agglomerates, and that intrusive rocks are rather sparingly represented. Dr. Howitt has discussed so fully most of the characters of the igneous rocks that it is not necessary to do more than refer briefly to them, except the more altered rocks, in relation to the question of the origin of the silicification of the Heathcote rocks.

Intrusive Rocks.—Dr. Howitt has described some of the diabases as intrusive rocks, and among the small intrusions in the form of bosses are the Diorite Knob at S. Heathcote, and another similar mass just west of S. Heathcote station. Another rock from about ⅓ mile N. of the Selwynite outcrop, which I have examined (No. 630), is holocrystalline, and is clearly an intrusive diabase. They show distinct petrological characters from the diabase series, as Dr. Howitt has pointed out, yet they are almost certainly genetically related to the diabase magma, and represent rather later and somewhat less basic intrusions of the magma.

Basic Lavas.—Rocks of this character appear to be sparsely represented in the southern part of the area examined, but have been met with in several areas between the Selwynite outcrop and Lady's Pass. Some of the diabase rocks just south of Lady's Pass appear to be lavas, and two other rocks may be specifically referred to.

Opposite the Junction Hotel, about a mile S. of Lady's Pass, is a massive outcrop of a compact diabase. Under the microscope (Section 601) the rock is seen to be distinctly porphyritic, comparatively fresh phenocrysts of plagioclase, and chloritised pseudomorphs after hornblende or augite are set in a fine felted groundmass, which has been recrystallised as a mixture of needle-shaped actinolites and a colourless base, possibly felspar and quartz. Associated with the chloritic pseudomorphs are secondary crystals of epidote. In its altered condition the precise nature of the rock is difficult to determine; it might be an intrusive or an effusive rock. From its field characters I am inclined to regard it as a porphyritic lava. Another rock of less equivocal character was examined in a paddock about 300 yards W. of the Murray road, and about 1½m N. of the Selwynite outcrop, in allotment A6, Knowsley East. The diabase rocks here form a ridge, and are considerably altered to siliceous and calcareous diabases.

A rock section (No. 602) shows that no original minerals remain, the rock now consisting of chlorite, carbonates, chalcedony, secondary quartz and secondary albite. Some of the original structures remain, however, and the presence of amygdaloidal cavities filled with secondary minerals is noticeable, not only in the rock section, but abundantly in the field, and demonstrates that the rock was originally a vesicular lava flow.

Pyroclastic Rocks.—Fragmental igneous rocks in my opinion represent the predominant type in the area I have examined. They include agglomerates, tuffs and other altered rocks, originally composed mainly, if not entirely, of diabasic fragments which may be tuffs or detrital sediments. The latter are generally well bedded, and usually more or less completely altered to cherts.

Agglomerates.—The best example of these occurs at Photograph Knob, in S. Heathcote. A small eminence here marks the position of the plug of an old volcanic rent, in and near which the coarser diabase fragments fell. Subsequent alteration has converted the mass into a very tough, hard rock. The agglomerate, from its relation to finer tuffs exposed in a stream bed to the S., and also seen to the north, appears to be rather younger than and intrusive into them. My interpretation of relations of the rocks near here is shown in the accompanying sketch section (Pl. XVII., Fig. 1). Under the microscope (No. 545) (Pl. XIV., Fig. 2) the agglomerate consists of angular fragments of a dark basaltic rock with lath-shaped felspars in a groundmass of a more felspathic recrystallised diabase, possibly originally fragmental. It consists now entirely of secondary minerals, including felspars, quartz and needle-shaped actinolite. Vivid green chlorite fills cavities in the rocks, and also replaces primary minerals, probably felspar and augite. The large size of some of the rock fragments gives the rock the character of a typical agglomerate.

Another rock (No. 576) (Pl. XIV., Fig. 3) occurring as boulders in the foliated diabase of Red Hill, near the junction with the granitic rock, is also coarsely fragmental in character. Under the microscope some of the fragments are seen to be similar to the platy diabase. They are set in a dense groundmass whose character is obscured by alteration, and the boundaries of the fragments are defined by a red-brown ferruginous layer.

Tuffs.—Under this description I place the platy diabase of Red Hill, described by Dr. Howitt as a sheared diabase, and similar rocks near Photograph Knob, just south of the cherts of Lady's Pass, below the cutting in Ordovician on the Derrinal road about ⅓ mile N. of the Murray road junction, the diabase from allotment 3q, Knowsley East, and from the isolated diabase mass in E. Tranter's allotment M. of W., Knowsley East. Some of the highly altered diabase rocks to be described later are also quite possibly fragmental in origin. Owing to the alteration and foliation of these rocks, in no case is the characteristic structure of the groundmass of a normal tuff preserved. Both in the diabase of Red Hill and in the rock in the gully S. of Photograph Knob the fragmental character can be seen in the field, and in hand specimens, and a passage from these into finer-grained rocks, presumably volcanic ashes, is to be observed. The inclusion of coarser types like the agglomerate (No. 576), described above in the finer platy diabase of Red Hill, is significant, and is of assistance in determining the original character of these altered rocks. The rock from the stream bed S. of Photograph Knob shows in section (No. 582) parallel development of chlorite and secondary quartz and felspars, and some magnitite. Irregular lighter coloured areas may represent fragments of a rock of different character. The dense, fine-grained diabasic rocks from the paddock ¼ mile S. of Photograph Knob (No. 597), and from the area previously mapped as Ordovician, just N. of the felspar porphyrite (No. 614), have been previously referred to, and their resemblance to a fine indurated bluish diabase at the S. end of Red Hill (No. 633). From their association with rocks whose fragmental character is clearly visible, I regard these types as probably volcanic ashes, which by alteration and subsequent pressure have been indurated and have developed a marked foliation. Their character is in striking contrast to the diabases which can be shown to have been lava flows and intrusions, and which appear to have undergone the same mineralogical changes as the foliated diabases.

A rock whose fragmental character is clearly manifest (No. 583) (Pl. XIV., Fig. 4) is the type represented in allotment 3q, Knowsley East, where, according to the Quarter Sheet and to Prof. Gregory, no diabase occurs. Under the microscope the rock is seen to be composed of larger and smaller angular fragments of diabase altered to a chloritic rock. Many fragments by the introduction of silica in solution have been converted into cherty rocks. The process of partial silicification has in the case of this rock not been attended by the removal from the rock of its original felspathic material. This has recrystallised as secondary felspars, and with them occur secondary quartz crystals. Irregular chalcedonic areas are also to be seen, and small quartz veins. The secondary character of both the quartz and felspar is indicated in places by the fact that the replacement of the original diabase has been only partially effected, so that the secondary mineral has included some of the diabasic material.

Flanking the foliated diabase of Tranter's paddock, M. of W., Knowsley East, there is a bedded silicified rock mapped as Ordovician. It occurs between the platy diabase and the Ordovician shales, but its relations with each are not clear, as no exposures are visible. Its bedded character tends to link it with the sedimentary series, but its mineralogical constitution shows its relationship to the diabase series. The hand specimen has a pitted surface, due to the solution and removal of minerals. The shapes of the cavities are of two kinds, the one elongated prismatic, suggesting the former presence of actinolite, the other clearly having the shape of felspar crystals. Under the microscope (No. 584) (Pl. XV., Fig. 1) the bedded and cavernous characters are visible. Numerous altered crystals of pyroxene and larger fragments of igneous rocks are set in a fine textured groundmass, which is now silicified. Tho rock appears to have been a bedded submarine tuff, or possibly a clastic rock derived from a diabase shore line. A precisely similar rock occurs flanking the diabase just W. of the S. Heathcote railway station, and some of the rocks in the area mapped as *Dinesus* Beds are similar in character, and generally more or less silicified. Under the description of the black cherts I shall have to point out similarities which exist between many of them and rocks of this character.

The Granitic Rocks.—Dr. Howitt has given full petrological descriptions of these rocks. One type he refers with some hesitation to aplite, and notes that it is frequently granophyric, and the other he refers to as labrador-porphyrite.

Professor Gregory agreed with Dr. Howitt in the naming of the porphyrite, but regards fine-grained grano-diorite as being a more suitable term for the rock which Dr. Howitt has referred to the aplites.

I can appreciate the difficulty in finding an appropriate name for this type, and I think this difficulty is connected with its mode of origin. The minerals present are plagioclase (oligoclase to labradorite), hornblende, biotite, a white mica, quartz and orthoclase in the rock (No. 627) from just S.W. of Gate 45, S. Heathcote, while in the Red Hill exposure very little hornblende or biotite occurs (No. 587), but the rock is more altered, and they may have been removed by solution. I think that perhaps the term micro-granite, using it in a wide sense, would be an appropriate name for most of the occurrences, while many of the rocks show so marked a granophyric or micrographic intergrowth of quartz and orthoclase that the term granophyre may be used to define these varieties.

The origin and relations of these rocks merit some consideration. They are certainly not normal plutonic rocks. The fine-grained character and other peculiarities show that the magma consolidated under a comparatively small thickness of rock, and its mineral composition and the micrographic and granophyric intergrowth of the quartz and orthoclase suggest that it represents a residual relatively acid, part of a basic magma, and having more or less the composition of an eutectic mixture it remained molten after the intrusion and consolidation of the more basic part of the magma. I regard these micro-granites and granophyres and the labrador porphyrite as genetically related to the diabases, belonging to the same volcanic period, and representing the last of a series of intrusions, of which the diorites mark an earlier phase.

The microgranite in places comes into relation with the Ordovician series, although no good contact has been observed. Of course, if the granite were the older series no contact metamorphism should be seen. Even if the granite were intrusive into the Ordovician the amount of alteration to be expected at the juncton would, I think, be very small in view of the probable relatively superficial conditions and low temperature of its consolidation. The contact of diabase and micro-granite is well exposed on Red Hill, and here the alteration effected by the granitic intrusion is certainly trivial, amounting only to a slight bleaching in colour, and the production of a rather fissile-jointed character in the diabase for a distance of about three feet from the contact. The labradorite-porphyrite occurs as a small intrusion in the diabase, just north of Photograph Knob, and as a marginal rock at the junction of the micro-granite and diabase at Red Hill. It is a dark rock (No. 599) with porphyritic labradorite, biotite and hornblende, in a dense granophyric groundmass of quartz and orthoclase. It must be regarded as a modification of the micro-granite which may possibly have absorbed some diabasic material before consolidation.

8.—Nature and Origin of the Ordovician Sediments.

This question has been discussed in considering the relation of the Ordovician and cherty series to the diabases, and the appearances of Ordovician shales in hand specimens, and under the microscope have been compared with those of fine-grained diabase rocks. It has been shown that at the S. end of Red Hill a continuous conformable succession is seen from a rock composed of diabase fragments, through finer-grained types to the normal Ordovician shales. The evidence points strongly to the Ordovician series, near the diabase, being composed mainly of diabase fragments. This is supported by the observation, first made by Mr. Dunn, which can be verified at several localities, that magnesite nodules segregate from the Ordovician shales. The junction between the foliated diabase of Red Hill and the diabasic Ordovician is a sharp one (Pl. XVII., Fig. 2). It may be explained either as an unconformable junction or as a fault junction. In the first case the diabase might be pre-Ordovician, in the latter the diabase may be of Lower Ordovician age, and consist of unbedded tuffs passing into a bedded series.

The *Dinesus* beds, which also are mainly composed of diabase fragments, appear to be interbedded submarine tuffs; they may possibly be, however, detrital sediments formed from a pre-Ordovician diabase. No section showing the relations of the two rocks has been observed.

9.—Altered Rocks.

A.—*The Age and Origin of the Cherts.*

The lighter, less silicified rocks seen in many places near the contact of diabase and Ordovician present few difficulties, as they are clearly only moderately altered shales of the Ordovician series.

A peculiar type of more silicified bedded rocks occurs flanking the isolated diabase of Tranter's paddock, Knowsley East. Another outcrop occurs W. of S. Heathcote railway station, and is also represented among the rocks mapped as *Dinesus* Beds. The S. Heathcote occurrence is mapped with the diabase, the one flanking the isolated diabase is mapped as Ordovician. There can be no doubt that all the occurrences represent the same type, while the cherts of Lady's Pass appear to differ only in more complete silicification. Their characters can be studied from a section (No. 584) (Plate XV., Fig. 1) of a rock from the flanks of the isolated diabase outcrop, Knowsley East. The rock is bedded and cavernous, and some of the cavities have the shape of felspar crystals, others more elongated suggest actinolite. The bedding is only slightly defined in the section. Numerous altered crystals of pyroxene occur, and larger fragments of igneous rocks lie in a fine-textured groundmass now silicified. The rock has all the appearance of a silicified submarine tuff.

In the case of the Black Cherts the problem is more complicated, owing to the complete mineralogical change which most of the rocks have undergone. A rather special type of black chert occurs at the margin of the foliated diabase in Tranter's paddock, Knowsley East. It is dense, dark in colour, and not well bedded, but less altered stages occur with it, and show a passage into diabase.

The more normal well-bedded type of black cherts occurs, among other places, at the N. end of Red Hill, near Gate 47 on the railway line south of the station, near and N.W. of Diorite Knob, near Lady's Pass in Dargile, and at a hill just south-west of Gate 51 on the railway north of the railway station.

The cherts near Gate 47 junction with the micro-granite, and with the alluvium, so that their relations with the diabase and the Ordovicians cannot be made out in the field. Under the microscope (No. 612) (Pl. XV., Fig. 2) the bedding planes, defined in the hand specimen by red band, are seen to consist of iron-stained fragments, some of which can be seen to be igneous. The bulk of the rock has been silicified, and in it occur minute rods which may be volcanic glass. Some colourless circular chalcedonic areas may be secondary segregation of silica, but their definite outlines suggest that they are probably organic. The rock appears to have been originally a submarine bedded tuff, or a detrital rock formed from igneous material. The bedded cherts of Lady's Pass are surrounded by members of the diabase series, some of which are foliated tuffs. The cherts are continuous in strike with the foliation of the tuffs, and the former presence of crystals in the rocks is indicated by the shapes of the hollows left after their removal. Less silicified forms were seen, which approached in character a diabase tuff, and, no doubt, that was their original character. Their relations to the Ordovician rocks, of course, cannot be made out in the field.

The cherts of the hill south-west of Railway Gate 51 occur between Ordovician shales to the W. and diabase to the eastwards: but no section showing their relations is to be seen. In places they pass from black bedded and folded cherts into ironstones, and to the east in the shallow railway cutting they can be seen to pass into fragmental diabase. One of the less cherty types (No. 631) shows in section under a high power (1-9in.) a chalcedonic matrix, and scattered through it are actinolite needles, small rounded shapes, possibly Radiolaria and larger irregular clear cellular masses having a different refractive index from the matrix, which are almost isotropic. They are probably fragments of cellular volcanic glass, and the rock is a fine basic volcanic ash in which the minutely fragmental groundmass has been silicified.

The best field evidence showing the relations of the black cherts to the Ordovician series is to be seen near Diorite Knob, S. Heathcote, and at Red Hill. In both localities dips and strikes of the black cherts agree almost precisely with those of the Ordovicians, and less cherty types occur between the two series. Furthermore, no sign of conglomerates containing chert fragments occur between the two. The presence of chert fragments in the Silurian conglomerates constitutes the best evidence that the cherts are pre-Silurian. The total absence of conglomerates at the junction of the cherts and Ordovician shales is strong negative evidence that there is no stratigraphical break between them, that is, that the cherts are not pre-Ordovician. The field evidence strongly points to the black cherts representing highly silicified Ordovician tuffs or fine-grained bedded fragmental rocks made up of diabasic material. The mineralogical and petrological similarity of the black cherts from near Gate 47, and from the Lady's Pass, is so close that there can be little doubt that they also are altered Ordovician rocks, although they do not come into relation at the surface with normal Ordovician rocks.

Specimens of banded black chert (Nobby's chert) obtained by me when visiting Newcastle, N.S.W., in company with Prof. David, are almost indistinguishable from some of the Heathcote cherts. It is interesting to find that Prof. David[1] has obtained clear evidence in the field, and Mr. Card in microscopic sections, that this chert is a silicified bedded tuff. Its very close resemblance to some of the Heathcote cherts suggests, therefore, a similarity of origin for the latter.

Origin of the Silicification.—Dr. Howitt has claimed that the silicification of the Ordovicians represents the direct effects of contact metamorphism due to the intrusion of the diabase into the Ordovician. Prof. Gregory, on the other hand, maintains that the cherts represent the oldest rocks in the district, and were formed in pre-Ordovician times, and that the diabase was subsequently intruded into them. According to him, then, the cherts are not in any way genetically related to the diabase, but he does not discuss at all the question of how they were formed.

Dr. Howitt has shown that in some places as you recede from the diabase the silicification is less intense. The change is, however, not always so gradual.

I am unable to agree with Dr. Howitt that the silicification is due to contact metamorphism by the intrusion of diabase. The change does not consist in a production of new minerals by

1 "The Geology of the Hunter River Coal Measures." Memoirs of Geol. Surv. of N.S.W., Geology, No. 4, Part I., p. 17.

recrystallization of material already present in a rock, which is the normal effect produced in a sediment by an igneous intrusion. The ordinary minerals produced by contact metamorphism are quite unrepresented. In place of this there has been a fundamental change in the chemical composition of the rock. The original diabasic constituents—lime, magnesia and iron—have been more or less completely removed, and replaced by chalcedonic silica. It seems to me quite improbable that a magma of the composition of diabase should be capable of supplying to an invaded rock silica in such large quantities. This view, moreover, can only be maintained on the hypothesis that the diabase is intrusive. I have stated above my reasons for regarding the bulk of the diabase as consisting of lavas and pyroclastic rocks, and the cherts as being probably silicified bedded submarine diabase tuffs, or at any rate fragmental diabase rocks. On this view the diabase may be older than the cherts, but is more probably practically contemporaneous with them, and therefore cannot be regarded as the direct agent of chemical change.

The explanation which I offer of the production of the cherts and cherty rocks is that they are the result of metasomatic replacement in certain parts of the Ordovicians by silica-bearing solutions traversing the rocks subsequent to the formation of the diabase and the Ordovicians in contact with it. This view receives confirmation from the fact that the diabase, like the Ordovicians, is locally silicified, and in places almost completely replaced by silica, as will be described below. This circumstance makes it improbable that the diabase, which is itself silicified, can be the direct cause of silicification of the cherty rocks.

The limitation of the silicification to those rocks near the junction with the diabase is a noteworthy feature, and must, I think, be discussed in connection with the original composition of these rocks. These I have shown to be mainly composed of fragmental diabasic material near the diabase, and as you go westwards from the diabase junction you pass into higher beds in the series, which gradually take on the characters of normal shales. I think, then, that solutions carrying silica traversed diabase and Ordovician alike, and that selective silicification took place; some of the diabases, and the Ordovicians which were composed of diabase fragments, were of such composition and character that chemical interchange most readily took place, resulting in the formation of various kinds of silicious diabase, and of the different types of cherts associated with the sediments. Even in these rocks of basic composition the replacement has taken place in varying amounts in different places, and this may possibly be due to differences in chemical composition or to physical differences in different parts of the series, such as original differences in texture or in the porosity of the rock through which the solutions passed.

Evidence from Tatong and Lancefield Areas.—The selective character of the silicification is perhaps more strikingly illustrated from other areas. Mr. Summers (op. cit.) has shown that near Tatong cherts are interbedded with normal sediments. A visit which I recently made to the Mt. William and Lancefield districts provides another illustration. In the quarry from which the typical Lower Ordovician Lancefield graptolites have been obtained, unaltered graptolite bearing shales are clearly interbedded with silicified shales containing graptolites, and with dense cherts in which no organisms are visible. In both these cases it seems to me to be clear that the alteration of the rocks cannot be due to contact metamorphism by diabase intrusions, for some of the shales are quite unaltered. The selective silicification must, I think, be connected with original chemical and physical conditions in the beds themselves.

The only evidence I have seen in the field of typical contact alteration of the Ordovician rocks near the diabase series is at Mt. William, a short distance from Mr. Donaldson's house, and I am indebted to that gentleman for showing me the principal rock outcrops. Near here, besides the Ordovician rocks there occur a dense diabase, a granite porphyry intrusive into the diabase, and an outcrop of a coarse-grained granitic rock which is an extension of the granitic rock of the Cobaw Ranges. The granite-porphyry is intrusive into the diabase as the micro-granite of Heathcote is intrusive into the diabase there. I think it has probably orginated in the same way as a residual more acid part of the diabase magma. It has caused little or no visible alteration in the diabase, and is probably of comparatively superficial origin. The coarse-grained granitic rock, on the other hand, is typically plutonic in aspect, being coarsely crystalline and porphyritic. It is connected with the Cobaw massif which has metamorphosed the Ordovicians in contact with it. The Ordovician shales near here are in places altered to Chiastolite slate, and there can be little doubt but that the coarse-grained granitic rock is responsible for the alteration, and not the diabase or the later granite-porphyry.

B. *Abnormal Features of the Diabase Series.*

(*a*) *Silicification.* The diabase of Tranter's paddock, Knowsley East, is in places changed to a dark, dense silicious rock, somewhat resembling the black cherts, but showing no bedding planes.

South of the Gully at the south end of Red Hill there is a southerly continuation of the foliated diabases, which here have undergone remarkable chemical replacement. The rock presents various stages in silicification, and in places solutions have removed practically all the diabasic material, and there now remains a very cavernous rock, consisting mainly of well-shaped small quartz crystals.

Production of the Jasperoids.—The most interesting and remarkable of the metasomatic changes is that to which the formation of the red jasperoids is due. No discussion as to the origin of these jasperoids has yet appeared. Dr. Howitt and Professor Gregory and Mr. Lidgey refer to them as metamorphic, and in a recent note (op. cit.) Mr. Dunn has described their northward extension near Tooleen, where, he says, "they are associated with an ancient igneous rock."

Jaspers appear always to be formed by metasomatic replacement of certain rocks by silica, with the separation of some oxide of iron. Red jaspers are associated with the ironstone of Nowa Nowa, at the head of Lake Tyers, but in this case they can be clearly seen to arise from the alteration of ancient, highly folded sandstones. The jasperoids of Heathcote, however, are derived from the diabase. The clearest evidence of their mode of origin can be seen in a limited exposure of massive diabase, about 40 yards west of the Murray road, and about 300 yards south of the selwynite outcrop. Here, within a few feet, all stages can be traced between a compact diabase through stages more and more silicious to a bright red jasperoid. The jasperoid here is of quite limited occurrence, and passes outwards in all directions into the dark, dense diabase. Silica-bearing solutions appear to have traversed the rock along some joint or fracture plane, and have altered the rock for a foot or two from a central point. The jasperoid is itself traversed by later formed white quartz veins.

Under the microscope (No. 549) (Pl. XV., Fig. 3) the original structure and minerals of the diabase have been completely lost. The rock now consists of a chalcedonic replacement, stained red by hematite, probably derived from iron containing minerals in the original diabase. The deposition of the iron-oxides has been irregular, darker and opaque areas passing across the section in bands. The chalcedony has crystallised from centres in radiating groups of crystals. Their boundaries are defined in the rock section by colourless lines of secondary silica. In polarised light these radiating aggregates show irregular black crosses.

In allotments 3q and 3m, Knowsley East, a thin strip of metamorphic is shown on the map, while the diabase is not represented. I have shown above that foliated diabase actually occurs, and some at least of the outcrop of "Metamorphic" is in reality jasperised diabase.

In the Heathcote district it is safe to regard the jasperoid, wherever found, as being one of the forms of silicified diabase.

Calcareo-siliceous Rocks.—A strip of very altered rocks occurs in South Heathcote, extending to the N.W. from just north of the South Heathcote Hotel, crossing the main road, and terminating against the micro-granite near the railway cutting at the back of the Ben Nevis Hotel. Its character varies from place to place. At one spot it is almost a carbonate rock, in another almost a chert, and greenish patches, sporadically developed, resemble selwynite in colour, being probably due to the separation of oxide of chromium. It was originally a diabase rock. A section taken from an outcrop 200 yards N.W. of the S. Heathcote Hotel will serve to illustrate some of the characters of the rock. Under the microscope (No. 592) (Pl. XV., Fig. 4) one can trace two stages in the alteration of the original rock. It was first converted into a ferruginous carbonate rock by decomposition of the original silicate by carbonated water. Crystallization of the carbonates proceeded from isolated centres, and eventually became confluent. Later silica-bearing solutions have replaced a good deal of the carbonates by chalcedonic silica, but the original boundaries of the carbonate areas are still traceable in the cherty areas by fine dusty inclusions.

The exact nature of the carbonates cannot be determined under the microscope, but they probably consist of a mixture of lime, magnesia and ferrous carbonates, the latter by subsequent partial oxidation have imparted a red-brown colour to the mass.

On the W. bank of the McIvor Creek, about 200 yards N.W. of this point, there is an exposure of the bedded chert series. The relations of this to the calcareo-siliceous diabase rock cannot be clearly made out.

(*b*) *Corundum in the Diabase.*—Close to the jasperoid, 300 yards south of the selwynite outcrop, is a small gully, and in it I found a mass of a heavy, purple and green coloured rock, which was found to consist of a mixture of corundum and a green micaceous mineral. The specimen was not in situ, but could not have rolled far, as the gully terminated about 100 yards north of where it was found.

On examining the workings at the selwynite outcrop, Mr. Summers found a second lump of the same rock associated with the selwynite. A section from the first specimen (No. 550) (Pl. XVI., Fig. 1) shows prismatic, pink, highly refractory needles and irregular masses of corundum. They are noticeably pleochroic, and have polarization colours about the same as those of quartz. Stouter prisms, probably of a pale orthochrombic pyroxene, showing good prismatic cleavage, generally straight extinction and bright polarization colours of the second order, also occur. The background is composed of a very pale green to colourless micaceous mineral, probably chromiferous. Red brown to opaque grains of chromite are also sparsely scattered through the rock slice.

On examining sections cut from the siliceous diabase which passes into jasperoid at the outcrop, 300 yards south of the selwynite, evidence was obtained that the corundum occurred in situ in the diabase. Under the microscope (No. 551) (Pl. XVI.,

Fig. 2) it is seen that the original texture of the diabase is almost completely lost owing to secondary silicification. In one place, however, an original vesicular structure is still visible. The secondary silica occurs both as allotriomorphic quartz crystals, but mainly in the form of radial chalcedonic aggregates. In ordinary light dots of opaque iron oxide separate the radiating fibres, and in polarised light the fibres give a black cross. Scattered through the rock are long prisms with hexagonal cross sections, which have precisely the habit of the corundum previously described. The corundum has, however, been almost entirely replaced by secondary minerals, including opaque oxide of iron, chalcedony, chlorite and carbonates. This is only the second record of corundum in Victoria, apart from its occurrence in the deep leads and alluvial deposits. The first occurrence was noted last year in association with the serpentine of the Mt. Wellington district, in Gippsland. This occurrence has been described by Mr. Dunn[1] and by Mr. Thiele.[2] The corundum occurs as blocks on the surface of the serpentine, and may be "in situ," but this cannot be proved.

This occurrence of corundum at Heathcote appears to be the first in Victoria in which it has been traced to its parent rock. Its crystallization evidently took place from a part of the diabase magma, not only locally rich in alumina, but also in chromium, and it may represent a local segregation from the normal diabase.

(*c*) *The Selwynite and its Origin.*—This substance, described as a mineral, was first referred to in the Exhibition Essay for 1867. It was more fully dealt with by Ulrich.[1] Four quantitative analyses were made by Cosmo Newbery, and one is here recorded.

SiO_2 - - - -	47.15
Al_2O_3 - - - -	33.23
Cr_2O_3 - - - -	7.61
MgO - - - -	4.56
Na_2O - - - -	
H_2O - - - -	6.23
Total -	98.78

1 'Mining Standard," Oct. 16th, 1907.
2 Proc. Roy. Soc. Victoria (this volume).
3 Contributions to the Mineralogy of Victoria, 1870, pp. 21-25.

Traversing the green "selwynite" are veins of an almost colourless micaceous mineral, described by Ulrich as "talcosite." An analysis by Newbery gave the following results:—

SiO_2 - - - -	49.01
Al_2O_3 - - - -	45.1
Cr_2O_3 - - - -	tr
FeO - - - -	tr
MgO - - - -	tr
H_2O - - - -	4.98
Total -	99.09

It has been recognised for many years that the substance, "selwynite," is not a true mineral species, but a mixture, and is, in fact, a rock. Microscopic examination of a thin section of the substance (No. 566) (Plate XVI., Fig. 3) confirms this view, and shows that at least four minerals are present. The groundmass forming the bulk of the rock is a mineral which is probably chrome-bearing, and imparts the green colour to the rock in the hand-specimen. It occurs as a granular or scaly meshwork of microscopic colourless crystals, polarizing in neutral tints as an aggregate. Scattered through this background are a few opaque grains, probably chromite, and many larger granular crystals of a mineral showing rather high refraction, purplish-brown colour and polarization colours of the second order similar to augite. The mineral is slightly pleochroic, and may be an altered orthorhombic pyroxene. The remaining mineral, the so-called "talcosite," occurs in a vein through the rock, and consists of radiating and parallel prismatic crystals of a colourless to pale-green micaceous mineral showing high polarization colours.

Corundum, while not identified with certainty in section, occurs with the selwynite in the outcrop by the Murray road, as mentioned above.

The selwynite outcrop, while near the junction of diabase and Silurian on the surface, is certainly within the diabase boundary, and there can be little doubt but that it represents one type of alteration of a diabase rock formed from a magma locally rich in chromium and aluminium oxides. Solutions passing through this rock have leached from it most of the lime and magnesia, and have introduced water, leaving a rock consisting chemically of silicate of alumina, water and oxides of chromium and aluminium.

10.—The Age of the Rocks of Heathcote.

(*a*) *Fossils of the Dinesus Beds.*—The evidence for the age of these rocks rests on a few fragments of trilobite, some badly preserved brachiopod fragments, and some obscure markings, thought at first to be graptolites of the *Bryograptus* type, but later regarded as probably algal in character. These latter and the brachiopods afford little help in determining the age of the rocks. The trilobites, according to Mr. Etheridge, junr. (op. cit.), have Cambrian affinities. Professor Gregory, with more material to work on, regards the fragments as containing two genera, both new, and on the whole probably of Lower Ordovician age. In rock sections of some of the *Dinesus* beds I have noticed some minute circular chalcedonic areas, some apparently tubular, which may be cross sections of sponge spicules, but no definite structure can be made out. Other areas suggest the possibility that Radiolaria may be present.

From a locality near the junction of Dinesus beds and the normal Ordovician I found on splitting open some shales several casts of large spicules intersecting at right angles, characteristic of *Protospongia* a form which in Britain I believe is only found in Cambrian rocks. In view of the occurrence of Bryograptus in Victoria associated with Lower Ordovician forms, not much weight can, I think, attach to the occurrence of these sponge spicules in the *Dinesus* beds. Their presence probably would not necessitate placing the rocks with the Cambrian series if the evidence of the trilobites points to the Lower Ordovician age of the rocks.

(*b*) *Fossils of the Ordovician Rocks.*—I have above stated my reasons for dissenting from the separation of the beds containing the *Dinesus* fauna from the beds which succeed them, and which have been, on lithological grounds, regarded as Ordovician. Sections were made from a rock (No. 634) (Pl. XVI., Fig. 4) occurring in the Ordovicians 20 feet west of the outcrop of the brecciated conglomerate on the road running W. from the Murray road towards the diabase of Tranter's paddock. Under the microscope the rock is seen to be more or less chertified, and to contain numerous longitudinal and transverse sections of a tubular organism, some of which are branched. The cross-sections are circular, and show a central cavity now filled with chalcedony. I am unable to determine the nature of these organisms. Small circular bodies in the rock are suggestive of the former presence of Radiolaria.

Another section cut from the same rock shows some triradiate spicules, and other four rayed spicules intersecting at right angles, which are referable to *Protospongia*. This is the first record of fossils from the normal Ordovician rocks near Heathcote, but their evidence does not help much in fixing the age of the series. Small circular areas similar to those described above are seen in sections of some of the cherty shales of the *Dinesus* rocks, and are also recognisable sometimes in an iron-stained condition in some of the black cherts, as for instance those near Gate 47, south of the Heathcote Railway Station. It is possible that they may be inorganic segregations of chalcedony, but their defined boundaries and occasionally the suggestion of an inner wall suggest an organic origin, and I have doubtfully compared them to Radiolaria, whose structure has been destroyed by secondary silicification. It will be seen that the palaeontological evidence from these rocks is still inconclusive, and it seems to me to be safer to continue to regard them as of Lower Ordovician age until better evidence is forthcoming.

(*c*) *The Age of the Black Cherts.*—I have shown above that these rocks were composed mainly of diabase fragments, and that their peculiar composition led to their almost complete silicification. Their general agreement in dip and strike with the Ordovicians, and the complete absence of conglomerates containing chert fragments between them and the Ordovicians, points to their being the lowest part of the bedded Ordovician exposed to view. At Lancefield, where cherts occur not only between the diabase and the fossiliferous Ordovician, but also interbedded with graptolite-bearing shales, their Lower Ordovician age is clearly demonstrated.

(*d*) *The Age of the Diabase and other Igneous Rocks.*—The field and microscopic evidence is not so complete as to fix with certainty the age of the igneous rocks and their relations to the bedded series. The sharp break between the foliated diabase at the south end of Red Hill and the diabasic fragmental rocks which pass upward into normal Ordovician shales, may be interpreted as an unconformable junction of an older series, the diabase, with a younger one largely composed of detritus from it. Even granting the unconformity, the relations might be explained if Lower Ordovician submarine volcanic tuffs were piled up so that at this place they became sub-aerial and with further eruptions part of the material was deposited on land and part falling into the sea near the shore line, became more bedded. Subsequent lateral pressure would impart foliation to the subaerial series and tilt the submarine series at a high angle. The strike of the foliation of the diabase differs from that of the bedded series, but both dip at almost the same angle, 70 deg.-80 deg.

An alternative, and, I think, on the whole a more probable explanation, is that the junction between the two rocks at this place is a fault junction. The line of junction runs northerly from here in almost a straight line, and it seems probable that the beds to the west have been let down, and discontinuity produced in what was formerly a continuous series.

Evidence from the northern part of the district rather supports this hypothesis, for the *Dinesus* Beds and also the black cherts (making allowances for subsequent alteration) have a strong resemblance to submarine bedded tuffs passing upwards on the cessation of volcanic activity into more normal sediments. The bosses of diabase, diorite, felspar-porphyrite and micro-granite are somewhat later intrusions from the diabase magma, and in most cases are intrusive into the diabase series. Some part of the acid rocks, however, come into relation with the cherts and cherty Ordovicians, and, as far as can be observed, have not effected any marked alteration of the sediments. In view of their probable comparatively superficial origin and low temperature of consolidation, this is not surprising.

While much of the diabase was of the character of a tuff, undoubted massive lavas and intrusions occur, and if the diabase were pre-Ordovician one would expect in places where the Ordovician shore line came into relation with massive diabases that coarse conglomerates containing diabase fragments would occur. None such have, however, been found.

The irregularities in the surface boundaries between Ordovician and diabase, and the more or less inconstant development of black cherts along the junction, as shown on the map, are features some of which are, I think, due to a misinterpretation of the field evidence. Some, however, are real, and I think they can be explained on the view that submarine vulcanicity started in Lower Ordovician times, that a mixed series, consisting largely of unbedded and bedded tuffs and lavas, with relatively minor intrusions, was developed, and passed gradually upwards into more normal sediments. There would be developed irregularities in thickness in the diabase series, and on subsequent folding and denudation the present more or less embayed junction between Ordovician and diabase would be produced.

The evidence as yet available of the relations of diabase and Ordovician is not, I think, so clear as to enable a positive statement of the Ordovician or pre-Ordovician age of the diabase to be made, but for the reasons given above I am at present inclined to group it with the Lower Ordovician sediments rather than as forming a distinctly pre-Ordovician series.

(*e*) *Physical Geography of the Lower Ordovician Period.*—Professor Gregory has given an interesting sketch of the probable relations of land to sea in Lower Ordovician times, based on his view of the pre-Ordovician age of the cherts and diabases. He correlates with the Heathcote rocks outcrops at Lancefield, Dookie, near Geelong, etc., and maintains that a barrier of pre-Ordovician land stretched across what is now Victoria, eastwards from a more or less N. and S. line from near Geelong through Heathcote to Dookie. These places, according to Professor Gregory, lie along the eastern margin of the Lower Ordovician sea, and define the easterly boundaries of the Lower Ordovician beds.

Holding as I do a different view of the origin and age of the cherts and the diabases, I am unable to agree with Professor Gregory in this sketch of the Lower Ordovician boundaries. In my opinion there are no good grounds for regarding the present eastern boundaries of the Lower Ordovician series as marking their most easterly development in Victoria. I regard the cherts which lie on the eastern flanks of the diabase and granitic rocks of Heathcote as altered Ordovician rocks, and think that they probably continue for some distance unknown underneath the Silurian sediments.

South of Lancefield, and again north of Keilor, the igneous rocks are not represented at the surface, and the Ordovician and Silurian series come into direct relation with each other. Although no precise contact of the two series has been observed, it is probable that the Ordovicians pass underneath the Silurians, and that the latter are laid down unconformably upon them. I think the lineal development of the diabases at the surface may be due to their being brought up in or near the axis of a big fold of the Ordovician series, and if so, the Ordovicians may continue eastwards for some distance beneath the Silurian rocks. Of course a pre-Ordovician series must have provided the bulk of the detrital material from which the Ordovician sediments have been formed, and such a series may be represented underneath the Silurian series, but of its position we have, I think, no positive evidence. No Middle or Upper Ordovician rocks are known near the Heathcote district. It would appear that movements of elevation took place, and probably during the Middle and Upper Ordovician periods this was a land area. The exposure of the harder igneous rocks at the surface would lead to their forming a ridge which, where developed, probably defined the western shore line of the Silurian sea, along which coarse conglomerates containing cherts and diabase fragments were laid down.

(*f*) *Correlation of the Heathcote Rocks with Other Areas.*—Professor Gregory and Mr. Dunn have correlated with the rocks of Heathcote somewhat similar diabasic and cherty rocks from a number of other localities. References to these papers is given at the commencement of this paper. In most of the cases cited the rocks in question are either surrounded by rocks of much newer age or by rocks whose age is unknown. In such cases the lithological resemblance of basic rocks, and sometimes cherts, to the Heathcote series is considerable, and quite possibly may imply a similarity in age, but I think such a correlation, in the absence of stratigraphical relations, should be cautiously applied, especially in view of the recent work of Mr. Thiele,[1] in which he has shown that cherts and jaspers associated with the serpentine area of Mt. Wellington, Gippsland, contain Upper Ordovician graptolites.

Mr. Summers[1] has also shown at Tatong that a series of cherts is interbedded with unaltered slates whose age is not definitely fixed, but is probably Ordovician.

11.—Conclusion.

With regard to the conclusions at which I have arrived in this paper, I find myself only in partial agreement with previous workers.

I am in agreement with Mr. Dunn in regarding the diabases as mainly effusive. With Professor Gregory I agree that the diabase is pre-Silurian, and with Dr. Howitt that the Ordovicians are altered along the contact with the diabase, and that the black cherts are altered Ordovician rocks. On the other hand, I disagree with Dr. Howitt, who regarded the diabase as a rock intrusive in Devonian times. I regard it as mainly effusive in origin and probably of Lower Ordovician age. With Professor Gregory I am unable to agree in the interpretation of some of the field evidence, and I differ from him in regarding the cherts as altered Ordovicians and the diabase as being probably Lower Ordovician in age, and in his interpretation of the relations of land and sea in Lower Ordovician times.

The new evidence which is brought forward in this paper is as follows: —

1. Some alteration in the geological boundaries and considerable alterations in interpretation of field evidence.

2. The finding of *Protospongia* and of other minute organisms in the Ordovician rocks, and the possible occurrence of Radiolaria.

3. The evidence for regarding much of the diabase as consisting of foliated diabase tuffs.

4. The explanation of the original composition and mode of silicification of the cherts.

5. The diabasic character of some of the Ordovician rocks.

6. The origin of the jasperoids.

7. The mode of origin of the micro-granite and its relation to the diabase.

8. The finding of corundum in the diabase and in the selwynite.

9. The possible mode of origin of the selwynite.

10. The evidence for the Lower Ordovician age of the cherts and of the diabase series.

DESCRIPTIONS OF PLATES XIV–XVIII.

The numbers of the rock sections have reference to the collections at the University of Melbourne. All the rock sections were photographed by Mr. H. J. Grayson, and were taken in ordinary light.

Plate XIV.

1. Rock section 618 × 11 diameters.

"Brecciated conglomerate," exposure in road running west between allotments 3m and 3j, Knowsley East. Possibly a coarse grained tuff. It consists of fragments of two types of diabasic rock more or less altered to chert by secondary silicification.

2. Rock Section 545 × 11 diameters.

Agglomerate of Photograph Knob, S. Heathcote. Larger and smaller angular diabasic fragments are set in a fine grained indurated ground-mass.

3. Rock Section 576 × 11 diameters

Boulder in foliated diabase of Red Hill, Heathcote. An agglomerate consisting of large and small angular fragments of diabase in a fine ground-mass.

4. Rock Section 583 × 11 diameters.

Diabase tuff, allotment 3q, Knowsley East. The rock is distinctly fragmental and contains secondary quartz and secondary felspars partially or wholly replacing disbase material.

Plate XV.

1. Rock Section 584 × 11 diameters.

Bedded diabase tuff (?) Tranter's Paddock, M. of W. Knowsley East. A silicified cavernous rock, cavities originally occupied by felspars and actinolite (?) Irregular altered augite crystals lie in a fine-textured silicified ground-mass.

2. Rock Section 612 × 11 diameters.

Bedded chert, section on railway, 30 yds. S. of Gate 47, Heathcote Some of the dark patches are of igneous material. The circular colourless areas with inner walls (?) are probably organic. The rock has been intensely silicified.

3. Rock Section 549 × 11 diameters.

Jasperoid alteration of diabase, 300 yds. S. of selwynite outcrop and W. of Murray Road, Heathcote. The igneous texture of the rock has been completely lost by secondary silicification. Radial chalcedonic aggregates form the bulk of the rock and are traversed by later quartz veins.

4. Rock Section 592 × 11 diameters.

Calcareo-siliceous alteration of diabase or diabase tuff, 200 yds. N.W. of S. Heathcote Hotel, and E. of Murray Road. Calcareous areas represent the earlier alteration of the rock. Later silicification has obliterated much calcareous material, the boundaries of areas formerly calcareous being defined by dark lines in the present chalcedonic ground-mass.

Plate XVI.

1. Rock Section 550 × 11 diameters.

Boulder of corundum and green micaceous mineral from Gully just E. of jasperoid and 300 yds. S. of selwynite outcrop, Heathcote. Corundum occurs in elongated prisms and also in irregular masses at the right-hand side of the photograph. Orthorhombic pyroxene (?) occurs in broad prisms on the left-hand side, and the light background consists of a pale green micaceous mineral.

2. Rock Section 551 × 18 diameters.

Silicified diabase with corundum, a few feet from jasperoid and 300 yds. S. of Selwynite outcrop, Heathcote. The long prisms formerly corundum, are now replaced by secondary minerals. The igneous texture of the rock is partially obscured by radial crystallization of chalcedonic silica.

3. Rock Section 566 × 11 diameters.

Selwynite from outcrop junction of Murray Road and road running N.W. towards Derrinal; about 2½ miles N. of Heathcote township. The vein crossing the photograph consists of a light green micaceous mineral polarizing brightly. The pale background of the rock is a low polarizing aggregate of a micaceous or scaly mineral which is green in hand specimen. Grains of opaque chromite occur and many granular brownish crystals of altered orthorhombic pyroxene (?)

4. Rock Section 634 × 11 diameters.

Fossiliferous Ordovician shale 20′ W. of "brecciated conglomerate" in road between allotments 3m and 3j, Knowsley East. The rock is crowded with sections of sponge-spicules. Circular chalcedonic areas may represent altered sections of Radiolaria.

Plate XVII.

Fig. 1. Section through Photograph Knob, Heathcote.
Fig. 2. Section at Red Hill, Heathcote.

Plate XVIII.

Geological Sketch Map of the Heathcote District.