# CONTRIBUTION TO THE GEOLOGY OF TASMANIA.

## SYSTEMATIC GEOLOGY

## THE PRE-CAMBRIAN.

## (PLATES VII., VIII.)

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SUMMARY OF CONTENTS:

## I.—INTRODUCTION.

It may not be altogether inappropriate, in contributing a paper on the systematic Geology of Tasmania, to commence at the bottom of the geological column.

In the following pages the writer has the honour to present some portion of the information now available concerning that great series of rocks which constitutes the base of the geological record in Tasmania.

There are several questions connected with these rocks and their relations to the succeeding sediments which cannot but be, in the present state of our knowledge, debatable. Yet it may now be confidently asserted that these rocks are truly Pre-Cambrian in age; and this paper is largely concerned with the nature of the evidence upon which this assertion is made. Hitherto there has been a certain lack of definite information available, and the accurate classification of the series has been, in consequence, impossible of achievement.

However, within the last year the work of the Geological Survey staff has taken Mr. W. H. Twelvetrees and the writer into areas in which these fundamental rocks are well developed, and in which some details of their relationships to other members of the geological record are displayed. The geological exploration of the Great Western Railway route has provided material for an almost continuous section across Tasmania from Gormanston to Tyenna; and during the progress of this work a fund of matter has accumulated which is of inestimable value in the correlation of the strata encountered. This information is here presented in so far as it concerns the Pre-Cambrian rocks; and in the light of these recent discoveries some account is given of the deductions which may be drawn with regard to the origin, growth, and decay of the Pre-Cambrian rocks of Tasmania.

## II.—PREVIOUS LITERATURE.

The rocks which are here treated of have been referred to in the earlier literature which deals with the Geology of Tasmania as "Pre-Cambrian" or "Archaean"; but the reasons for which this provisional classification has been adopted have been admitted to be insufficient.

Mr. R. M. Johnston has clearly stated (1) the lack of the necessary evidence required before the "quartzites and metamorphic rocks" of his Geological Table (2) could be definitely referred to this position in the column.

More recently, in a paper read before the Australasian Association for the Advancement of Science (3), Mr. W. H. Twelvetrees gave a brief account of "Probable Pre-Cambrian Strata in Tasmania." In this paper Mr. Twelvetrees has stated that the several occurrences of quartzites, mica schists, and hornblendic schists are to be referred to the Pre-Cambrian mainly on the grounds that they are lithologically dissimilar from any members of the Cambrian, Ordovician, or Silurian systems which are capable of more rigid classification.

Since this paper was written the country between Tyenna and Gormanston has been geologically explored, and the uncertainties and doubts have given place to confident assertions based upon the newly-acquired information. The increase of knowledge, also, with regard to the stratigraphical position of the early Palaeozoic sediments of Tasmania, and the recent correlation of these strata in different parts of the island have assisted to no small degree in placing the classification of the Pre-Cambrian on a firm basis.

The departmental literature which deals with the several districts in which these rocks are developed is mentioned below, when reference is made to these areas.

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(1) R. M. Johnston, Geology of Tasmania, 1888, p. 17.

(2) Ibidem, p. 15.

(3) Proceedings A.A.A.S., Adelaide, 1907, p. 466.

## III.—THE STRATIGRAPHICAL SUCCESSION IN TASMANIA.

It is necessary to consider briefly the succession of the lower Palaeozoic strata and the relations of these to the rocks here described, so that the grounds for the classification of the latter as Pre-Cambrian may be properly appreciated.

The recognised base of the Ordovician system is the "Gordon River Limestone." With this limestone are associated sandstones and slates (1) which may belong to the same system.

This fossiliferous limestone at Railton and at the Humboldt Divide lies directly upon the fossiliferous Upper Cambrian beds. It is a persistent geological horizon, and therefore of great stratigraphical importance.

The strata, to which an age greater than that of the Gordon River limestone may be ascribed, whether on palaeontological or on stratigraphical grounds, are these:—

1. The Dundas slate series—with the associated intrusive and effusive porphyritic igneous rocks. These rocks may be equivalent with slates and sandstones at the Needles, and near Mounts Mueller and Wedge.
2. The Caroline Creek beds, and their fossiliferous equivalents discovered by Mr. T. Stephens on the Humboldt Divide in the Florentine Valley.
3. The "tubicolar" sandstone (commonly known as the "pipestem" sandstone); and the "discoidal" sandstone overlying it.
4. The Denison Range conglomerates and quartzites, together with the similar rocks constituting the West Coast Range conglomerate series. The pebbly sandstone and conglomerate of Railton also probably belong to the same horizon.
5. The sandstones, quartzites, slates, grits, and conglomerates of Cabbage Tree Hill, Beaconsfield.

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(1) See Section III.

A short explanation appears necessary in order that the character of the evidence, upon which the age of these five groups has been stated to be, in all probability, Cambrian, may be clearly stated.

1. The Dundas slate series consists of clay slates, sandstones, conglomerates, and breccias, with which are associated a characteristic series of massive and schistose igneous rocks. They extend from the North Coast between Penguin and Ulverstone to Birch's Inlet on Macquarie Harbour, and probably still further to the southward.

The rocks of this series are judged to be of greater antiquity than the Gordon River limestone on stratigraphical evidence (1).

2. The Caroline Creek beds consist of yellow sandstones, which are fossiliferous in both localities where they outcrop, and have been definitely referred to the Upper Cambrian upon the evidence of the organic remains preserved in them.

3. The "tubicolar" sandstone forms a well-marked horizon, which has been recognised at Mount Zeehan, Middlesex, Mount Claude, the Five-mile Rise near Lorinna, and on the Loddon Plains to the eastward of the Frenchman's Cap.

To this horizon has hitherto been assigned a much higher position in the geological column by other authors. The writer considers that it is of Cambrian age for the reasons here briefly stated:—

The peculiar tubular impressions have been recognised in the West Coast Range conglomerate on the Mount Lyell peaks.

The tubicolar sandstone proper overlies the West Coast Range conglomerate conformably at Mount Zeehan, and the relationship of the two formations is shown in Mr. Waller's section across Mount Zeehan (2).

Hence, whatever may be the nature of these problematical fossil casts, they are persistent through at least

(1) Geological Survey of Tasmania, Bulletin No. 5, pp. 8-10.

(2) G. A. Waller, "Report on the Zeehan Silver-Lead Mining Field," 1904.

a portion of the West Coast Range conglomerate series and the overlying sandstone. They have not been observed in any other sandstones, and never in actual association with any other fossils. So we may apparently conclude with safety that the tubicolar sandstone is the next succeeding formation to the West Coast Range conglomerate (where the full sequence is represented) and of slightly less antiquity.

Moreover, during the recent exploration of the country in the vicinity of the Frenchman's Cap, the writer found an extensive development of the tubicolar sandstone in the Loddon River Valley. Here it is conformably overlain by another white sandstone of similar grain; and in this latter sandstone are certain peculiar discoidal impressions. The exact nature of these markings is unknown, and Mr. Etheridge, of the Australian Museum, to whom specimens have been referred, has declined to express an opinion concerning them, since no traces of the organic structure remain.

Mr. W. H. Twelvetrees has pointed out that entirely similar, but smaller, discoidal moulds exist in the fossiliferous Upper Cambrian beds of Caroline Creek. In the event that the discoidal markings should prove to possess stratigraphical value, the discoidal sandstone must belong to the Cambrian system.

It should perhaps be here stated that the tubicolar sandstone has formerly been looked upon as of Silurian age, the reason being that at Zeehan and the Five-mile Rise strata bearing Silurian fossils have been found above this sandstone.

A re-examination of the occurrences of the tubicolar sandstone is therefore required, with a view to the discovery of a possible break in the succession. Should such a break be found between the pipestem rock and the superincumbent Silurian, the explanation of the previous classification of the strata will be provided.

4. The Denison Range is built up of a great series of siliceous sediments—crystalline pebbly sandstones, quartzites, and conglomerates. These rocks have been traced without interruption for many miles from the Thumbs across the gorge of the Gordon River, and northwards along the Denison Range.

The writer has observed a small isolated hill of reddish quartzite entirely similar to that of the Denison Range on the western border of the central plateau, at a spot just to the north of the Linda Track, and a mile to the eastward of Mount Arrowsmith.

Moreover, this sedimentary series, which consists of conglomerate, pebbly sandstone, crystalline sandstone, and quartzite, is, apparently, precisely that which is referred to as the West Coast Range conglomerate series. That is to say, the Denison Range is composed of rocks which appear to be identical in all respects with those which contribute so largely to the bulk of Mounts Jukes, Huxley, Owen, Lyell, Sedgwick, Murchison, Farrell, and Zeehan. The lithological resemblance between the rocks from all these places is striking; and the differences between the rocks of this character and all other known sediments in Tasmania are equally well marked.

These rocks have hitherto been considered to be much younger, but there has been no satisfactory proof of age. The West Coast Range conglomerate has been placed at the base of the Silurian system for the reason that it is clearly older than the tubicolar sandstone. The probable Cambrian age of the latter formation has already been indicated here, and if this be admitted a still greater antiquity must be assigned to the West Coast Range conglomerate series.

By far the most important information bearing on this matter which has yet been gathered is that which was obtained early in 1908 by Mr. W. H. Twelvetrees, in his westward traverse of the country between the Valley of Rasselas and the Prince of Wales Range.

The bedrock of the Valley of Rasselas is the Ordovician limestone, with a strike of N. 25deg. W. and a north-easterly dip at an angle of 70deg. This limestone rests unconformably upon the siliceous sediments of the Denison Range (1), which strike N. 30deg. W. and dip (at the Thumbs and Mount Wright) towards the north-east at 50deg.

Since the Gordon River limestone horizon is regarded as the base of the Ordovician in Tasmania, it

(1) See Section I.

necessarily follows that the great series of quartzites and conglomerates must be of Cambrian (or even possibly of Pre-Cambrian) age.

Confirmatory evidence again is afforded by the apparent relationship of the West Coast Range conglomerate to the Dundas slate series (2).

Moreover, the porphyritic igneous rocks, which are partly contemporaneous with these Dundas slates, have never been seen in the form of pebbles in the West Coast Range conglomerate. Diligent search has been made by the writer in localities where the two rocks are in the closest proximity, and always without finding any rounded pebbles of the porphyries, or the schists derived from them, in the conglomerate. This seems to him to be highly significant, although negative evidence.

Again, certain structural phenomena are more readily explicable by the view that the porphyries have intruded into the conglomerate beds, rather than that subsequent complex faulting has produced the isolation of blocks of the sediment within the igneous boundaries.

At Railton, the pebbly sandstone and conglomerate appears, from its position, to underlie the Caroline Creek fossiliferous sandstone.

The relation of the Caroline Creek beds to the Dundas slates has not yet been determined, so that a complete chain of evidence regarding the exact age of the conglomerates and the slates has not yet been obtained.

No fossiliferous zone which may serve as a line of demarcation for the base of the Cambrian system has yet been detected.

Our knowledge at the present time is such that it seems advisable to include the Denison Range and West Coast Range conglomerates within the Cambrian system, of which they would therefore seem to form the base.

5. In the vicinity of Beaconsfield a series of sandstones, quartzites, slates, grits, and conglomerates are found to dip under the Ordovician limestone, which lies

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(2) See Section IV.

to the eastward. But the junction of the two systems is rendered complex by faulting (1).

These infra-Ordovician sediments cannot yet be satisfactorily correlated with any of the other developments of Cambrian rocks in Tasmania.

The character and succession of these beds, albeit questions of great interest, cannot here be more fully discussed. We are concerned rather with the relationship of these Cambrian rock groups to the foundations upon which they rest.

In this matter also the most satisfactory evidence has been gathered by Mr. W. H. Twelvetrees near the northern extremity of the Denison Range.

Passing westwards, Mr. Twelvetrees has observed that the siliceous sediments, upon which the Ordovician limestone rests unconformably, themselves rest unconformably upon the foliated rocks which are here referred to the Pre-Cambrian. The actual junction has been observed on the western side of the Denison Range, in the neighbourhood of the North Star (2).

The writer has observed the similar reddish quartzite on the edge of the central plateau near Mount Arrowsmith, resting unconformably on the quartz-mica schists which are described below.

In the valley of the South Loddon River the tubicolar and discoidal sandstone have been observed resting unconformably upon micaceous schists (3).

At Mount Farrell, the eastern wall of the valley of the Sophia River is constituted of the quartz-mica schists mentioned below. These give place, on the western wall of the valley, to the West Coast Range conglomerate and quartzite which form the ridge of Mount Farrell; and these in turn are followed by the

(1) See Section III.
(2) See Section I.
(3) See Section II.

Dundas slates on the western slopes of the mount (1). Unfortunately the junction of the siliceous sediments which form the backbone of Mount Farrell with the quartzite schists on the other side of the valley of the Sophia River, is hidden by the later sediments. But the sequence displayed by this section is significant.

The relationship between the Cambrian sediments of the Beaconsfield district and the schists of the Asbestos Range is shown diagrammatically in a section (2). The relationship is, in part at least, masked by an intrusion of serpentine and aplite between the rocks of the two systems.

The porphyritic igneous rocks, which have now been observed at Mount Farrell (3), Gunn's Plains (4), and North Dundas (5), to be contemporaneous with certain members of the Dundas slate series are only known as intrusives in the quartz-mica schists.

The rounded pebbles of the West Coast Range conglomerate are composed of fragments of the quartzites and quartz-mica schists described below. All of the more durable varieties of these latter rocks are represented in the conglomerate.

We may, therefore, in summing up the evidence collected, state the following facts:—

(a) Whatever may be the inter-relationship of the several groups here referred to the Cambrian system, there is one feature which they possess in common—viz., where an actual contact has been observed, they are found to occupy a higher stratigraphical position than the schists, now for the first time strictly termed Pre-Cambrian.

(b) The Cambrian formations are separated from the subjacent schists by a strong unconformity wherever contacts have been observed.

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(1) See Section IV. Also Geological Survey of Tasmania, Bulletin No. 3.

(2) See Section III.

(3) Geological Survey of Tasmania, Bulletin No. 3, pp. 17 and 34.

(4) Geological Survey of Tasmania, Bulletin No. 5, p. 9.

(5) Geological Survey of Tasmania, Bulletin No. 6, pp. 17 and 38.

(c) The Cambrian sediments are in common much more free from foliation than normal members of the Pre-Cambrian series.

(d) Igneous rocks which were formed contemporaneously with certain of the Pre-Ordovician rocks appear only as intrusive rocks intersecting the Pre-Cambrian schists.

(e) The Pre-Cambrian rocks have been the source whence the material of certain of the Cambrian formations (lying stratigraphically at the base of this system) has been derived.

The writer would therefore submit that the Pre-Cambrian age of certain rocks, described below, has now been satisfactorily established.

## IV.—THE LITHOLOGICAL CHARACTERS OF THE PRE-CAMBRIAN ROCKS.

The bulk of these fundamental schists is, beyond doubt, constituted of metamorphosed sediments of aqueous origin; but there are present also certain component parts of the series to which an igneous origin would be ascribed by the writer. It is proposed to give a brief description of these separately.

### (a) Schists of Aqueous Origin.

The evidence upon which the origin of these rocks is affirmed is not equally conclusive in every case. But when any large area, in which these rocks are developed, is examined, the observer cannot but be convinced of the unity of origin of the several varieties which are to be found inextricably interlaminated.

The greatest weight, in determining the origin of the series, must necessarily be placed upon those varieties which afford the least questionable evidence. And the varieties which, more than others, possess this quality are those in which original characteristics of composition and texture have been least masked by molecular readjustment and mechanical deformation. These are the schistose conglomerates

Many slightly different varieties of these exist, and although the origin of most is readily recognisable at once, that of others becomes apparent only after the progress of weathering.

The usual variety of schistose conglomerate is perhaps best seen in the beach exposures between Ulverstone and Penguin—notably at Goat Island. The pebbles are quartzose, and are often greatly elongated. The finer-grained portion of the rock is precisely similar to many of the micaceous schists which do not contain pebbles.

A more altered, but still more easily recognisable conglomerate occurs at the eastern end of Calder's Pass and on the low country between that pass and the Jane River. In this variety the jasperoid pebbles are excessively flattened, and often sheared, by the crushing forces.

Not far from the locality where this variety was seen, and close to the northern extremity of the Prince of Wales Range, the writer observed a quartzitic schist, which seems to be a crushed quartzose conglomerate. The rock when freshly broken appears to be a quartzitic schist of the usual type described below, but weathered surfaces show smooth elongated protuberances standing in relief above the general surface of the rock. The character of these weathered surfaces is thus entirely similar to that of the schistose conglomerate of Goat Island, near Ulverstone. And the rock would appear to be a true conglomerate, the nature of which is not at first sight obvious, on account of the similarity of composition between the original pebbles and interstitial sand, and the consequent like alteration of coarser and finer ingredients by secondary processes.

In several other places within the observed limits of the Pre-Cambrian the writer has observed rocks which he regards as conglomerates, the original characters of which are masked by an intimate impregnation with silica. They now appear as dense quartzites, showing slight variations of colour and texture in the several portions of the same rock mass. These portions, which thus differ inter se, exhibit semi-rounded to subangular outlines.

With these crushed and altered sediments of coarser grain are associated a great variety of schists and

quartzites, in such a way that the whole group must be considered together as a series of sediments formed by aqueous agencies. The interstratification of the schistose conglomerates and the genetically related argillaceous, micaceous, and quartzitic schists is perhaps most clearly displayed on the northern coast, near Ulverstone. There the beds are tilted, so that they stand on edge, and the succession of the several varieties is seen to be just such as is usually found where sediments have been deposited under varying conditions.

The variety displayed by these schists of finer grain is remarkable. The nature and proportions of the constituent minerals, and the degree of schistosity acquired, all vary from point to point.

Most commonly the schists are constituted of an aggregate of quartz and a sericitic mica. These quartz-mica schists pass on the one hand, by insensible gradations, into pure quartzites, and on the other into mica schists. The intermediate varieties are characteristic of the series as a whole.

The quartzite-schists are at times remarkable for the perfection of the cleavage which they display, the development of the mica being such that thin flakes, no more than a millimetre in thickness, can be successively detached. In some cases this fissile schist exhibits a minute but elaborate puckering, which shows admirably the nature of the stresses to which the rock has been subjected. This latter variety is especially noticeable on the Linda Track, between the Collingwood and Franklin Rivers.

The argillaceous schists are widely distributed through the regions occupied by these Pre-Cambrian rocks, and are especially abundant in the neighbourhood of Cox's Bight. They show clearly, in some cases, the original planes of stratification, and are little different in any particulars from unaltered shales. In other cases these argillaceous varieties have had a slaty cleavage impressed upon them, and are converted into true slates.

They merge into schists, in which mica predominates. These possess a colour which usually varies between pale green and yellowish grey, and possess a greasy feel. The quartz is commonly restricted to lenticles and wavy bands. Other varieties are reddish from

the development of haematite. In other varieties, again, the colour is dark grey, from the presence of some colouring matter the nature of which is obscure. Some of the dark varieties are clearly graphitic, but are not commonly seen.

In the upper part of the Collingwood River valley some garnetiferous varieties have been found by the writer. And near the latter, as elsewhere throughout the neighbouring district, there are present some embryonic minerals in the schist which, from their presence, exhibits knots and complementary depressions on the cleavage surfaces.

The quartzites found among these markedly schistose rocks are frequently perfectly free from all signs of foliation. They are almost always pure white in colour and extremely dense in texture.

The freedom from foliation in these rocks is probably largely due to an original purity of composition. The absence of the foliation, nevertheless, appears remarkable when the quartzitic beds, perfectly free from visible schistosity, are seen interlaminated with the foliated mica schists. The microscopical characters of such quartzites have not yet been studied.

It may be that the quartzitic bands have moved as a whole before the crushing forces. However, it appears to the writer more probable that the foliated appearance of the micaceous schists is largely caused by recrystallisation under pressure rather than by actual displacement of adjacent particles. Over and above this foliation there has been induced also, in very many cases, elaborate crumpling; but a foliated texture may result where crumpling has not occurred. It will be seen later that in some places the quartzites are folded and fractured.

Summing up, the several schists of which mention has been made must undoubtedly represent a great series of sediments—psephites, psammites, and pelites —which have suffered dynamical metamorphism.

This lithological division of the Pre-Cambrian comprises by far the larger portion of the rocks to which reference is made in this paper.

### (b) Schists of Igneous Origin.

Associated with these quartzites, quartz-mica schists, argillaceous, and micaceous schists are certain amphibolites, to which the writer would ascribe an igneous origin.

The largest development of these amphibolites is that which has been observed in the Rocky River district by Mr. W. H. Twelvetrees.

Less extensive occurrences have been recorded from Hamilton-on-Forth and the Collingwood River Valley. In both of these latter cases there is a notable development of garnet and zoisite.

The detailed description of these interesting rock types is postponed, pending a more minute microscopical examination.

The only other rocks of igneous origin which may possibly belong to the Pre-Cambrian are certain pegmatites, which have been found in the Collingwood River Valley and in the neighbourhood of Calder's Pass. There is, however, a very strong probability that these have been introduced into the schist series in Devonian time.

## V.—THE STRUCTURAL FEATURES OF THE PRE-CAMBRIAN.

Few constant features of structure have been recorded from the several exposures of these rocks which have been examined. The distribution is so wide that, in the absence of complete and systematic surveying, this is not a matter for surprise. And although much is to be gained by the careful examination of the structural characters of the group as a whole, little achievement has so far been possible in these matters.

The recognition of any definite horizons in the system is naturally a matter of importance for purposes of stratigraphical delimitation.

In the case of the highly schistose and crumpled members of the system, it is almost impossible to arrive at any satisfactory conclusion regarding the total thickness of the beds or their original order of stratification.

With regard to the development of these rocks on the South Coast of Tasmania, Mr. W. H. Twelvetrees has estimated the thickness at 13,000 feet as a minimum (1). This calculation is based on the assumption that no large anticlinal folds exist, and that the average dip is not less than 10 degrees.

During the recent western exploration work in the neighbourhood of the Frenchman's Cap, the writer was enabled to make some observations which should here be recorded.

The outstanding feature of the Pre-Cambrian in that region is the existence of a considerable thickness of bedded quartzite schist lying in an approximately horizontal position upon the top of the quartz schist, quartz-mica schists, and micaceous or argillaceous schists.

Viewing this thick layer of quartzite schist from the tops of the ranges, one gains the conviction that it is a single horizon, resulting from the alteration of a once continuous horizon of sandstone. This horizon apparently extended from the Raglan Range southwards to the Frenchman's Cap and the Surveyor's Range, and eastwards to a mountain (called by the writer Algonkian Mountain) at the northern extremity of the Prince of Wales Range, and slightly to the westward of the axis of that range. Whether the white serrate peaks of the Prince of Wales Range are on this horizon the writer cannot say.

Only the highest portions of the ranges mentioned are composed of this quartzite schist, which in most cases stands up boldly with precipitous walls above the slopes carved in the softer schists.

From a short distance the quartzite schist appears to be a bedded sandstone, since the progress of weathering accentuates the original bedding planes. But on closer examination a slight schistosity is noticeable throughout the rock.

This horizon, as a whole, is not free from foliation, and the best view of the folding is obtained from the

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(1) Proceedings A.A.A.S., Adelaide, 1907, "Probable Pre-Cambrian Strata in Tasmania," p. 470.

highest peak of the Surveyor's Range. Looking thence towards the north, the eastern portion of the summit of the Frenchman's Cap is seen to be folded into gentle anticlines and synclines, and to have been fractured. The other portions of the horizon appear to have remained unaffected, and to be nearly horizontal. The massive layers so plainly visible on the north-western and western faces of Algonkian Mountain appear quite undisturbed by folding forces, and dip at a low angle towards the south-west.

Between these remaining summits of the ranges the quartzite schist stratum has been removed by denudations, and the subjacent schists are exposed.

The horizon of quartzite schist rests unconformably upon the quartz-schist and mica-schists, which show a much more intense folation. This unconformity is clearly seen on travelling along the top of the Surveyor's Range. The higher peaks of this range (which lies between the Jane and Acheron Rivers) are of the more massive variety, and the abrupt change into the highly contorted schists of the main mass of the range is most noticeable.

The existence of plainly horizontal layers of the rock overlying the contorted schists is a strong argument for not only the presence of a marked unconformity, but also for a long period of erosion between the time of foliation of the lower schists and that of the deposition of the upper quartzose sediments, which have since been rendered slightly schistose.

Confirmatory evidence must be obtained throughout this region before these views can be fully accepted; but the writer is strongly of the opinion that there is a distinct unconformity present in the district, and that two distinct periods of sedimentation are represented, and that a protracted period of erosion has intervened between the deposition of the lower and upper members. The greater degree of contortion displayed by the lower series may be accounted for by the fact that these rocks have suffered plication before the upper horizon was formed.

If it be granted that there are two such distinct series among the Pre-Cambrian sediments in Tasmania,

an interesting comparison may be drawn between the Tasmanian occurrences and those of Canada. This matter is discussed in a later portion of this paper.

In estimating the thickness of the sediments represented in the region surrounding the Frenchman's Cap, it is evident that the structural features, referred to here, must be duly considered. Enough detailed information has not yet been acquired to give even an approximate idea of the true thickness of the upper and lower series of which mention has been made.

The writer claims that there is a marked unconformity, above which several hundred feet of sediments exist, and below which a very much greater thickness is represented by the more schistose members of the Pre-Cambrian. About 2,000 feet of the latter schists are visible in the immediate neighbourhood of the Frenchman's Cap, if we calculate only the vertical distance between the lower limit of the upper quartzite on the top of the range and the bottom of the river gorges carved in the foliated schists. But it is more than probable that the vertical thickness of the schistose strata in this region differs from that of the original beds. No account has been taken of the effects of compression and foliation, nor can these be quantitatively estimated in the present state of our knowledge.

The recognition of two distinct horizons in the Pre-Cambrian necessitates a very careful treatment of the structural features of strike and dip, unless it is perfectly plain which horizon is under examination.

In the region traversed by the Franklin River and its tributaries the upper horizon is, on the whole, as indicated above, nearly horizontal, but the variations in dip and strike of the lower members are very marked.

A general absence of regularity of structure is noticeable in every district, and the axes of the main foldings do not appear to have extended for long distances.

Nor have the folds exerted any appreciable effect upon the topography. No traces of ancient fold ranges have remained in those areas where these rocks have been examined by the writer. And the outlines of the present mountain ranges are noticeably independent of the rock structure.

Where the Pre-Cambrian rocks are penetrated by igneous intrusions, the latter do not, in general, appear to acquire forms which are moulded by the structure of the schists. The only exception which may be cited is that of the small dykes or veins of pegmatite in the valley of the Collingwood River.

## VI.—THE GENESIS, HISTORY, AND PRESENT PHYSIOGRAPHICAL FEATURES OF THE PRE-CAMBRIAN IN TASMANIA.

Having come to the conclusion that the great bulk of these Pre-Cambrian rocks represent aqueous sediments, more or less altered subsequently to their deposition, but accumulated under conditions similar to those existing on continental borders at the present time, we naturally look for the sources of the fragmental material which built up these ancient beds of conglomerate, sandstone, and shale.

The composition of these beds gives some idea of the nature of the rocks whence the fragments were derived. For the vast accumulation of clay and silica must have resulted from the disintegration of quartz and aluminous silicates. By the action of the many processes involved in the weathering of such rocks, the transport of the fragmental matter to the sea, the sorting distribution and final deposition of this material on the sea floor, these Pre-Cambrian sedimentary beds were built up.

But there have not yet been seen in situ in Tasmania any rocks of greater age than these sediments. Detached boulders (1) have been found which present analogies, in both composition and structure, with the lower Pre-Cambrian rocks of other parts of the world; but these boulders have not yet been traced to their source.

The quartz and aluminous silicates must have been derived from some still older primary rocks, probably now hidden beneath the sea.

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(1) One of these boulders, of a coarse gneiss, was found by Mr. G. A. Waller at the 29-mile peg on Innes' Track to Barn Bluff. Garnetiferous gneiss boulders also occur in the permo-carboniferous glacial beds which outcrop on the North Coast at Wynyard.

No definite clue being provided in Tasmania, we look to the Australian continent for signs of the existence of Archaean rocks, which may be remnants of the Pre-Cambrian land mass that was the source of these sediments.

Brief mention is made below of the Australian occurrences of Pre-Cambrian rocks. Of these the rocks which bear most directly upon the question now being discussed are the gneisses, gneissose granites, and hornblendic schists of Western Australia; and the gneisses of South Australia. These bear the strongest lithological resemblance to the Archaean rocks of other countries.

The Pre-Cambrian schists of Tasmania may well have derived their material from these ancient crystalline gneisses, schists, and granites, and possibly from the more proximate southward extensions of the masses referred to above now covered by the Southern Ocean.

This question of genesis demands a much greater elaboration than can here be effected. It is sufficient to state that these quartzites, argillaceous, and micaceous schists and schistose conglomerates constitute the terrigenous deposits formed on the borders of the Pre-Cambrian Australis—a land mass known from its exposed remnants to be competent to provide such material.

After the prolonged period of sedimentation which is represented by the lower schists and conglomerates, a period marked by intense dynamic metamorphism must have ensued. The subsequent erosion of these older schists levelled the floor upon which the upper sediments were deposited.

The schistosity observed in these upper members of the Pre-Cambrian may have been induced before the period of deposition of the Cambrian sediments. For there is a notable difference in appearance between the appearance of the upper Pre-Cambrian quartzitic schist and that of any sedimentary rock of later date.

A notable unconformity exists between the Cambrian and the Pre-Cambrian sediments at the northern end of the Denison Range. There is, however, not yet sufficient evidence available upon which to base an account of the physiography of Western Tasmania at the time of the Cambrian sedimentation.

Orogenic movements, which have tilted the Cambrian rocks till they stand vertically in some places, must have affected the subjacent Pre-Cambrian rocks as well.

After the close of the Cambrian period no schistosity of any moment appears to have been developed in any of the Tasmanian rocks.

The Ordovician sediments indicate a deep submergence of Western Tasmania beneath the ocean, and traces of the marine limestones still occupy the beds of some of the western rivers. These are not deposited conformably upon the sediments of Cambrian age, and their position in deep troughs carved in the schists argues for a mature erosion of the areas covered by the Pre-Cambrian rocks before submergence in Ordovician time.

Since the exposed peaks and ridges of Pre-Cambrian rocks appear to attain altitudes which are approximately the same, the idea suggests itself that a peneplain may have been developed in late Pre-Cambrian or Cambrian time. This peneplain may have been deeply dissected before the Ordovician period. However, this matter demands much more detailed investigation over the whole of the Pre-Cambrian terrain.

The area lying between the Raglan Range and the Prince of Wales Range, examined by the writer, appears to have regained many of the fundamental outlines which it possessed at the beginning of the Ordovician period. These outlines were masked by the deposition of Ordovician and Silurian sediments, and then, after an interval, of those of Permo-Carboniferous and Mesozoic age.

The only igneous invasion which was sufficiently widespread to deserve mention here is that of the upper Mesozoic diabase. This diabase still remains in the form of outliers capping the mountains built of Cambrian and Pre-Cambrian rocks. Its distribution argues a much wider extent than is now apparent, and its existence postulates a cover of sedimentary rocks, since removed by subaerial denudation.

Since the close of the Mesozoic era progressive degradation of the whole of Western Tasmania has continued almost without interruption; and in the final stages of this long cycle of erosion the physiography of

early Palaeozoic time has exerted a powerful influence in the moulding of the land forms of to-day.

The overlying sediments have been worn down, and great gorges have been carved through the diabase down on to the Pre-Cambrian bedrock.

On the flanks of these valleys there remain in some places the remnants of former sedimentary basins. For instance, on the north-western face of Mount Arrowsmith lies the fragment of a Silurian sandstone formation dipping to the westward at a low angle. The same formation has been to a greater degree preserved in the area lying to the northward of the Raglan Range. And even here the Nelson River is now steadily removing the softer sandstone, while the relatively harder quartz schist of the Raglan Range is forcing the river channel ever to the northward.

Still more significant of the surviving control exerted by the lower Palaeozoic physiography over present land forms is the distribution of the limestone in the valleys of the western rivers—especially of the Gordon River and its tributaries. Recent exploratory work has proved a remarkable restriction of limestone (all the exposures of which appear to be of Ordovician age) to the bottom of some of these valleys. In some cases the limestone is only visible actually in the beds of the rivers which traverse these valleys. These latter remarks apply to the Jane and Denison River valleys.

In the case of the Surprise River, which occupies the gorge between Mount King William 1st and the Loddon Range, the limestone has been cut through by the corrosive action of the river, and is now situated a few feet above river level.

The manner in which these ancient sediments conform to the present physiographical outlines is at least suggestive of the theory here advanced.

But it must be remembered that an explanation of the phenomena exhibited by such a restricted area cannot be applied beyond the limits of this area. The Ordovician limestone of Western Tasmania is not always found in the depths of the valleys, and occurrences which might seem to contradict the hypothesis here put forward are probably to be easily explained in different ways. The corrosive action of the different rivers may have outstripped erosion and left the lime-

stone on the higher country; or, again, local displacements of the crusts may give rise to modes of occurrence which may seem at variance with this theory. Yet, in the case of the occurrences of limestone in the valleys of the Jane and Denison Rivers, at least, we seem to be forced to the conclusion here stated. It will be interesting to ascertain the limits over which the theory may appear applicable as the geological survey of the island proceeds.

While we may, in the opinion of the writer, safely accept the theory for the restricted area, it must be borne in mind that changes are continually being effected. The cycle of erosion now operative has certainly modified the former features, but the main scheme of existing topography seems to correspond closely with that which obtained at the close of the Cambrian period.

The physiography of the central western area has been determined by erosion rather than by structure, by epigene rather than by hypogene agencies.

This account of the physiographical history of the Pre-Cambrian has been written mainly from the evidence afforded by the central western area, since the writer is most familiar with that area. Modifications may be necessary with an increase of information, but it is contended that this historical outline is substantially correct.

## VII.—THE DISTRIBUTION OF THE PRE-CAMBRIAN IN TASMANIA.

A map of Tasmania showing the several areas occupied by Pre-Cambrian rocks has been prepared to accompany this paper. On this map the several areas are numbered, and reference is here made to the different districts in the order in which they have been numbered on the map.

I. The Asbestos Range area, lying to the west of Beaconsfield, and extending southwards from the coast-line at Badger Head, comprises a series of micaceous schists, slates, and grits, with a strike of N. 10deg. W. to N. 20deg. W. (1). These rocks are bounded on the east by serpentine and other igneous rocks in the vicinity of Beaconsfield (2). On the coast-line recent sands and drift overlap the Pre-Cambrian on both sides of the range (3).

The southward extension of this belt of schistose has not yet been fully mapped.

II. At Hamilton-on-Forth there is an exposure of the Pre- Cambrian bedrock in the gorge of the Forth River. The rocks represented are quartzites, quartz-mica, micaceous and graphitic schists, and with these a belt of garnetiferous-zoisite-amphibolite.

The strike of the schistose sediments varies from N. 10deg. W. to N. 30deg. W., and they dip to the south-west.

This exposure is covered, save in the river gorge, by Tertiary basalt; and on being followed southwards is found to disappear below the Cambrian formations (4).

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(1) See W. H. Twelvetrees' "Report on Coal near George Town, and Slate near Badger Head," 1904.

(2) See W. H. Twelvetrees' "Report on the Mineral Resources of the districts of Beaconsfield and Salisbury," 1903.

(3) See T. Stephens' "Notes on the Geology of the North-West Coast of Tasmania from the River Tamar to Circular Head," Proc. Linnaean Soc. of New South Wales, 1908.

(4) See W. H. Twelvetrees' "Report on the North-West Coast Mineral Deposits," 1905.

III. On the northern coast-line, at Ulverstone, a complex series of the schistose sediments and quartzites described above is to be seen (1). These rocks extend eastwards as far as Button's Rivulet, and westwards to the middle of Barkworth's Bay, west of Goat Island.

On both sides the schists are bounded by Tertiary basalt.

At the mouth of the Leven River the strike is, on the average, about N. 10deg. E., while to the west of Goat Island it ranges from N. 12deg. E. to N. 30deg. E. The dip is to the north-west.

IV. Between Jacob's Boat Harbour and the Detention River, on the northern coast, there are found quartzites and quartz-schists (2). Rocky Cape is built up of massive bedded quartzites, which extend a mile and a half southwards beyond the main road.

At Rocky Cape port the bedded quartzites strike N. of E., and the contorted quartz-schists which succeed them on the west strike N. 80deg. E. At Jacob's Boat Harbour the strike is N.W., and the dip towards the N.E.

The southern extension of these rocks is covered by Tertiary basalt.

V. A narrow belt of Pre-Cambrian rocks has been observed at the junction of the Whyte and Rocky Rivers, crossing the Waratah-Corinna road (3). This road, between points distant from Waratah 19 miles and 31½ miles, traverses the belt referred to diagonally. However, the observed width of these rocks is only about four miles.

The Rocky River schists are amphibolites, sometimes compact and granular, sometimes distinctly schistose, flanked on either side by schistose sediments.

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(1) Geological Survey of Tasmania, Bulletin No. 5, 1909.

(2) See W. H. Twelvetrees' "Report on the North-West Coast Mineral Deposits," 1905.

(3) See W. H. Twelvetrees' "Report on the Mineral Fields between Waratah and Corinna," 1900.

The Long Plain, on the east of the amphibolite, contains quartzitic, sericitic, and graphitic schists. To the westward the country contains slate and quartz schist, but no detailed geological examination has yet been made.

This zone of schists is known to extend in a north-westerly direction for 10 miles, where it crosses the Savage River.

The strike of these rocks is N. 10deg. W., and the dip to the N.E..

VI. The most northerly of the larger areas covered by the Pre-Cambrian rocks is that which extends from the Mackintosh River on the west to the Forth River on the east, and almost to the Dove River on the north (1).

The western portion of this area is penetrated by the granite of Granite Tor (2) and there is a larger area of Permo-carboniferous sandstone, capped by diabase, overlying it at Barn Bluff. On the south similar rocks to these last-mentioned go to build up the Eldon Range, which separates this area from that which is numbered VIII.

The rocks are chiefly foliated quartz-schists, with micaceous and argillaceous schists as well, the strike of which is a few degrees N. of W. at Barn Bluff.

VII. What is probably a small outlier of the latter area is situated between the head of the King River and the North Eldon River, to the east and south-east of Lake Dora.

VIII. The largest unbroken development is that which extends southwards from the vicinity of the Eldon Range throughout the greater part of the basin of the Franklin River (3). On the north-west it is bounded by the superincumbent Silurian sediments

(1) See G. A. Waller, "Report on the Mineral Districts of Bell Mount, Dove River, Five-mile Rise, Mount Pelion, and Barn Bluff," 1901.

(2) Geological Survey of Tasmania, Bulletin No. 3.

(3) See "Report of the Department of Lands and Surveys for 1907-1908."

which lie to the north of the Raglan Range. On the north-east it extends to the edge of the Central Plateau, where the upper Mesozoic diabase covers it.

The Raglan Range, the Frenchman's Cap, and Deception Range form the observed western borders of this area. On the eastward the lower slopes of Mount Gell, Mount Arrowsmith, and the western slopes of the Loddon Range form the limits of these schists. A considerable area of Cambrian rocks has been seen to overlie the Pre-Cambrian to the east of the Frenchman's Cap. And Ordovician limestone has been located in the beds of the Denison and Jane Rivers. (It has been found impossible to represent the Jane River limestone on the map, for the reasons that the outcrop is absolutely restricted to the river bed, and the scale of the map will not admit of the representation of such a narrow band.)

The eastern boundary of the Pre-Cambrian lies to the west of the Denison Range, and crosses the Gordon River near the junction of the latter with the Wedge River. Thence it has been observed to run southwards a little to the east of Lake Pedder. Beyond this point it has not been followed, but it is thought to continue to the south coast near the New River.

This southern extension of the Pre-Cambrian embraces the Frankland Range, and probably the country between that range and Port Davey.

All varieties of quartzites, quartzite-schists, micaceous, argillaceous, and graphitic schists are found within the limits of this area. The probable existence of an upper horizon of quartzite-schist has been indicated above.

To the west of the Denison Range the strike is usually north-easterly. South of the Gordon River the strike varies between N. 5deg. and N. 30deg. W.

IX. The most southerly development is that which extends from a point to the westward of New River along the south-western coast beyond Port Davey. This area is pierced by a small intrusion of granite at Cox's Bight (1).

(1) See W. H. Twelvetrees' "Report on Cox's Bight Tin Field," 1906.

The northern and north-western limits have not yet been determined. The area is probably continuous with that which has last been described (VIII.).

There are quartzites interbedded with argillaceous schists at Cox's Bight. These have a strike between N.N.W. and N.W., and dip to the south-west at low angles.

Of Port Davey there is but little known, save that the white quartzites of the port extend northwards along the coast for some distance.

## VIII.—NOMENCLATURE AND CORRELATION.

It is impossible to discuss the nomenclature of these rocks without at the same time briefly discussing the relationship which they bear to rocks of like age in extra-Australian areas.

In assigning an age to the strata which have been deposited since the beginning of the Cambrian era, the evidence of the fossils preserved in the rocks is the most important. But with regard to the Pre-Cambrian no such criteria are available.

It is true that there are well-authenticated cases of the existence of organic remains in beds which are stratigraphically lower than those containing the typical lower Cambrian fauna; and it is also true that the diversity of the Cambrian fauna presupposes a Pre-Cambrian fauna. But all organic remains are ill-preserved in the Pre-Cambrian rocks, while in Tasmania no such remains have yet been detected.

On stratigraphical evidence we have come to the conclusion that the Tasmanian rocks here discussed are truly Pre-Cambrian. But the word "Pre-Cambrian" cannot but be regarded as merely a temporary epithet, to be replaced by one which will define the age more exactly when our knowledge of these rocks has become sufficiently advanced to ustify a refinement in classification.

For the word "Pre-Cambrian," used in its literal sense to designate those rocks which are of greater antiquity than the Cambrian, embraces several rock-

groupings now fully recognised in the regions in which they are represented. It has been estimated that these groupings of the Pre-Cambrian are comparable in importance to the systems (Cambrian, Ordovician, Silurian, etc.) into which the Palaeozoic has been divided.

Hence Messrs. T. C. Chamberlin and R. D. Salisbury have in their Geology (1) divided the Pre-Cambrian rocks into two main groups of systems—the Proterozoic and the Archaeozoic—which rank more nearly with the main subdivisions of the upper portion of the Geological Record, viz., Palaeozoic, Mesozoic, and Cainozoic.

By these authors the Proterozoic and Archaeozoic are again divided in the manner indicated in the table of classification which has been prepared to show the various systems of nomenclature.

The Pre-Cambrian succession in North America has been specially studied by a committee appointed by the Geological Surveys of the United States and Canada, and the classification adopted by the members of this committee (2) is given in the accompanying comparative table.

It will be seen that the succession stated by this committee, to be applicable to the North American areas, differs from that of Messrs. Chamberlin and Salisbury. The chief difference lies in the transposition of the two lowest groups. Messrs. Chamberlin and Salisbury agree with other American geologists in placing the Laurentian above the great schist series (which includes the Keewatin), for the reason that in many cases the granites and gneisses of the Laurentian occur as intrusions into the schist series. However, this question has no direct bearing on the Tasmanian developments, and will not be further discussed.

On the whole, therefore, it will be conceded that a definite succession of groups has been established for the North American region.

There are, however, differences of opinion as to how these Pre-Cambrian series may best be included in major groupings.

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(1) Loc. cit., Vol. II., p. 139.

(2) Ibidem, Vol. II., p. 161. Also Journal of Geology, Vol. XIII., No. 2, 1905, pp. 89-104.

There are, according to C. R. Van Hise, two main divisions of the Pre-Cambrian which are to be recognised in all parts of the world where rocks of this age are found (1). This twofold division is based upon the essential differences in the lithological character of the upper and lower members of the Pre-Cambrian.

The term Archaean is now restricted to that portion, of dominantly igneous origin, which constitutes the basal complex. It corresponds to the " Archaeozoic " of Messrs. Chamberlin and Salisbury.

On the other hand, the term " Algonkian " is applied to those rocks the origin of which is, in the main, aqueous (2). Igneous rocks are associated with these, but are subordinate in amount. The term Algonkian corresponds to the " Proterozoic " of Messrs. Chamberlin and Salisbury.

This subdivision of the Pre-Cambrian into these two groups has not, however, met with universal acceptance.

In the light of the more recent researches in the North American region, doubt has arisen in the minds of the Canadian geologists as to the value of lithological character alone as the basis of correlation.

Professor F. D. Adams, in a recent paper (3), suggests the use of epochs of diastrophism in the comparative study of the Pre-Cambrian rocks of North America and Asia, with a view to correlation.

In this paper Professor Adams shows that there are " three major periods in the Pre-Cambrian history of Laurentia, separated by two critical periods of diastrophism " (4). Of these breaks, the lower coincides with that which separates the Algonkian from the Archaean; while the upper break divides the Middle Huronian from the Upper Huronian (Animikean).

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(1) United States Geological Survey, Bulletin No. 86. Also Journal of Geology, Vol. XVII., No. 2, 1909, pp. 97-104, 118-122.

(2) It is interesting to note that the late M. A. de Lapparent brought this upper division into his Palaeozoic group, calling it the Pre-Cambrian system. Below the Palaeozoic group he places the Archaean group. Traité de Géologie, 1906, Vol. II., pp. 723, 752-765.

(3) Journal of Geology, Vol. XVII., No. 2, 1909, pp. 105-118, 122-123.

(4) Loc. cit., p. 115.

The same author has drawn attention to the existence of similar epochs of diastrophism in Asia, and correlates the Asiatic succession with that of North America by a time relation to these diastrophic epochs.

With the question of the North American-Asiatic correlation we are not here concerned; but we are bound to consider most carefully Professor Adams' contention that the Pre-Cambrian group should be divided into three systems rather than two. For Professor Adams insists that the upper break—called by Professor Lawson the "eparchaean interval"—is "one of the greatest unconformities in the whole of the Pre-Cambrian succession of Laurentia, and probably quite as important, if not more so, than the break at the close of the Keewatin" (1).

As regards the Tasmanian Pre-Cambrian terrain, any attempt to apply in detail the conclusions arrived at by American geologists is not yet warranted.

While close correlation cannot be attempted, some account should be given of the more general relationships of the Tasmanian occurrences.

We know that the Pre-Cambrian rocks of Tasmania are typically such as would be designated Algonkian by Van Hise. Moreover, the writer holds the opinion that there is, at least in the district surrounding the head of the Jane River, a twofold division of these rocks, and that the two groups are separated by an unconformity. But much detailed field work must yet be done before any sound deductions can be drawn from the existence of this unconformity. Exact correlation with the rocks of distant geological provinces is quite impossible.

Moreover, it must be borne in mind that one unconformity only has yet been observed in the Tasmanian Pre-Cambrian development. In the North American succession three unconformities above the Lower Huronian series (2) are recognised by the members of the classification committee, although there is a want of agreement in the matter of the importance that should be attached to the different unconformities. On this question the special committee expressed no opinion.

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(1) Loc. cit., p. 122.
(2) See comparative table at the end of this paper.

Supposing for the moment that the Tasmanian unconformity should correspond exactly to one of those recognised in the North American region, we do not know which of these it might be, nor whether it is a major or minor one.

Nevertheless, in the future attempts to unravel the Pre-Cambrian history of Tasmania, the observations of North American geologists must be kept constantly in view.

It may be possible to effect some compromise between the schemes of nomenclature proposed by Van Hise and Adams, which are shown side by side in the accompanying table. The use of terms with a "zoic" termination appears to the writer to involve the assumption of a greater knowledge of Pre-Cambrian life than that which we really possess. And, on the other hand, the term Algonkian is rapidly gaining acceptance in countries outside of America. Perhaps the modifications, Analgonkian and Katalgonkian may serve to distinguish the two major groupings of those Pre-Cambrian rocks which post-date the Archaean.

It has been found impossible to correlate the Pre-Cambrian rocks of Tasmania with those of Australia from a lack of familiarity with the extra-Tasmanian developments.

In the latest volume of the Official Year Book of the Commonwealth of Australia (1), condensed summaries are given of the geology of the various States. From a perusal of these it will be seen that rocks of Algonkian type are developed in Victoria, South Australia, Western Australia, and in the Broken Hill area of New South Wales.

(1) Op. cit., No. 2, 1909, pp. 78-111.

# APPENDIX.

## NOTES IN EXPLANATION OF THE PLATES.

I. Map of the distribution of the Pre-Cambrian rocks in Tasmania.

The boundaries of the Pre-Cambrian areas are drawn where they have been determined.

Where no boundary line is drawn round the hatched areas it is implied that further investigations may reveal a more extended distribution of these rocks in those directions not limited by observed boundaries.

II. The generalised sections are not drawn to scale. They are intended to represent only the relationships between the several formations represented.

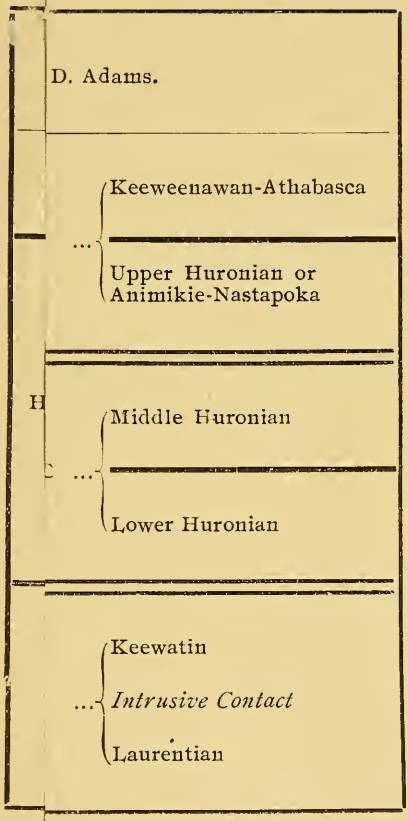
While they are to be regarded as diagrams only, the dips of the various beds are represented as accurately as is possible by the inclination of the lines which serve to indicate, in a general way, the bedding planes.

Section I. represents a length of about five miles.

Section II. represents a length of about one mile.

Section III. represents a length of about five miles.

Section IV. represents a length of about four miles.

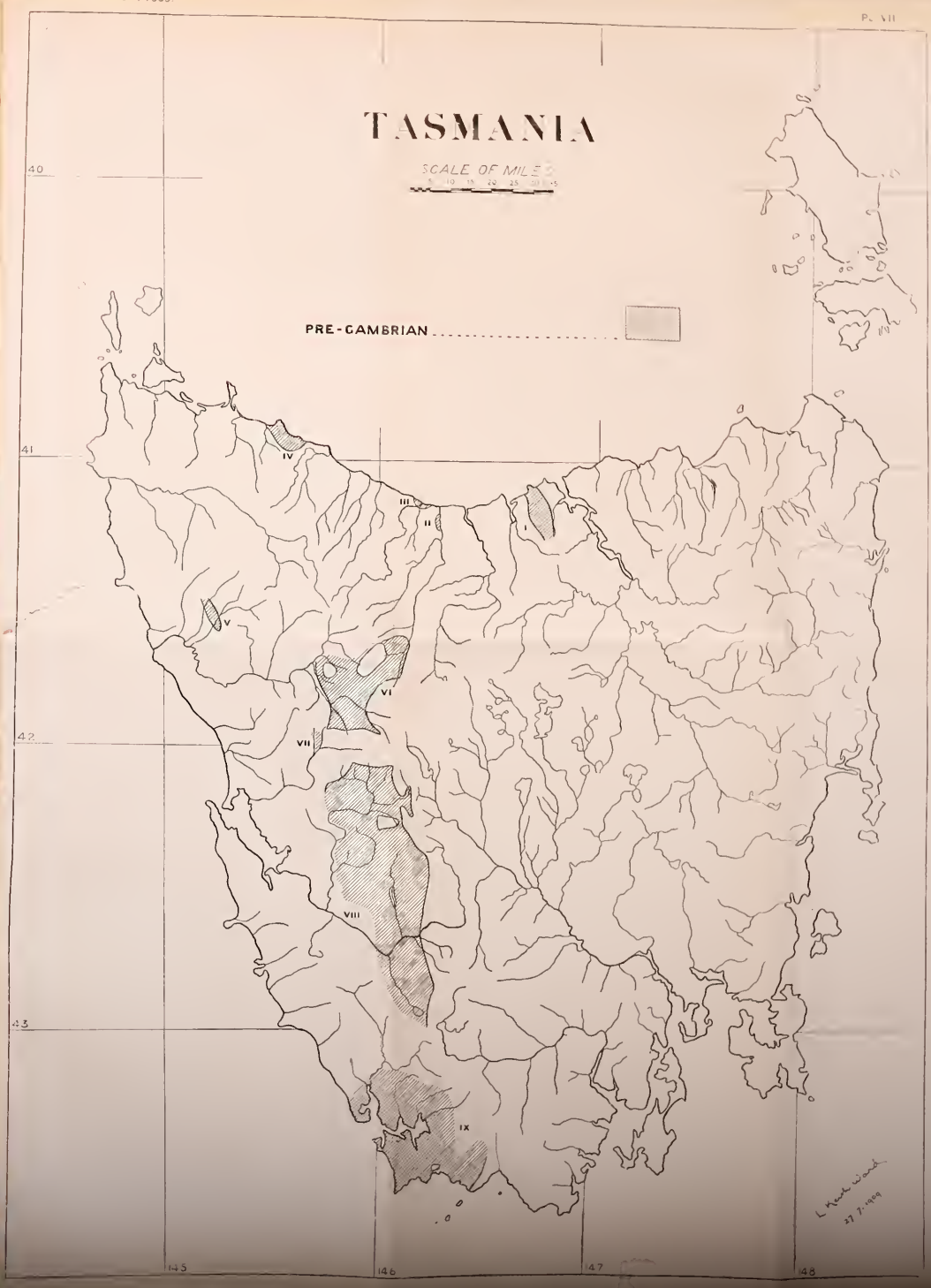

D. Adams.
Keeweenawan-Athabasca
Upper Huronian or
Animikie-Nastapoka
Middle Huronian
Lower Huronian
Keewatin
Intrusive Contact
Laurentian

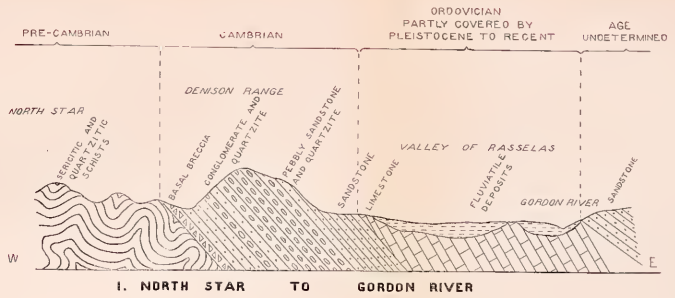
formities.

# THE PRE-CAMBRIAN SUCCESSION IN NORTH AMERICA.

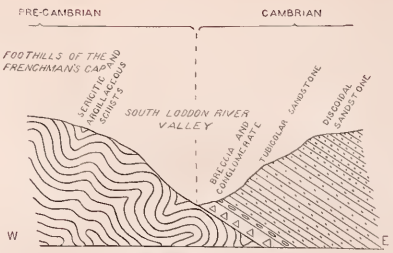
| Classification Committee of the Geological Surveys of the U.S.A. and Canada. | T. C. Chamberlin and R. D. Salisbury. | C. R. Van Hise. | F. D. Adams. |
|---|---|---|---|
| Keeweenawan (Nipigon) | PROTEROZOIC — Keeweenawan | ALGONKIAN — Keeweenawan | NEO-PROTEROZOIC — Keeweenawan-Athabasca |
| Huronian — Upper (Animikie) | PROTEROZOIC — Animikean | ALGONKIAN — Upper Huronian | NEO-PROTEROZOIC — Upper Huronian or Animikie-Nastapoka |
| Huronian — Middle | PROTEROZOIC — Huronian | ALGONKIAN — Middle Huronian | MESO-PROTEROZOIC — Middle Huronian |
| Huronian — Lower | | ALGONKIAN — Lower Huronian | MESO-PROTEROZOIC — Lower Huronian |
| Keewatin | ARCHÆOZOIC (Archæan Complex) — Great Granitoid Series | ARCHÆAN — Keewatin | EO-PROTEROZOIC — Keewatin |
| *Eruptive Contact* | | ARCHÆAN — *Eruptive Contact* | EO-PROTEROZOIC — *Intrusive Contact* |
| Laurentian | ARCHÆOZOIC (Archæan Complex) — Great Schist Series | ARCHÆAN — Laurentian | EO-PROTEROZOIC — Laurentian |

NOTE.—The horizontal lines indicate the position of unconformities; Double lines are used to designate the major unconformities.

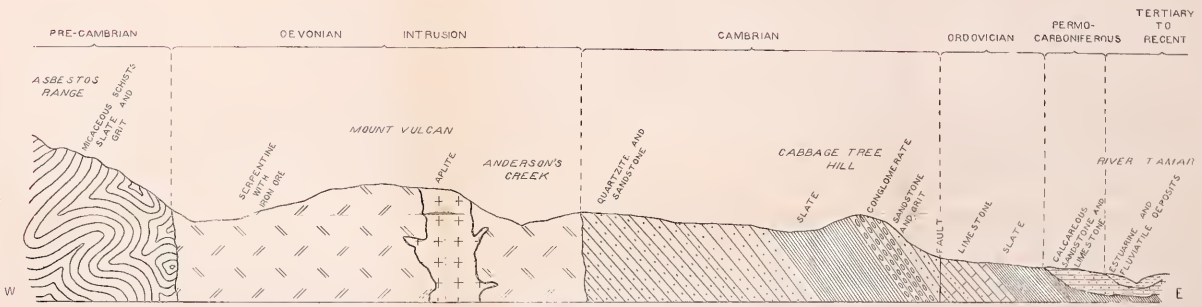

TASMANIA
SCALE OF MILES
PRE-CAMBRIAN
I
II
III
IV
V
VI
VII
VIII
IX
40
41
42
43
145
146
147
148



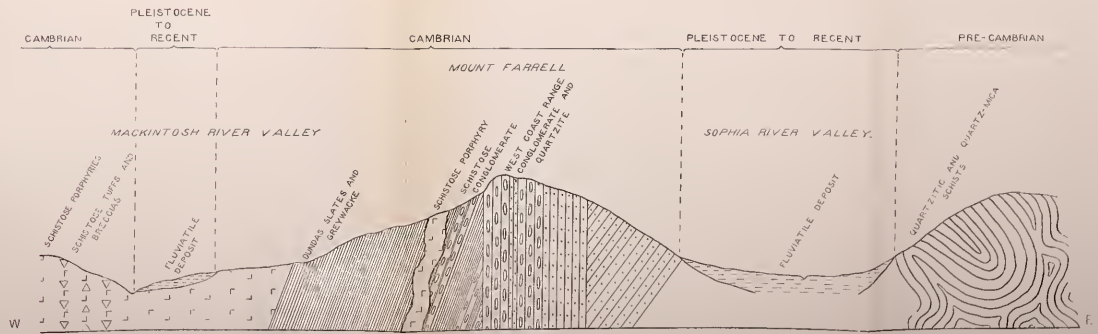

I. NORTH STAR TO GORDON RIVER




II. CALDER'S PASS




III. ASBESTOS RANGE TO RIVER TAMAR




IV. Mt FARRELL

## GENERALIZED SECTIONS

L. Keith Ward
21.7.1909