THE PROGRESS OF GEOLOGICAL RESEARCH IN TASMANIA SINCE 1902.

By

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I. INTRODUCTION.

On the occasion of the last meeting of this Association in Hobart the late W. H. Twelvetrees presented a paper entitled "The Outlines of the Geology of Tasmania." A period of eighteen years has elapsed since that paper was prepared, and a great advance has been made in our knowledge of the geology of Tasmania during that interval. It, therefore, seems desirable to take the opportunity afforded by the reassembly of the Association in Tasmania of summarising our progress—to take stock of our knowledge and to see what problems still await solution.

It must be stated at once, however, that in spite of the great amount of work accomplished during the period under review, the result, when viewed in relation to the complete geological survey of Tasmania, is to some extent disheartening. This was particularly apparent when the preparation of the Geological Sketch Map of Tasmania was undertaken in 1914 by the Geological Survey of Tasmania. When there had been plotted on the base map the geology of the areas of which geological surveys had been completed, the greater portion of the State still remained blank, and to produce the map as ultimately published, the information contained in R. M. Johnston's original geological map was utilised with sundry modifications. The reason for this is easy to see, for the conditions under which the Geological Survey carries out

*Owing to the Shipping Strike the meeting of the A.A.A.S., which was to have been held in Hobart in January, had to be held in Melbourne. As a consequence, numerous difficulties had to be overcome. It was found impossible to bring out the usual Report of the A.A.A.S. meeting, and print all papers. Arrangements were, therefore, made for certain papers to be read before the Society and published in the Papers and Proceedings for 1921.

its work are such as to necessitate detailed investigations of limited areas, rather than cursory examinations of larger areas. It must be remembered that the *raison d'etre* of the Geological Survey is the demand of the Mining Industry for reports on mineral and coal deposits, and the portions of the State subjected to such detailed geological examination are almost wholly confined to our mineral and coal areas. With the ever-growing demand for examination of mining fields it has not been possible to pay much attention to the general geology of the remainder of the Island.

It is not intended to imply that this intensive examination of limited areas is undesirable. In fact, these detailed investigations are essential to the ultimate elucidation of the factors controlling ore-deposition in Tasmania, and they have already enabled important deductions to be made regarding certain important phases of general geology. The only disappointing feature in regard to them is that indicated above in relation to the areal geology of the Island.

Before proceeding to deal with the actual progress in the various branches of geology recognition must be given to those whose work has made this progress possible.

It is with mixed feelings of admiration and regret that the writer mentions the name of the late W. H. Twelvetrees —admiration for the great work he accomplished, and regret that he was not spared to be present at this meeting and to be still amongst us. He had looked forward to this meeting since before its first postponement, and it would have been very fitting if this summary could have been presented by him, as it deals very largely with the achievements in geological research by himself and those working under his genial and able direction. For twenty years the late W. H. Twelvetrees occupied the position of Government Geologist of Tasmania, and for seventeen years of the eighteen covered by this review he directed the acquisition of our knowledge of the geology of Tasmania. It was he who was responsible for the initiation of systematic geological surveys of definite areas in place of the restricted examinations of mining prospects—a change beneficial both to geological science and to the mining industry. The contributions by this indefatigable worker to our knowledge embrace all of the branches of geology, but, perhaps, his greatest achievements were in the domain of petrology. The geological literature of Tasmania has been greatly enriched as the result of his labours, and Tasmania undoubtedly must ever remain indebted to him, his example, and his memory.

Important contributions to our knowledge were made by G. A. Waller, who was Assistant Government Geologist from 1901 to 1904. In addition to his valuable descriptions of many of our ore deposits and his pioneer work on their genesis, this enthusiastic worker did much to advance our knowledge of the stratigraphy of the Lower Palæozoics on the West Coast, as well as succeeding in throwing much light on the petrology of the associated igneous rocks.

L. Keith Ward, B.A., B.E., during the time he occupied the position of Assistant Government Geologist from 1907 to 1911, was responsible for very great progress in geological research in Tasmania. Immediately after his appointment to the Survey there was instituted the present series of Geological Survey publications which is in accordance with the system in vogue in modern Geological Surveys. His own contributions to this series of publications set a very high standard both as regards literary merit and method of treatment. The thoroughness of his investigations and the illuminating conclusions he drew therefrom have great value both from the importance of the acquired information itself and from the fact that his conclusions and hypotheses supply an invaluable method of approach to many of our petrologic and metallogenic problems.

The work performed by L. L. Waterhouse, B.E., Assistant Government Geologist from 1912 to 1916, has also added to our knowledge. The detailed descriptions contained in the two bulletins prepared by him supply a wealth of information concerning the two areas with which they deal. To this investigator there is undoubtedly due the credit of throwing much light on the detailed petrography of our Devonian granites, and their contact metamorphic deposits, as well as considerable information concerning the factors controlling tin deposition in Tasmania.

To this enumeration of former officers of the Geological Survey of Tasmania, who have materially advanced our knowledge, mention must be made of the present officers of that organisation who are at work on important geological problems. The writer joined the Department in 1912, on the occasion of an increase in the staff of the Survey. Mr. A. McIntosh Reid joined the Geological Survey in 1917, and, together with Messrs. P. B. Nye, B.M.E., and H. G. W. Keid, B.Sc., who were appointed early in 1920, are actively engaged in conducting geological surveys according to the programme authorised by the Honourable the Minister for Mines for Tasmania.

Passing now to those who have contributed towards our knowledge from outside the ranks of the Geological Survey, the name of the late R. M. Johnston, I.S.O., must first be mentioned. The death (in 1918) of this investigator deprived Tasmania of one of her pioneer geologists, and one to whom we are indebted for a great part of our knowledge in regard to the stratigraphy of the Permo-Carboniferous and later systems.

To the late Thos. Stephens, M.A., who died in 1913, we owe appreciable additions to our knowledge of the general geology of the State.

The Grim Reaper has also deprived us of that indefatigable worker in the realms of mineralogy and petrology—the late W. F. Petterd, whose demise took place in 1910. His "Catalogue of the Minerals of Tasmania," published by the Mines Department in 1910, is still the standard work on this subject. In collaboration with the late W. H. Twelvetrees, the late W. F. Petterd contributed largely to our knowledge of the petrography of Tasmanian igneous rocks.

To Professor Sir T. W. Edgeworth David, K.B.E., C.M.G., D.S.O., D.Sc., we are indebted for much advice during the researches of this period under review, as well as for contributions to the literature on the Permo-Carboniferous and Pleistocene glacial geology of Tasmania.

In 1903 Professor J. W. Gregory, D.Sc., visited the West Coast, and his description of the geology and ore-deposits of Mount Lyell, and several other papers on the physiography and glaciation of that portion of Tasmania are valuable additions to our literature.

To Professor E. W. Skeats, D.Sc., is due the credit of definitely determining the Tertiary age of the Port Cygnet alkaline rocks.

Important work on palæontological questions was carried out by W. S. Dun, especially in connection with the age classification of the upper and lower palæozoics. Record No. 1 of the Geological Survey of Tasmania is the work of this palæontologist.

In this domain of palæontology A. F. Chapman, of the National Museum, Melbourne, has assisted us to a great degree in making determinations, and one of his contributions has been published as Geological Survey Record No. 5.

H. H. Scott, Curator of the Victoria Museum, Launceston, has carried out very valuable researches on *Nototherium tasmanicum*, and the results of his labours are embraced by Geological Survey Record No. 4, and that very creditable restoration of the skeleton in the Victoria Museum, Launceston. During the past year this keen investigator, in collaboration with Clive Lord, of the Tasmanian Museum, Hobart, has started the systematic description of *Nototherium mitchelli*, which is the latest discovery in this direction, and the mounted skeleton now on view in Hobart is the work of H. H. Scott.

The late Colonel R. V. Legge did much to increase our knowledge of the topography of Tasmania, particularly the north-eastern portion. His death in 1913 removed another valuable worker in the field of geology.

Professor W. N. Benson, D.Sc., besides contributing towards our petrographical knowledge of our granites and alkaline series, has helped towards the elucidation of the problem of pleistocene glaciation by publishing a study of the Cradle Mountain portion of our highlands.

In addition to these workers in the various branches of geological research, the following have from time to time contributed towards our knowledge:—Fritz Noetling, M.A., Ph.D.; Hartwell Conder, M.A., A.R.S.M.; W. H. Clemes, B.A., B.Sc.; Griffith Taylor, D.Sc., B.A., B.E.; E. C. Andrews; R. C. Sticht; Hyman Herman; H. S. Summers, D.Sc.; Rev. H. H. Anderson, M.A.; Rev. E. D. Atkinson, B.A.; F. Osann; H. Rosenbusch; W. A. MacLeod, B.Sc.; O. E. White; F. P. Paul, Ph.D.

It is thus apparent that the greatest of our unofficial workers have passed the Great Divide, and that the number remaining is lamentably small. Particularly it is noticeable that the number of our Tasmanian observers is limited to two or three—a fact which is much to be regretted, and which must delay the advance of our knowledge to a considerable degree. This lack of geological observers is, in the writer's opinion, very largely due to the fact that for some years past the University of Tasmania has neither provided instruction in the subject of Geology nor held examinations therein, owing to shortage of funds. This neglect of a subject which must inevitably play a very important part in the development of our natural resources is much to be regretted, and every effort should be made to initiate a school of geology at the University. The failure of the University authorities to give this subject the attention which it deserves, both from the utilitarian point of view and from its undoubted educational value, is reflected in our secondary schools, for in the public examinations held last year only two candidates presented themselves for examination in

Geology. Under such conditions it is not to be wondered at that there is such a paucity of observers with sufficient knowledge to make observations of value.

The conditions existing in Tasmania at present are, therefore, such that the work of investigating the complex geology of the Island devolves entirely on the Geological Survey. With practically no help from outside, and because of the complexity of our problems, the inclement climatic conditions, the rugged topography, and the heavy forest growth, our progress must be somewhat slow.

II. PHYSIOGRAPHY.

The advance in this branch of geology has been considerable, but we are still far from a complete understanding of the evolution of the topographic features of Tasmania.

As a matter of fact, there has not yet been produced a topographic map of Tasmania of even approximate accuracy. The existing map of Tasmania is admittedly inaccurate to a marked degree. In fact, there has not yet been completed a trigonometrical survey of the State, as although such a survey was started many years ago, it had not been nearly completed before work on it was suspended, and has not been resumed to date.

The most detailed maps available are the Mineral and Land Charts, which show boundary lines of sections and some of the principal streams and occasional mountain peaks, but even these latter details are to some extent unreliable.

The necessity, therefore, arises of mapping the topography concurrently with the geology in carrying out the work of the Geological Survey. In 1909 the late W. H. Twelvetrees endeavoured to arrange for the addition of a topographer to the Geological Survey staff, but was unsuccessful. The geologists of the Survey, therefore, are compelled to map topographic features as far as opportunity allows or necessity dictates. Under these conditions progress must necessarily be slow.

To Professor J. W. Gregory is due the credit of first recognising the peneplain on the West Coast, which has been so deeply dissected as to make its recognition difficult. The work carried out by the various officers of the Geological Survey since Professor Gregory first drew attention to it has shown that this peneplain extends from northwards of Port Davey to the Mersey River, over an area roughly crescentic in shape, varying in height from 200 to 2,000 feet above sea-level, and having a slope of from 40 to 100 feet per mile. Its age is certainly Pre-glacial, but its relation to the Tertiary basalts has not been satisfactorily demonstrated.

The Central Plateau is clearly a horst as regards its northern, western, and southern precipitous slopes, but recent work by P. B. Nye, B.M.E., has shown that the eastern face is not a fault scarp, but is due to the upthrust of a huge transgressive diabase mass. The work of this investigator in the Midlands has demonstrated that the Midland plain is not a rift valley, as maintained by E. C. Andrews and Dr. Griffith Taylor, but that the diabase masses on either side of this plain are in the approximate positions relatively to the similar rock of the plain which they assumed when originally intruded. It seems, therefore, that the horst must embrace portion of the Eastern Highlands, since undoubted block faulting occurs towards the East Coast. It is hoped that the geological surveys of the East Coast coal-fields at present in progress will definitely settle this question.

A considerable amount of work has been done on the problem of our Pleistocene glaciation, but as this is dealt with in a special report by the Glacial Sub-committee, there is no need to repeat a description of it. Suffice it to say, that a number of glacial cirques have been located and described, as well as lakes of glacial origin, and the maximum descent of the glaciers determined to be 460 feet above present sea level.

Some advance has been made in our knowledge of the Recent oscillations of sea-level on the North and West Coasts, but we are far from being able to outline these with any degree of accuracy. The work of E. C. Andrews, Charles Hedley, and Fritz Noetling must be acknowledged in this connection.

III. STRATIGRAPHICAL GEOLOGY.

(1). Pre-Cambrian.

Since the late W. H. Twelvetrees presented a summary of our knowledge of Tasmanian Pre-Cambrian geology before this Association in 1907, there has been some definite advance in our knowledge. This advance resulted mainly from two exploratory journeys made in 1908 and 1909 by the late W. H. Twelvetrees, in conjunction with L. K. Ward, B.A., B.E., on the route of the proposed Great Western Railway.

In the description of these Pre-Cambrian rocks presented by L. K. Ward, in a paper read before The Royal Society of Tasmania in 1909, the age determination is based on the well-determined fact that they underlie with a marked unconformity the West Coast Range Conglomerate series, which was regarded by Ward as of Lower Cambrian age. It has subsequently been demonstrated, however, that this West Coast Range Conglomerate series is the basal conglomerate of the Silurian System, so that the observed stratigraphical succession gives no more definite age determination than that of Pre-Silurian. The only occurrence *in situ* of rocks of Cambrian Age in Tasmania is that of the Dikelocephalus sandstone near Railton, but as the exact relationship between this series and any other rock series in the vicinity has not been demonstrated, there must be some doubt as to the Pre-Cambrian Age determination. Certainly, the very fresh character of the Cambrian sandstone as compared with the schistose character of the rock series referred to as Pre-Cambrian is suggestive, and the Pre-Cambrian age determination is largely based on lithological character.

That the reference of this rock series to the Pre-Cambrian is most probably correct is indicated by the fact that the following is the definitely ascertained succession:—

Silurian.—West Coast Range Conglomerate Series.
Diastrophic Period and Erosion Interval.

Cambro-Ordovician. — Porphyroid Igneous Complex.
Diastrophic Period and Erosion Interval.

Pre-Cambrian (?).—Quartzites and Mica-Schists.

Accepting their Pre-Cambrian age, L. K. Ward refers them to the Algonkian, and subdivides them into an Upper and Lower Series—the upper consisting of a relatively gently folded series of white quartzites, and the lower series of intensely crumpled mica and quartz schists, the two being separated by an unconformity. In the vicinity of Point Hibbs the mica-schists contain intercalated beds of dolomitic limestones, this being the only locality in Tasmania where calcareous beds are known to occur in the Pre-Cambrian.

The areas occupied by these rocks have been indicated in the latest geological map of Tasmania. Their greatest development is in the south-western portion of the Island, although isolated areas of much lesser extent occur on the west, north-west, and north coasts. The late W. H. Twelvetrees estimated the total thickness to be 13,000 feet, but in view of the fact that the structural geology has not been worked out in even approximate detail, this must be regarded —as the author of it himself regarded it—as a tentative approximation.

(2). Cambro-Ordovician.

It is in this system and in the succeeding Silurian system that the greatest progress in Tasmanian stratigraphy has been accomplished during the period under review.

In 1902 the late T. S. Hall described some graptolites from the slates in the Dundas district, and determined them as being Ordovician types. Unfortunately, however, there is some doubt in regard to the reliability of this determination in fixing the age of the Dundas slates, for repeated search, both at the locality whence Hall's specimens were supposed to have been procured and elsewhere in the series, has signally failed to provide another specimen. Undoubted Ordovician graptolites have been found in the Permo-Carboniferous glacial till at Wynyard, but with the above exception of the late T. S. Hall's specimens no graptolites have been discovered *in situ* in Tasmania, in spite of diligent search.

The Dundas slate and breccia series, of which the typical rock-type is a finely fissile purple slate, underlie with a marked unconformity the slates and sandstones definitely determined as Silurian. They are similarly definitely established as unconformably overlying the mica-schists to which a Pre-Cambrian age has been ascribed. The series then is either Cambrian or Ordovician in age, and owing to the failure to obtain information of the Ordovician determination by the discovery of further graptolites, it is at present preferred to refer to them as of Cambro-Ordovician age.

To this dual system are also referred the following rock series named after the localities in which the chief development of each occurs:—

Read-Rosebery Schists.

Balfour Slates and Sandstones.

Mathinna Slates and Sandstones.

These three series have been described in some detail. The Read-Rosebery schists have been dealt with somewhat fully by the writer in Bulletins 19 and 23 of the Geological Survey. These schists, the origin of which was previously very obscure, have been now demonstrated to have been mainly sedimentary in origin, pyroclastic material constituting what is not purely sedimentary. Their structural features have been mapped in detail, and their relation to the felsites and keratophyres of the porphyroid igneous complex definitely determined, for the mapping of the structural features has shown that the felsites and keratophyres overlie them as effusive lava sheets which have been involved in the same orogenic movement which produced the folds and the schistosity in the schists. It has further been demonstrated that the Read-Rosebery schists conformably overlie the Dundas slates and breccias. The Dundas slates and breccias, the Read-Rosebery schists, and the felsites and keratophyres constitute in fact a conformable series, having the above ascending order of succession, composed of mixed sediments, pyroclastic accumulations, and effusive lava flows. The evidence further goes to show that some at least of these lava flows were submarine.

The Balfour slates and sandstones have been described by L. Keith Ward in Geological Survey Bulletin No. 10. They present many similarities to the Dundas slates, but the relationship with this latter series has not been determined. They are wholly sedimentary rocks, the pyroclastic members of the Dundas slates and breccias being absent. They have up to the present yielded no fossil remains whatever. Similarity of structural features and the close resemblance between certain rock-types of both series seem to indicate that we here have two members of a great sedimentary system.

The Mathinna slates and sandstones, which have been described by the late W. H. Twelvetrees in his reports on the Mathinna field, closely resemble the Balfour slates and sandstones in lithological character and structural features. Although widely separated geographically, they are probably parts of the same sedimentary system. Like the Balfour series, they are apparently unfossiliferous.

(3). SILURIAN.

In the account of the Geology of Tasmania presented by the late W. H. Twelvetrees before this Association in 1902, the whole of the metamorphosed igneous rocks now referred to as the Porphyroid Igneous Complex, together with the Read-Rosebery and Mt. Lyell schists as well as the Dundas slates and breccias, were referred along with brachiopod sandstones at Middlesex, Zeehan, and Queen River to the Upper and Middle Silurian. The Gordon River limestone, together with the Mathinna slates and sandstones were referred to the Lower Silurian.

Since that date it has been satisfactorily demonstrated that the Porphyroid Igneous Complex, the Read-Rosebery and Lyell schists, and the Dundas slates and breccias are separated from the Silurian sedimentary rocks by a period of very pronounced diastrophism. As explained above, these older rocks are referred to as Cambro-Ordovician. The series which are now definitely recognised as belonging to the Silurian system are the slates and sandstones of the Queen River, Zeehan, and Middlesex, and other localities on the West Coast; and the blue limestone, generally known as the Gordon River limestone, but which occurs at numerous localities throughout Northern, Western, and Southern Tasmania. Suites of fossil remains from these series have been examined by W. S. Dun, whose final conclusion was to the effect that the species of the various genera were of Silurian types, but possessed to some extent an Ordovician facies. On the whole, however, this palæontologist concludes that both series are of Silurian age, and most probably Lower Silurian.

And now it is necessary to mention a sedimentary series which is such a prominent factor in West Coast geology, and which has been the subject of much discussion and investigation, being within the last 18 years referred to systems ranging from Devonian to Cambrian. The series referred to is the West Coast Range Conglomerate Series. This series was referred by the late W. H. Twelvetrees in 1902 to the Devonian, and L. K. Ward, mainly on negative evidence, transferred it in 1909 to the base of the Cambrian system. The negative evidence referred to consisted of the non-discovery within the conglomerate of pebbles of rocks of the Porphyroid Igneous Complex. The discovery in 1913 by the writer of numerous pebbles of such rocks in the conglomerate series as developed in the Jukes-Darwin field showed the uncertainty of basing conclusions on negative evidence, and finally determined the Post-Porphyroid age of the conglomerate series. Investigations carried out since that time by the writer, and which are still in progress, have supplied abundant confirmatory evidence.

The age of the West Coast Range Conglomerate Series is by this succession shown to be Post-Cambro-Ordovician. The study of the structural geology of this series and the Silurians, which has been carried out in the Zeehan field by G. A. Waller, and by the writer on the greater part of the West Coast Range, serves to strengthen to almost certainty the conclusion arrived at by G. A. Waller in 1903, that the West Coast Range Conglomerate conformably underlies the Silurian limestone series, and is itself of Silurian age, constituting, in fact, a basal conglomerate series of the Silurian system in Tasmania.

The much-discussed Tubicolar or Pipe-Stem Sandstone belongs to the uppermost horizon of the West Coast Range Conglomerate Series, and is more highly developed in the North than in the more southerly portion of the known occurrences. The limestone immediately succeeds this Tubicolar Sandstone, and is itself conformably overlain by the slates and sandstone series, the Silurian system in Tasmania thus consisting of:—

(3) Slates and Sandstone series of Queen River, Zeehan, Middlesex, etc.

(2) Limestone series of Gordon River, Railton, etc.

(1) West Coast Range Conglomerate series.

(4). DEVONIAN.

There are no sedimentary rocks so far located in Tasmania which can be referred to the Devonian system.

Consequent on the collapse of the geosynclinal in which the Silurian sediments were laid down, there ensued an orogenic period of considerable intensity. This orogenic movement consisted largely of folding, but thrust faulting on a considerable scale was a marked characteristic. It is this orogenic folding and faulting which is responsible for the very complicated relationships between the older rocks and the Silurian sediments which have been the cause of so many misinterpretations of the geological succession.

The final phase of the orogenic period consisted of the irruption of the principal granitic rocks of Tasmania. The fact that the next sediments to accumulate are of Permo-Carboniferous age, and that they rest in many cases directly on the granite, points to the conclusion that during the Devonian period Tasmania was a land surface, and was subjected to a prolonged cycle of denudation. In fact, work recently carried out by the writer has shown that at the close of the Devonian period this land surface had been reduced to a peneplain.

(5). PERMO-CARBONIFEROUS.

An important advance in our knowledge of the Permo-Carboniferous system was made by the late W. H. Twelvetrees in 1911, when he demonstrated that the Tasmanite shale beds of the Mersey basin were the marine facies of the Mersey (East Greta) Coal Measures. The discovery and investigation of the Preolenna Coal-field have supplied further evidence of the geological horizon of our Lower Coal Measures, and the coal seams and the associated kerosene-shale present much valuable information in regard to sapropelic coals.

The glacial conglomerate forming the base of the Permo-Carboniferous system in Tasmania has been studied in detail by Professor Sir T. W. Edgeworth David at Wynyard.

With these exceptions, the work accomplished on our Permo-Carboniferous system has not been sufficient to give us greater information than we possessed 18 years ago.

(6). Trias-Jura.

The retention of the above dual nomenclature at once indicates that we have not to any appreciable extent advanced our knowledge of the Mesozoic sedimentaries as developed in Tasmania. This is due to the fact that very little actual geological survey work has been attempted on our coal-fields. It is, however, very satisfactory to be able to announce that for the past ten months two geologists of the Geological Survey have been constantly employed on this work, and will be so occupied until the close of the summer, and our knowledge in this direction has already been extended. Mr. H. H. Scott is carrying out some work on the Trias-Jura flora which is being collected, and it is confidently hoped that within the next twelve months a somewhat comprehensive account of both the Permo-Carboniferous and Trias-Jura systems will be possible.

(7). Tertiary.

Beyond the recognition at various localities of deposits of Tertiary age and the areal mapping of some of them, no advance has been made in working out the stratigraphy of Tertiary sediments, either lacustrine or marine.

IV. PALÆONTOLOGY.

(1). Silurian.

A valuable addition to our knowledge of Silurian fossil types was made as the result of the study by W. S. Dun of a suite of specimens collected by the Geological Survey. The resulting determinations are contained in Geological Survey Bulletin No. 8.

More recently, F. Chapman, A.L.S., has studied certain fossils from the Silurian limestone, and has prepared a description of the occurrence of Tetradium therein, which has been published as Geological Survey Record No. 5.

(2). PERMO-CARBONIFEROUS.

As the result of the investigations carried out by the late W. H. Twelvetrees in the Mersey basin, our knowledge of the character of the organic component of the Tasmanite shale has been appreciably increased. In connection with the same examination also, W. S. Dun carried out some palæontological work on the Marine fauna of the Permo-Carboniferous beds in that area, and these are dealt with by that investigator in Geological Survey Record No. 1.

Apart from these increases to our knowledge there has been no advance in our Permo-Carboniferous palæontology.

(3). TRIAS-JURA.

No study similar to that carried out in recent years by Dr. Walkom in Queensland has been accomplished in Tasmania. The systematic geological survey of our coal-fields and other Trias-Jura areas now in progress is supplying material which promises to give important information. Mr. H. H. Scott is undertaking the palæontological work on these collections, and a contribution is anticipated which will mark a step forward in connection with this field of investigation.

(4). TERTIARY.

A considerable amount of work was accomplished by the late Miss M. Lodder on the marine beds of Table Cape. An indefatigable collector in the same locality was the Reverend E. D. Atkinson, B.A.

A marsupial from this formation—*Wynyardia bassensis*, Spencer—is believed to link the Diprotodonts with the Polyprotodonts.

There has, however, during the period under review been no work whatever accomplished on our particularly rich Tertiary flora, and as far as can be seen at present there is no likelihood of any attention being paid to this most interesting field for research for some years to come.

(5). PLEISTOCENE AND RECENT.

The Mowbray Swamp on the North-West Coast has supplied within the last ten years two most valuable and interesting skeletons of *Nototheria*. It is to the enthusiasm and perseverance of Mr. H. H. Scott that we owe the excavation and preservation of these skeletons. To the same worker belongs the credit of first describing the *Nototherium tasmanicum*, which is accomplished at length in Geological Survey Record No. 4. The original skeleton has been mounted by Mr. Scott, and is now to be seen in the Victoria Museum, Launceston.

During the past year the second *Nototherium* was discovered, and this has been determined as *Nototherium mitchelli*. H. H. Scott and Clive Lord have already presented preliminary notes on this skeleton before the Royal Society of Tasmania, and a complete description, as well as the mounting of the specimen, is in progress.

The discovery of these two skeletons and their immediate study and description have effected a distinct advance of knowledge of the *Nototheria* in general.

Another important discovery of marsupial remains was made in King Island. The remains are fragmentary, but sufficient has been found to allow of the recognition by H. H. Scott of the giant kangaroo—*Palorchestes*. Further work remains to be carried out in this direction.

It is very evident from the above resumé of palæontological investigations that the Geological Survey itself has done very little in the palæontological branch of geology. This is only to be expected when it is remembered that the *raison d'etre* of the Geological Survey is the necessity of intensive study of our ore deposits, and the demand is for investigations having an obviously practical value. The significance of the role played by palæontology in all geological investigations is not realised by the great majority of mining men, and consequently the palæontological work essential to our studies in economic geology is carried out more or less surreptitiously, and, in the non-provision of a palæontologist on the staff, is mostly accomplished by taking advantage of the keenness and good nature of palæontologists belonging to other institutions and other States.

V. STRUCTURAL GEOLOGY.

Much light has been thrown on the tectonics of Tasmania during the period under review. The definite fixing of the stratigraphical succession has materially assisted in deciphering the structural geology of certain areas, and it is now possible to form a broad general conception of the tectonics of the Island. Such generalisations must, however, be drawn with care in view of the relatively small areas in which structural geology has been investigated in detail.

The most recent summary of our tectonic geology is that included in Professor Sir T. W. Edgeworth David's Presidential Address to the Linnean Society in 1911. Since that date, however, considerable progress has been made towards supplying data for a more detailed general survey. The writer has dealt with this problem of the mapping of tectonic lines in connection with his work on the Metallogenic Epochs of Tasmania, and has summarised the conclusions which are justifiable on the evidence at present available.

It has been demonstrated that there have occurred in Tasmania at least three, and possibly four, distinct periods of orogenic movement, and one period of block faulting on a huge scale. To these diastrophic movements must be added the intrusion of the diabase, which, although unaccompanied by horizontal thrust, must on the evidence recently obtained by P. B. Nye in the Midlands have been characterised by vertical upthrusting on a very large scale.

The first definitely fixed orogenic period was that which followed the Pre-Cambrian sedimentation. If L. K. Ward's deductions in regard to the subdivision of the Pre-Cambrian are correct an earlier disturbance must be admitted. The direction of the tectonic lines of this Epi-Algonkian orogenic revolution swing in gentle curves from N.N.W. in the South, through N.N.E. near Cradle Mt., back to the N.N.W. to the Northwards, and ultimately end on the north coast with a N.N.E trend. The overfolding is towards the East. There was apparently no batholithic end-point to this Epi-Algonkian orogenic movement.

The period of sedimentation and contemporaneous effusive igneous activity which characterised the Cambro-Ordovician was followed by a pronounced orogenic revolution. The Epi-Cambro-Ordovician trend-lines are N.N.W. in the southern portion, bending to due N. in the neighbourhood of Rosebery, but resuming the general N.N.W. direction north of that locality. No overfolding has yet been observed. A batholithic end-point characterised the close of this orogenic period. The intense alteration and mineralogic reconstitution, which was characteristic of this orogenic movement, gave rise to the fissility of the Dundas slates and the schistosity of the Read-Rosebery and Mt. Lyell schists. The development of the schistose structure was complete at the time the Epi-Cambro-Ordovician plutonics reached their *mise-en-place*.

The close of the Silurian period of sedimentation witnessed the geosynclinal collapse and the occurrence of the Epi-Silurian orogenic movements. The trend-lines are regularly directed N.N.W., and overfolding occurs both to the East and to the West, overthrusting having taken place on a considerable scale. The movements, although undoubtedly intense, did not produce the universal schistose structure which was the result of the preceding diastrophic period. The batholithic phase of this Epi-Silurian orogenic period was one of great importance and size, as it was responsible for the intrusion of our so-called Devonian granites, gabbros, and serpentines, together with their associated congeners.

Since the cessation of the Epi-Silurian orogenic movements there has been no recurrence of compressive forces in Tasmania. The vertical and upwardly directed thrusts of the diabasic invasions at the close of the Mesozoic era apparently gave rise to no horizontal thrusts. This conclusion seems inevitable as the result of the recent researches of P. B. Nye, and the evidence is to the effect that this diabasic upthrust carried upwards to varying heights isolated masses of Permo-Carboniferous and Trias-Jura sediments.

It has been long recognised that the present configuration of Tasmania is very largely due to the effect of tensional faulting on a large scale. During the period under review it cannot be claimed that this conception has been elaborated to any considerable degree. The contention advanced by E. C. Andrews and Dr. Griffith Taylor that the Midlands is a Rift Valley seems to have been disproved by P. B. Nye's recent investigations.

It is undoubtedly true, however, and a mass of confirmatory evidence relating thereto has been collected during the last 18 years, that block faulting has taken place parallel to the general trends of the coast-line. The basal beds of the Permo-Carboniferous system have, for example, been found at sea-level, and 3,000 feet above that level, and a great part of this is due to tensional block faulting, but the exact contribution to this difference of level by the upthrusting during the diabase injections has not been determined. Minor faults of this tensional series have been recognised, but it cannot be claimed that the major breaks have been accurately located. It is hoped that the work now in progress on our coal-fields will result in some valuable data in connection with this problem.

VI. PETROLOGY.

(1). Petrography.

The knowledge gained during the period under review of the petrography of the igneous rocks of Tasmania has been considerable. This is not surprising when it is remembered that the late W. H. Twelvetrees was one of the most skilled petrographers of the Commonwealth, and the result of his 18 years' labour, combined with the work carried out by other officers of the Geological Survey, represents a distinct advance towards a complete description of our igneous rocks.

It may at the present time be confidently claimed that the petrographic descriptions of our Epi-Silurian plutonic acid and basic rocks by Twelvetrees, Ward, Waller, Waterhouse, McIntosh Reid, and Professor Benson represent an approach to a complete knowledge of the character of the numerous rock-types of this series.

Similarly it is justifiable to claim that the descriptions of the composition and microscopic structure of the diabase which constitutes such a great proportion of Tasmania, presented at various intervals by Twelvetrees, Petterd, Ward, Professor Benson, A. Osann (Frieberg), and F. P. Paul, constitute an almost complete demonstration of the petrography of this rock.

Completeness in petrographic descriptions also characterises the investigations of our Tertiary basalts, whether they be the normal olivine basalts, the limburgite, or the trachydolerite of Table Cape and Stanley. It is to Twelvetrees, Petterd, and Ward that we owe our detailed knowledge of these.

Although considerable advance has been made in deciphering the variations in rock-types in the Port Cygnet alkaline series and the probably comagmatic nepheline basalts of Bothwell, and the melilite basalt of Sandy Bay—work in which Twelvetrees, F. P. Paul, and Professor Benson have been most prominent—yet there remains a very large amount of investigating to be done before anything approaching the detailed character of our knowledge in regard to the Epi-Silurian plutonics is attained. It is in such a case as this that there is severely felt the handicap to progress which is occasioned by the elimination of the subject of geology from the University curriculum, as the Port Cygnet alkaline series, by reason of both their interest and their proximity to Hobart, must inevitably appeal as a subject of research to an active School of Geology located at Hobart. The most complete description of this series so far published is that by Dr. F. P. Paul, which appeared in 1906. (1)

There now remains to be discussed the advance in knowledge of the Porphyroid Igneous Complex during the last 18 years. The work accomplished in this field is considerable, as is evident when it is remembered that it is during this period that the conception of this Porphyroid Igneous Complex as a distinct igneous rock series has been gradually evolved. The petrographic studies carried out on the innumerable varieties of quartz-porphyries, felspar-porphyries, felsites, syenites, granites, etc., occurring in close association on the West Coast have resulted in a gradual separation of a very large group of these igneous rocks which are characterised by mineralogic reconstitution and evidence of great physical strain, from a group relatively less plentiful in varieties which possess no internal evidence of such dynamic metamorphic action. To the former group the name "porphyroid" was applied by G. A. Waller in 1902, and subsequently this term was adopted as a group name as the result of considerable study by the late Professor H. Rosenbusch, to whom recognition must here be made of very great assistance in elucidating the petrography of this group of igneous rocks.

It is a very difficult task, in view of the mineralogic reconstitution and mechanical deformation which this series of rocks has undergone, to recognise the original character of the several rock-types from petrographic study. Gradual progress in description and in deductions as to original character has been made, mainly by Twelvetrees, Ward, Professor W. Gregory, and the writer, and it is now perfectly clear that in this Porphyroid Igneous Complex we have a comagmatic series consisting of effusive, intrusive, and plutonic types ranging in composition from basic to acid. There still remains, however, a great amount of work to be done in the petrographic study of an almost unlimited number of varieties of this series particularly in the case of the effusive and fragmental types, and also in connection with the basic plutonics.

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(1) F. P. Paul: "Beitrage zur petrographischen Kenntniss einiger foyaitisch thiralitischen Gesteine aus Tasmanien" Mineral. petr. Mitteil Band 25, Heff IV., Wien, 1906.

(2). Petrogenesis.

Viewing the igneous rocks of Tasmania from the broader standpoint of petrology and accepting the most comprehensive significance of that word, the questions of chemical composition, structure of the igneous masses, and mode of origin come up for consideration and investigation.

In regard to chemical composition it must be at once admitted that our progress has been practically nil. The number of rock analyses carried out during the last 18 years is practically negligible. It was hoped when the Geological Survey Laboratory was established in 1914 that rock analyses would be systematically carried out if only slowly, but it has been found impossible up to date, owing to the time taken in routine assay work, to devote any time to rock analysis. It is hoped, however, that the conditions will be improved in the near future. The serious hindrance to progress that this lack of rock analyses imposes is so obvious that no further comment is needed.

The petrogenic problems in Tasmania are decidedly complex, and it cannot be said that any near approach has been made to their solution. It can, however, be claimed that some progress has been made.

In regard to the question of geologic age it cannot be more definitely stated of the Porphyroid Igneous Complex than that it belongs to the Cambro-Ordovician. Some of the effusive and fragmental members of that complex are contemporaneous with the larger sedimentary series of that system, while others undoubtedly succeeded the main sedimentation. On the whole the evidence points to the fact that the greater part of the igneous series belong to the closing phases of the Cambro-Ordovician, although this has by no means been completely demonstrated. It is clear, however, that the acid plutonic members represent the end-point of the Epi-Cambro-Ordovician orogenic disturbance, as these show much less crushing than the other members of the complex.

It has been demonstrated by Ward, and confirmed by Waterhouse and McIntosh Reid, although originally suggested by Waller, that the basic and ultra-basic members of the Epi-Silurian igneous series are slightly older than the acid and sub-acid members—in other words, that the basic portion of the magma appeared at the beginning of the petrogenic cycle, while the acid portion followed shortly afterwards. As previously pointed out in this review, this petrogenic period occurred at the close of the Epi-Silurian orogenic paroxysm.

No more definite determination of the Diabase has been made than that it is Post-Trias-Jura and Pre-Tertiary. It is generally referred to the Cretaceous, but there has been no further evidence of this adduced since the late W. H. Twelvetrees wrote his summary in 1902.

An important discovery was made by Professor E. W. Skeats in 1916 when he located a dyke of the Port Cygnet Alkaline Series cutting the diabase near Woodbridge. In a paper read before the Royal Society of Victoria (2) Professor Skeats discusses this discovery and demonstrates the Tertiary age of this most interesting alkaline series. Up to the time of this discovery the series was regarded as of Permo-Carboniferous age.

No data whatever have been obtained from which to determine the relative ages of our olivine basalts, limburgite, trachydolerite, and melilite basalt. We know that they are Tertiary, but our knowledge has not advanced in this direction during the period under review.

In only one district have sufficient investigations of the structural features of the Porphyroid Igneous Complex been carried out to enable definite conclusions to be drawn in regard to the actual structure of the masses of various rock-types of the series. The area referred to is the Read-Rosebery district, in which the writer has mapped the fold axes of the Cambro-Ordovician sediments and the associated igneous rocks, and demonstrated that the felsite or keratophyre which is so well developed in that locality is in the form of an extrusive sheet now characterised by a complex series of folds. Evidence gathered at other localities on the West Coast gives confirmation of this effusive character of many of the porphyries, porphyrites, spilites, etc , but the mapping of the structural geology has not advanced far enough to allow of the definite demonstration of the structure as that of contemporaneous extrusive sheets in the same detail as in the Read-Rosebery district. Neither is it yet possible to give any indication of the order of succession within this petrogenic cycle—an achievement which will only be possible when the structural features of the whole Cambro-Ordovician system have been elucidated.

As indicated above the end-point of the Cambro-Ordovician petrogenic cycle, as well as that of the Epi-Cambro-

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(2) Proc. Roy. Soc. Vic., Vol. XXIX., Part II. (1917), pp. 155-164.

Ordovician orogenic period, was the intrusion of the granite. This granite has been recognised at four localities:—South Darwin, Dove River, Mount Farrell, and Bond's Peak. At the two former localities it is clearly intrusive into other members of the complex, but in the vicinity of Mount Farrell there is a mergence by insensible gradations into members which are clearly extrusive. This very puzzling structure is being dealt with by the writer in his work on the "Metallogenic Epochs of Tasmania," and it seems probable that we have here a possible illustration of "extrusion by de-roofing," as propounded by R. A. Daly. If this is so, however, the granitic phase of the batholithic period is not confined to the end-point alone.

Apart from the areal mapping of the basic and acid members of the Epi-Silurian petrogenic period there has been very little progress, with one noticeable exception, towards arriving at general conclusions in regard to the structure and relationships of the various igneous massifs. The exception referred to is the paper read before this Association in 1911 by L. Keith Ward, entitled "The Heemskirk "Massif—its Structure and Relationships." In that paper the conception is developed that the Heemskirk Massif possesses a definite bottom and is chonolithic in character rather than laccolithic or batholithic. Ward further proceeds to hypothecise two parallel lines of crustal weakness along which igneous intrusion has taken place, and maintains that the various Epi-Silurian igneous massifs, although possibly connected in depth along these lines, are elsewhere quite separate intrusive bodies. Work carried out since the preparation of that paper, however, throws serious doubt on the accuracy of these conclusions. A great difficulty in regard to the acceptance of the existence of the Bischoff and Heemskirk-Middlesex lines of crustal weakness which have been the loci of igneous intrusion lies in the significant fact of the concordance between the orientation of the major axes of the igneous massifs and the Epi-Silurian fold axes. As stated above, the Epi-Silurian trend lines have a bearing of N.N.W.—a direction which is at right angles to that of the two lines indicated by L. K. Ward. Add to this the irregular but wide distribution of the outcrops of both basic and acid massifs of this series, which is obvious from a glance at the Geological Map of Tasmania, and the difficulty of accepting Ward's conclusions is apparent.

The evidence seems to point to the conclusion that the Epi-Silurian magma reached its final resting place in the form of a limited number of composite batholiths. It, moreover, seems possible that there finally resulted one huge batholith underlying the greater part of Tasmania, the cupolas and satellitic injections from which now represent the apparently isolated massifs as we at present see them.

In spite of the great amount of work that has been accomplished, and the numerous descriptions written in regard to the petrography of the Tasmanian diabase, yet, as pointed out by Osann, there is very little in existence descriptive of its field occurrence and structural relationships. We know that it is intrusive and that undoubted sills and dykes occur, and this was the state of our knowledge in 1902 with the addition that other masses had had a laccolithic structure suggested for them. It is therefore disappointing to have to announce that up to the beginning of the past year no material advance had been made in this connection. Certainly L. K. Ward recognised two distinct horizons of intrusive sheets near the King William Range, but no work was done on the larger diabase massifs to elucidate their morphology and mode of origin. During the past year, however, the geological surveys carried out in the Midlands by P. B. Nye, on the East Coast by H. G. W. Keid, and during the last few months by A. McIntosh Reid, have supplied valuable data which, along with that being acquired at the present time in the extensions of those surveys, will probably enable a very complete summary of the field occurrence of our diabase to be prepared. The evidence so far obtained points to our larger diabase massifs being asymmetric laccolithic intrusions possessing an almost vertical face on one or more sides, but grading off into an intrusive sheet on one or more of the others.

Very little work has been done on the field occurrences of the Cygnet Alkaline series and the probably associated nepheline and melilite basalts, and the status of our knowledge in this connection is practically as it was in 1902.

Beyond the areal mapping of some of our olivine basalt areas no advance has been made as to the mode of origin. Certainly the negative evidence provided by the failure to locate a single volcanic cone is valuable but not conclusive evidence of fissure eruptions.

This short review of the progress in petrologic science cannot be complete without a reference to that most interesting discovery—the Darwin Glass. The credit of first bringing this substance under the notice of the Geological Survey belongs to Hartwell Conder, M.A., who in 1912, while acting as State Mining Engineer, had several fragments presented to him by one of his prospectors. These fragments were reported to have been derived from the Western portion of the Jukes-Darwin area, and the assignment of the writer to carry out a geological survey of that area early in 1913 gave an excellent opportunity for a detailed investigation of the occurrence. The results of such investigation are presented in Record No. 3 of the Geological Survey, and the conclusion there indicated that this substance is of cosmic origin and belongs to the Tektites, being most nearly allied to the Moldavites, but differing from the latter in the remarkably high silica content (89 per cent.). Since the publication of that official description Dr. H. S. Summers has discussed the composition in relation to the other members of the Tektites, and Dr. F. Suess, of Vienna, the world's authority on this subject, has fully discussed this substance and its bearing on the whole problem of the Tektites in a paper entitled "Ruckshau und Veneres uber die Tektitfrage."(3)

The writer would, however, here enter an objection to the name proposed by Suess, namely, "Queenstownite," on the grounds that the Darwin Glass does not occur at Queenstown, the nearest occurrence being ten miles from that town.

VII. MINERALOGY.

Considerable advance has been made in this branch of geologic science during the period under review. Most of the increase in knowledge has been gained during the petrographic researches indicated in the preceding chapter, and also incidentally to the intensive study of our ore-deposits, which will be dealt with in the chapter following this.

It is to the late W. F. Petterd that the greatest amount of credit must be given for our advance in our knowledge of the minerals of Tasmania. The "Catalogue of the Miner-"als of Tasmania," published by that enthusiastic mineralogist in 1896, was a valuable contribution, and served as the standard reference on Tasmanian Mineralogy until 1910, by which time the increased information acquired necessitated its re-writing, which was completed early in that year and published under the authority of the Mines Department. The advance made in that period is well indicated by the fact that this second edition contains descriptions of over one hundred more mineral species than the first compilation.

(3) Mitteil der Geol. Sesell. Wien. I., ii., 1914.

The State of Tasmania is further indebted to this investigator by reason of the bequests made by him to the Royal Society of Tasmania of his valuable collection of minerals. This collection, which is the best collection of Tasmanian minerals in existence, and in many particulars quite unique, is now to be seen in the Tasmanian Museum, Hobart.

In addition to this publication, which deals specifically with the subject of mineralogy, there has appeared a wealth of detail as to varieties and some new species in the various publications of the Geological Survey of Tasmania. In regard to one mineral species a special publication was issued as Geological Survey Record No. 2, entitled "Stichtite—"a New Tasmanian Mineral."

An interesting and important discovery was that made by the Geological Survey in 1913 of the occurrence of osmiridium in the parent serpentine rock. Since that date the two varieties of that mineral have been definitely determined—siserskite and nevyanskite. Some very valuable work has recently been carried out by A. McIntosh Reid and W. D. Reid, of the Geological Survey Staff, on the composition of osmiridium and several minerals of the platinum group, including one probably new species.

The most valuable contributions by the Geological Survey since the last edition of the "Catalogue of the Minerals "of Tasmania" in 1910 are those dealing with the paragenesis of the mineral components of our ore deposits rather than with the identification of new species. This type of investigation is in accordance with the recent development of the subject of mineralography, and the application of the latest methods of investigation has already thrown much light on the inter-relationships of the component minerals of our ore-bodies, and promises to be of even greater utility in the near future. The studies made by L. L. Waterhouse of the contact metamorphic deposits of Stanley River and Heemskirk are valuable contributions to our knowledge of the mineral paragenesis of this type of ore deposit. The complete paragenesis of the complex zinc-lead sulphide ore deposits of Read-Rosebery has been demonstrated by the writer, who is at present engaged on similar investigations in connection with the geological survey of the Mount Lyell field. In this connection it must be noted that Gilbert and Pogue, of the American National Museum, have carried out a mineralographic study of some of the ore of the Mount Lyell field forwarded to them by Mr. R. C. Sticht.

VIII. ORE-DEPOSITS.

(1.) The Development of the Investigations.

It is in this domain that our greatest advance has been made. This is not surprising, in view of the fact that the study of our deposits of economic minerals is the *raison d'etre* of the Geological Survey.

The earlier portion of the period under review witnessed intense mining activity in Tasmania, and it is to the developments resulting from such work, together with the concurrent demand for geological examinations, that we owe the opportunities for research which have been productive of appreciable results.

The year 1902 saw the late W. H. Twelvetrees and his assistant, G. A. Waller, busily engaged examining active mining fields and preparing incomplete geological maps of those areas. The work performed by Waller in the Zeehan field constitutes the first complete geological mapping of a mining field executed in Tasmania. There was gradually evolved at this period by both investigators the conception of a genetic connection between the plutonic igneous rocks and our ore-deposits, particularly between the granitic rocks and our tin, lead, zinc, and iron deposits.

After the resignation of Waller in 1904 the late W. H. Twelvetrees continued the examination of ore deposits, without, however, having the opportunity of carrying out detailed mapping. With the appointment in 1907, however, of L. Keith Ward as Assistant Government Geologist, an opportunity was afforded of initiating systematic studies of our ore-deposits, accompanied by the detailed geological research which is essential to an understanding of their genesis. The old ground traversed by Twelvetrees and Waller was retraced and new ground broken as opportunity offered, and these repeated examinations of our more important mining fields and their ore-deposits have continued up to the present time, with the result that the knowledge we now possess of these ore-deposits is considerable.

(2). The Galena Lodes of Zeehan.

The earlier investigations by G. A. Waller on the ore deposits of the Zeehan field were elaborated in detail by Twelvetrees and Ward, and the composition, structural features, and genesis thoroughly elucidated. The galena-bearing lodes are grouped into two belts—the Pyritic Belt and the Sideritic Belt. The difference in mineralogic composition has been determined by zonal precipitation, each zone representing certain limiting ranges of temperature and pressure which characterised the conditions during actual deposition of the mineral species from the ore-bearing solutions. The origin of the ore-bearing solutions is ascribed to the differentiating igneous mass which gave rise to both them and the underlying granitic mass.

L. K. Ward elaborated this conception of zonal precipitation in a paper read before this Association in 1911, entitled "An Investigation of the Relationship between the Ore-"bodies of the Heemskirk-Comstock-Zeehan Region and the "Associated Igneous Rocks." His conception demonstrates three zones—the Granite Zone; the Contact Metamorphic Zone; and the Transmetamorphic Zone—the latter being subdivided into the Pyritic and Sideritic Belts. The factor determinating the amount and kind of precipitation from the outwardly migrating ore-bearing solutions is the decrease in temperature and pressure as distance is gained from the magmatic hearth.

It must be here pointed out, however, that A. McIntosh Reid has recently adduced evidence which shows that the Comstock magnetite deposits, classed as contact-metamorphic by Ward, are magmatic differentiations within the basic phase of the Epi-Silurian plutonic period. There are, however, undoubted contact metamorphic magnetite and hæmatite deposits around the periphery of the granite, and Ward's conception of zonal distribution is not affected in general principle.

(3) The Read-Rosebery Zinc-Lead Sulphide Deposits.

These deposits have been studied in detail by the writer, and their composition, structural features, mineralogy, and genesis are fully delineated in Bulletins 19 and 23 of the Geological Survey. The northern extension of this belt is described by A. McIntosh Reid in Geological Survey Bulletin No. 28.

It is shown that the zinc-lead sulphide ore-bodies are metasomatic replacements of schistose calcareous beds in the Read-Rosebery schist series, which, as previously indicated in this review, are predominantly sedimentary in origin. The component beds of this schist series have been thrown into a series of complex folds by the same stress which brought about their schistosity. The axes of the two series of folds are at right angles to each other, and the more important of these have been mapped. The actual structure observable is that of a series of irregular domes and basins, so that at any mine level the outline of the ore-bodies is irregularly lenticular.

The origin of the ore-bodies is ascribed to ascending magmatic waters genetically associated with the Epi-Silurian quartz-porphyry and granite-porphyry dykes in the vicinity.

(4). The Tin Deposits of North-East Dundas.

These were examined in detail by L. K. Ward in 1908, and their structural features, composition, and genesis are described in Bulletin No. 6 of the Geological Survey. Some of the later developments in the various mines are dealt with by Hartwell Conder, M.A., in Bulletin No. 26.

The tin deposits are grouped by Ward under two heads—Pyritic-Cassiterite deposits and Quartz-Tourmaline-Cassiterite Veins. The composition and structural features have been somewhat completely elucidated, and the genesis referred to the associated granite-porphyry and quartz-porphyry dykes of Epi-Silurian age. However, it cannot be stated that the exact relationship to the pyritic-lead deposits, the garnet actinolite veins or the axinite veins, which occur associated with the tin-deposits, has been demonstrated. Neither can it be claimed that the mineralography of the pyritic-cassiterite ores has been closely studied, especially in regard to those of dense stanniferous pyrrhotite.

(5). The Ore Deposits of the Mount Farrell District.

The investigation carried out by Ward in 1907 on the ore-deposits of this district was an elaboration of previous examinations by Twelvetrees and Waller.

Ward's description of these deposits, contained in Geological Survey Bulletin No. 3, shows three types of lead deposits—Sideritic-Galena lodes, Pyritic-Galena lodes, and Barytic-Galena lodes. No attempt, however, is made at a zonal classification similar to that evolved for the Zeehan field.

Certain types of copper ores, as well as iron ores, are described, and the genesis of all of the ore deposits is ascribed to the Epi-Silurian plutonic period. However, the relationship between the lead-deposits, those containing copper, and the hæmatite and magnetite deposits is not elucidated, so that a common genetic origin for them all is by no means certain.

(6). The Tin Deposits of the Stanley River District.

These have been described in detail by L. L. Waterhouse in Bulletin 15 of the Geological Survey, following upon previous work by G. A. Waller.

The deposits are mainly of the Quartz-Tourmaline-Cassiterite type and what are termed Stanniferous Contact Metamorphic Deposits. These are both described in detail in regard to structural features, composition, and paragenesis. It is important to note that it has been demonstrated by Waterhouse that the cassiterite in the contact metamorphic deposits is later than the contact metamorphic minerals. The origin of the ore-bearing solutions is shown to be the Epi-Silurian granitic plutonics strongly developed in the field.

Sufficient evidence, however, is not available to establish the definite relation between the two types of tin deposits, nor between these and the zinc and lead veins.

(7). The Heemskirk Tin Deposits.

G. A. Waller described these deposits in considerable detail in 1902, and L. L. Waterhouse carried out a more comprehensive survey in 1914. The description of this field is contained in Bulletin No. 21 of the Geological Survey, and the description of the ore deposits is presented in meticulous detail.

The tin deposits are classified into six types:—

(1) Quartz-Tourmaline-Cassiterite Veins;

(2) Quartz-Quartzose Deposits;

(3) Pyritic Cassiterite Deposits;

(4) Pinitoid Veins;

(5) Greisen Veins;

(6) Pipe Formations.

The structural features, composition, and paragenesis of all of these types are described in detail. In addition, contact metamorphic deposits are described, as well as zinc and lead deposits and nickel ores. It is shown that certain of the zinc and lead deposits are variants of certain of the tin veins, and zonal precipitation is given as the explanation of the change in character with increasing distance from the magmatic hearth. The contact metamorphic deposits preceded the tin deposition.

The whole of the ore deposits in the field are shown to be genetically connected with the Epi-Silurian plutonics.

(8). The Ore Deposits of Mount Balfour.

These were examined by L. K. Ward, and described in Geological Survey Bulletin No. 10.

Two groups of deposits are shown to exist—the Copper Group and the Tin-Tungsten Group. Both are described, and a zonal distribution in relation to a hypothetical granite core to the Balfour Range is suggested, although not definitely established. However, it is assumed that they are both genetically connected with the Epi-Silurian granite of the district, although the evidence for the copper deposits is by no means conclusive.

(9). The Ore Deposits of Jukes-Darwin.

Following upon the work carried out by the late W. H. Twelvetrees twelve years before, the writer in 1913 made a thorough investigation of the ore deposits of this region. The results of this investigation are contained in Geological Survey Bulletin No. 16.

The ore deposits are classified into the following groups:—

(1) Copper-Silver-Gold Ore-bodies;

(2) Hæmatite and Magnetite Deposits;

(3) Blue Hæmatite-Bornite Veins;

(4) Barytes Lodes;

(5) Quartz Lodes;

(6) Epidote Veins.

The composition, structural features, and paragenesis of these deposits are described. It is shown that the hæmatite and magnetite ore-bodies are genetically connected with the granite of the porphyroid igneous complex. The problem of metallogenesis is discussed at some length, but the evidence was at that time not found sufficient to justify definite conclusions as to which metallogenic epoch or epochs the remaining groups were to be assigned.

(10). The Ore Deposits of the Middlesex-Pelion Area.

These have been described in successively greater detail by G. A. Waller, the late W. H. Twelvetrees, and A. McIntosh Reid.

The late W. H. Twelvetrees was the first to recognise the true nature and origin of the garnet rock which forms the country rock of the tin-wolfram-bismuth lodes of the S.

& M. Mine, Moina. The description of this rock and the structure, composition, and paragenesis of the lodes are presented in Geological Survey Bulletin No. 12. The origin is assigned to the adjacent Epi-Silurian granite, which gave rise to the garnet-magnetite rock as a contact metamorphic rock as a metallogenic phase preceding the tin-wolfram-bismuth phase.

The galena ore-bodies at Round Hill are also assigned to the same source as their origin, and are shown to have a saddle structure similar to the Bendigo saddles. They are assigned to an outer zone of the tin phase of the Epi-Silurian metallogenic epoch.

A. McIntosh Reid has described in Bulletin No. 30 the wolfram and copper deposits of the Pelion District. In the relatively undeveloped state of these deposits complete descriptions are not possible. The genesis of the wolfram is definitely assigned to the Epi-Silurian granite, but the evidence for the age determination of the copper deposits is not as conclusive.

(11). The Ore Deposits of Scamander.

These are described by the late W. H. Twelvetrees in Bulletin No. 9 of the Geological Survey. The structural features and composition are described, and they are grouped as follows:—

(1) Wolframite and Cassiterite Veins;

(2) Arsenopyrite-quartz-chalcopyrite lodes;

(3) Arsenopyrite-quartz-argentiferous lodes.

The distribution of these groups is interpreted as indicating a zonal precipitation outwards from the Epi-Silurian magmatic hearth in the order indicated above.

(12). The Osmiridium Deposits.

The occurrence of osmiridium in alluvial deposits has been known for many years, and its origin from serpentine was regarded as almost proved, but it was not until the year 1913 that this mineral was definitely established as being an original component of the serpentine rock. In that year the discovery of what were termed "osmiridium lodes" was responsible for the examination of the Bald Hill area by the late W. H. Twelvetrees, and as a result of this investigation the occurrence of osmiridium as a constituent of serpentine was definitely established. This is described in Geological Survey Bulletin No. 17.

During the summer of 1919-20 A. McIntosh Reid carried out a very thorough investigation of the occurrences of osmiridium in Tasmania, and his bulletin dealing with the questions of composition, mode of occurrence, and genesis is now in the Press. In this bulletin the differentiation of the basic phase of the Epi-Silurian plutonic period is studied in detail, and it is shown that the osmiridium is confined to the ultra-basic olivine-rich differentiates now converted to serpentine. It is further shown that the distribution within the serpentine masses is controlled by the occurrence of definite contraction fissures.

(13) Ore Deposits of Various Districts.

In addition to the ore deposits in the districts mentioned above which have been investigated in detail, there are a very large number of isolated deposits which have been subjected to more or less complete examinations without completely elucidating their relation to the general geology. It may in fact be claimed that we possess a good general knowledge of the mineralogic composition of the great majority of the ore-deposits of Tasmania. It cannot, however, be claimed with equal justification that either the structural features, paragenesis, or genesis of the deposits, other than those specifically mentioned above, have yet been completely elucidated and described. It is certainly a fact, however, that sufficient material is available, either published or unpublished, to enable such an elucidation and demonstration to be effected, and the writer is attempting this undertaking in his work on "The Metallogenic Epochs of Tasmania."

(14). Metallogenic Epochs.

It was recognised by the late W. H. Twelvetrees in 1909 that there have been at least two metallogenic epochs—one genetically associated with the porphyroid petrogenic cycle, the other with the Epi-Silurian batholithic epoch. Since that date additional material for the genetic classification of our ore-deposits has been acquired, and the writer is presenting such a complete genetic classification in his above-mentioned work, in addition to demonstrating the various phases and zones of the several metallogenic epochs.

IX. SOME PROBLEMS AWAITING SOLUTION.

(1). Areal Mapping.

The total area of Tasmania is 26,215 square miles. The areas of which geological maps have been made as the result of definite surveys measure in all 2,122 square miles. There, therefore, remain to be mapped 24,093 square miles. This, it must be admitted, is a big task.

In addition, it must be pointed out that the greater part of those geological maps already prepared are approximate only, and the more accurate survey of these areas is a problem for the future.

(2). Physiography.

(a). A more detailed description than anything attempted heretofore of the topographic features of Tasmania is a desideratum. A large amount of field work yet remains to be done before such an account can be completed. Particularly does this apply to the south-western portion of the Island.

(b). The exact relationship between the more prominent topographic features and geologic structure must be worked out. Particularly does this apply to the problem of the respective roles played by the diabasic upthrust, Tertiary tensional faulting, and erosion in the evolution of our Diabase Highlands. A similar problem confronts us in the origin of those "inland seas," Macquarie Harbour and Port Davey, as well as the D'Entrecasteaux Channel and the Derwent Estuary.

(c) Some of our highland lakes are of glacial origin, but the problem of the origin of the greater number of our lakes is still to be solved.

(d). The evolution of the drainage system of Tasmania has yet to be traced. Incidental to this is the problem pointed out by Dr. Griffith Taylor, in his "Australian Environ-"ment," of the pronounced bends in some of our largest rivers.

(e). The exact limits of the Darwin peneplain have yet to be determined. Does it extend to the North-East and East Coasts? What is its relation to the Tertiary tensional faulting?

(3). General Geology.

(a). The stratigraphy and structural geology of the old sedimentary system at present termed Pre-Cambrian yet remain uninvestigated in detail. This is undoubtedly an undertaking of considerable magnitude, necessitating, as it obviously will, explorations in uninhabited and heavily timbered and mountainous country. Correlation of this rock system with the Pre-Cambrians of the Australian mainland is a step which can only follow such an investigation.

(b). The relationship of the Dikelocephalus sandstone series to the other rock systems still remains to be determined. It seems highly desirable that the series should be thoroughly searched for a complete suite of fossils, and these examined in detail in order to definitely establish, or otherwise, the Cambrian age determination.

(c). The rock system now termed Cambro-Ordovician requires more exact age determination. Particularly should search be directed in the sedimentary members for fossils which so far have escaped observation.

(d). The stratigraphic relationship between the Dundas slates, the Balfour slates and sandstones, and the Mathinna slates and sandstones yet remains to be determined.

(e). The structural geology of the whole of the Cambro-Ordovician system must be worked out on the lines already accomplished in the Read-Rosebery district. In this connection it will be important to deduce from the strike and dip of the planes of schistosity of the schistose members of this system the position of the drag folds, and from these to determine the location of the axes and dimensions of the major folds.

(f). The petrology of the porphyroid igneous complex must be studied in greater detail, and the effusive and pyroclastic members distinguished from the intrusive and plutonic. With the solution of the structural problem will then come the opportunity of finally determining the order of succession within the petrogenic cycle. Incidental to this is the relationship between the Read-Rosebery and Mt. Lyell schists, which are probably different facies of the same geologic horizon.

(g). The sapropelic coals of the Permo-Carboniferous system are deserving of minute investigation, as they promise to throw much light on the natural history of coal. The exact details of the transition from these coal beds to the Tasmanite shale marine facies of the same horizon still remain to be determined.

(h). The stratigraphy and more definite age determination of our Trias-Jura system both demand attention. Particularly a detailed study of our Trias-Jura flora and comparison with that of the mainland must be undertaken. It is important also to determine whether the break between the Permo-Carboniferous and Trias-Jura is an unconformity or a disconformity, or whether there is a conformable succession.

(i). The study of the stratigraphy and the abundant flora of our lacustrine Tertiary beds is a desirable and attractive undertaking, and it is surprising that this has not been attempted in view of the very strong development of these beds at our second largest centre of population.

(j). The detailed mapping of the glaciated areas of Tasmania is a task yet before us, although some progress has been made. The location of the ice-sheets and the glaciers descending therefrom has only been partially effected, but the final solution of this problem necessitates work in some of the wildest and most inhospitable parts of the Island.

(k). The details of the separation of Tasmania from the Mainland have yet to be determined.

(l). The mapping of the Port Cygnet alkaline series has not yet been accomplished, and the order of succession within this petrogenic cycle yet remains to be determined.

(m). The study of the field occurrence of the diabase so long neglected has only recently been undertaken, but as this rock covers such a large proportion of Tasmania the amount of work to be accomplished on this problem is very considerable.

(n). The investigation of the structural relationships of our Epi-Silurian plutonics is an important one, and still remains to be satisfactorily dealt with.

(o). The determination of the exact relationship between our trachydolerites, limburgites, and normal olivine basalts.

(4.) Economic Geology.

(a). The detailed description of some of our most important ore deposits yet remains to be accomplished. This applies particularly to the copper deposits of Mt. Lyell, the tin deposits of Mt. Bischoff, and the galena lodes of the Magnet district.

(b). The mapping and description of the ore deposits of various types in many districts not yet examined in detail represent work for some years to come.

(c) The genetic classification of those of our ore deposits which have been examined to any appreciable extent is very desirable. This must entail the recognition of the metallogenic epochs, and in addition the greater refinement of the various phases within each epoch. This is the problem on which the writer has been engaged in preparing his thesis on the "Metallogenic Epochs of Tasmania."

(d) Much work remains to be done on the determination of the extent and value of our coalfields.

(e). No work of importance has been attempted in regard to our building stones. This is a subject for valuable study.

(f). The investigation of our deposits of the raw materials in the ceramic and glass-making industries is badly needed.

(g). An important mineralographic study awaiting attention is that of the stanniferous pyrrhotite ore-bodies of North Dundas. The determination of the mode of occurrence of the tin and its exact relationship to the pyrrhotite is an important preliminary in any metallurgical research on these ores.

(h). The whole problem of the genesis of our ore deposits and the factors controlling their deposition fairly bristles with intricate problems which are too numerous to attempt to indicate in this paper. Suffice it here to say that the progress already made is only a very small portion of the work necessary before anything approaching a complete elucidation of the factors controlling the distribution, extent, and value of our valuable mineral deposits can be attained.

(5.) Correlation.

With the exception of that accomplished in regard to the Permo-Carboniferous and Trias-Jura systems, practically no work has been done on correlating our Tasmanian systems and rock species with those of the mainland. This is important work which will only become possible of complete accomplishment as our investigations extend in Tasmania. Much, however, can be done at present, and it is very desirable that the first opportunity should be seized of summarising the conclusions which are possible on present evidence.