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UNIVERSITY OF MINNESOTA.

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A REPORT

ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA;  
MADE IN PURSUANCE OF AN ACT OF THE LEGISLATURE  
OF THE STATE, APPROVED MARCH 1,  
1872.

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PUBLISHED BY AUTHORITY OF THE STATE.



VOLUME V.

## LETTER OF N. H. WINCHELL, STATE GEOLOGIST.

UNIVERSITY OF MINNESOTA,  
MINNEAPOLIS, September 1, 1899.

*Hon. John S. Pillsbury, President of the Board of Regents:*

MY DEAR SIR: The last volume of the final report of the Geological and Natural History Survey of the state, which is herewith tendered for publication, contains the results of long-continued investigation of the mineralogy and petrology of the state. A large portion of this volume was already prepared when volume iv was presented,—indeed, the conclusions given in that volume were based on the investigations which are given in more detail in this. It is hoped that this volume will add something to the science of the crystalline rocks.

Respectfully submitted,

N. H. WINCHELL,  
State Geologist.

## LETTER OF HON. JOHN S. PILLSBURY.

MINNEAPOLIS, MINN., September 4, 1899.

*Professor N. H. Winchell, State Geologist, City:*

DEAR SIR: I take pleasure in acknowledging receipt of your favor tendering for publication volume v of the final report of the Geological and Natural History Survey. It will go to the printer at once, as a contract for the same has already been executed.

Very respectfully,

J. S. PILLSBURY,  
President of the Board of Regents.

THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

N. H. WINCHELL, STATE GEOLOGIST.

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1898—1900.

THE

# GEOLOGY OF MINNESOTA.

VOL. V OF THE FINAL REPORT.

STRUCTURAL AND PETROGRAPHIC GEOLOGY OF THE  
TACONIC AND ARCHEAN.

By N. H. WINCHELL,

ASSISTED BY U. S. GRANT.

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SUBMITTED SEPTEMBER 1, 1899, AND PUBLISHED UNDER THE DIRECTION OF THE  
BOARD OF REGENTS OF THE UNIVERSITY.

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ILLUSTRATED BY SIX PLATES AND FIFTY-FIVE FIGURES.

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## PREFACE.

It would have been probably a more logical order of publication to have issued the contents of this volume before the final conclusions and mapping contained in volume iv. Still in the main this volume was so far along that it was warrantable to make brief summaries of the main structural and petrological conclusions in the preface of volume iv, with reference to the discussions contained in this. In the course of the final revision of the manuscript of this volume but one point of importance has been discovered in which it is necessary to depart from the views presented in volume iv. That relates to the origin of the Mesabi iron-bearing rocks, which will be found fully presented in Part III.

In the final systematic discussion (Part III) of the facts embraced in Part II (petrographic descriptions) it was found that in order to limit the size of the book to reasonable bounds some considerations must be omitted and all must be abridged. Hence, the most important and fundamental results only are given. These embrace therefore only the discussion of the rock-forming minerals\* and a synoptical treatment of the rock groups. There remains material enough in our field-notes and in the drawers containing our samples to carry forward researches into the geology and genesis of the crystalline rocks through the space of another volume equal in size to this. Such investigation would pertain to the nature and extent of the original rocks that now carry the Mesabi iron ores. We have carried the research far enough simply to reach the main conclusion. The application and scope of that result are yet to be considered. Such additional research would also involve the "red rocks" of northeastern Minnesota and would lead to the inquiry as to how much of that group of rocks can be attributed to actual acid eruption and how much to alteration of basic eruption in submarine conditions. It would also lead to an investigation of the tectonic relation of such supposed altered basic rocks to the gabbro of the Cabotian, and of the Cabotian to the iron-bearing rocks of the Mesabi Iron range. Such investigation also would lead to the microscopical examination of the Animikie strata with view to ascertain whether an igneous debris is not more widely disseminated in them than has been supposed. There is also a large chapter yet in the future relating to the visible effects of progressive metamorphism of clastic sediments. The threshold only of this subject has been trod incidentally in the lines of this book.

\*It had been intended originally to include in the final report of the survey an annotated list of all the minerals of the state.

The data are much more numerous and are in need of definition and classification. From our study we have been able, as in the case of the Mesabi iron ore, only to reach a warrantable conclusion. Such conclusion must yet be pursued to its legitimate results, not alone theoretically, but through an inspection of other positive data and the interpretation and application of many minor steps and collateral issues.

Unfortunately, however, these and other questions must, for the present be left unsolved. It is the nature of all geological research to continually open up new fields. These, however inviting, must, in the case of the present survey, be relinquished with only a mention of their existence, in order that one or two, which have been sufficiently explored, may be described and thus preserved within the scope of positive geology.

The reader will find in this volume some conclusions as to the geology of the Archean which, while not entirely new, having been proposed in the main by others, sometimes on imperfect data and at other times with only partial apprehension of their scope, yet are not everywhere accepted as valid tenets of Archean geology. It may be well to succinctly mention some of these.

1. The Archean began with the crust of the earth a basic rock—greenstone. This crust, on cooling sufficiently to allow the condensation of water, was covered with chemical, detrital and volcanic sediments.

2. The metamorphism of these sediments produced later the schists and gneisses and the fusion of them by the combined action of heat and moisture gave rise to acid igneous rocks.

3. At the bottom of this series of sediments is a great mass of clastic greenstone which varies to acid rock, by chemical precipitation and by detrital accretion. The metamorphism and fusion of this, and other, intermediate rocks, gave rise to the intermediate schists and igneous rocks.

4. The basic igneous rocks, gabbro, diabase and their allies, are, in like manner, the result of the same forces acting on the basic rocks (greenstone) whether of the original crust or of the clastic series.

5. From the most basic to the most acid of the igneous rocks, therefore, there is an unbroken series of minute gradations, both chemical and petrographic, corresponding primarily to similar gradations in the clastic rocks, by reason of which it is impossible to establish definite classes or groups separated by constant characters.

6. Hence all igneous rocks of the Archean, after the first greenstone, are in one heterogeneous family, interlocked in different directions, and incapable of separation. Every rock sample has its own characters or combination of characters, but these are shared variously with its neighbors, or with its congeners from more distant localities, in almost an infinite series of differences and shades of variation, by reason

of which it is impossible to uniquely define any single group. The extremes and the mean are easily apprehended, and that is about all the classification that can be given. The history and the multiplicity of petrographical nomenclature verify this conclusion.

7. The igneous rocks of the Archean are not derived one from the other by any process of differentiation of magma.

8. The rocks of the Archean are not unstable, but fixed. Their Archean composition and characters have come down to the present without showing, normally, the least alteration.

9. There have been epochs of intense metamorphism, of folding, crushing and fusion, but these were local as to time and place and their effects were wrought out in Archean time—with the probable exception that in Taconic time similar revolutions produced similar effects on the Archean rocks adjacent.

10. The weather effects, which are superficial and have been removed by glaciation, the accidental location of oxidizable sulphides or carbonates so as to intensify locally the changes in the adjacent rocks, and the rare instances of post-Archean fracture and mountain-forming, are the abnormal conditions that may be appealed to to justify the idea that the crystalline rocks are *as changeable as an organic body!* But these conditions are exceptions to the normal state of the Archean rocks, and can hardly be said to establish a great principle which contravenes the general history and the verdict of the normal condition of the great mass of those rocks.

11. The Archean in Minnesota was fully crystalline and brought to vertical attitude before the deposition of the Taconic, and there was certainly a long time interval between the Archean and the Taconic not represented in Minnesota by any rocks, during which in other parts of the country there may have been formed other rocks, both fragmental and igneous.

12. As the Archean igneous rocks are derivable from Archean earlier rocks by metamorphism and fusion, so later igneous rocks may have been produced by similar alteration of later clastic rocks, and these would introduce a great many additional varieties and peculiarities into petrographical nomenclature.

13. But, whenever the basic original crust has been reached by such action, the resultant rock has been a *diabase*, whose constancy of composition vouches for the constancy and universality of its source.

*Diagrammatic scheme of the Archean in Minnesota.*

For the purpose of conforming to a conventional practice, and in order to make somewhat clearer the composition and order of the Archean and Taconic in Minnesota, as described in this report, the following structural scheme is given. Such schemes are liable to convey error by their exactness of definition and the meagerness of data they embody. Nothing is more plain to the practical geologist than that

structural changes in the Archean are seldom abrupt and evident, and that even from one rock species to another there are usually intermediate transitions which sometimes baffle reasonable interpretation. This scheme, therefore, must be understood to present only the broader features of the rock succession.

	<i>Upper Cambrian.</i>	The <i>St. Croix</i> and <i>Hinckley</i> sandstones of the Upper Mississippi valley, or the western "Potsdam." Seen at Fond du Lac. The lower portion interstratified with trap, and thus passing to the Keweenawan.	
TACONIC.	<i>Lower (and probably Middle) Cambrian.</i>	Keweenawan.	<i>Potsdam</i> (clastic) and <i>Manitou</i> (igneous) rocks. <i>Puckwunge</i> conglomerate at the base. The <i>Potsdam</i> at Potsdam, N. Y., but not at Saratoga.
		NON-CONFORMITY.	
		Animikie.	Slates, quartzites; conglomerate at the bottom of the clastic rocks, but sometimes without a basal conglomerate. Numerous dikes and sills of the age of the Keweenawan. The <i>Mesabi</i> iron ores, probably derived from original basic eruptives, are at or very near the bottom of the Animikie.
NON-CONFORMITY.			
ARCHEAN	<i>Upper Keewatin.</i>	Quartz-porphry, Volcanic tuff, Flint, Quartzite, Sericite schist, Jaspilite, Argillyte, Graywacke, Greenwacke, Greenstone (clastic), Ogishke conglomerate,	Metamorphosed and fused, producing mica schist, hornblende schist, gneiss, granite of various kinds, diorite, syenite, etc.; also muscovadyte and gabbro.
	NON-CONFORMITY.		
	<i>Lower Keewatin.</i>	Quartzite, Graywacke, Flint, Volcanic tuff, Argillyte, Greenstone (clastic), Jaspilite, Quartz-porphry, Greenstone conglomerate, Greenstone (igneous), oldest known rock,	Metamorphosed and fused, producing mica schists, gneiss, hornblende schist, diorite, syenite, granite and their modifications; also magnetic ore, muscovadyte, noryte and gabbro with their modifications.
		Kawishicin.	

The reader will find in Part I a description of these formations, and in Part III a discussion of their genetic relations.

The term Norian is replaced by Cabotian because of its original application to a Mesozoic formation of the Alps, as shown by Renevier.\*

ROCKS LEFT AT PARIS.

In order that European geologists may examine the rocks discussed in this volume, and thus be enabled to review the petrographic conclusions, a series of 118

\* Ambiguité du term Norien, et son inadmissibilité dans la classification internationale. *Eclogae geologicae*, vol. 5, p. 355.



of the type rocks was deposited in the Museum d'Histoire Naturelle, at Paris, in the possession of Prof. A. Lacroix, consisting of the following:

Nos. 1, 5, 68, 119, 129, 140, 158, 187, 200, 270, 443, 449, 450, 470, 473, 488, 514, 518, 520, 526, 528, 533, 536, 543, 544, 549, 550, 554, 555, 557, 563, 571, 598, 603, 607, 620, 624, 625, 627, 637, 638, 682, 695, 699, 744, 746, 754, 797, 799, 801, 805, 828, 835, 854, 864, 865, 866, 867, 868, 869, 871, 872, 873, 874, 877, 879, 882, 883, 890, 892, 903, 911, 916, 921, 923, 936, 947, 950, 954, 958, 960, 963, 979, 983, 989, 991, 1044, 1049, 1050, 1059, 1061, 1062, 1068, 1073, 1074, 1094, 1098, 1100, 1109, 1128, 1129, 1136, 1137, 1277, 1278, 1283, 1312, 1318, 1340, 1409, 1428, 1436, 1518, 1797, 1838, 1843, 66G.

An analytical key of the petrographical descriptions of this volume will be found after the Table of Contents.

NOTE. It is recognized that the criterion by which diopside has been determined (cleavage 010) is not alone reliable; but usually diopside has been identified further by its elongated form, its light color, and its association with acid and alkali minerals, and by its occurrence in secondary rocks.

The reader will please note the following corrigenda:

On p. 169, line 12, for magnetite read magnesite.

On p. 180, line 10, for LABRADORITE read LABRADORYTE.

On p. 209, line 24, add the words: See Nos. 132A and 667.

On p. 309, line 25, add the words: Plate V, figure 9.

On p. 313, line 18, add the words: Plate VI.

On p. 344, line 14, add the words: See No. 884.

On p. 350, line 24, after crystals, add: and coarser ones of tourmaline.

On p. 456, line 3 from the bottom, add: Plate II, figure 1.

On p. 464, read LABRADORYTE and THOMSONITE.

On p. 473, line 6 from the bottom, add: Plate II, figure 2.

On p. 559, line 10, erase 1842.

On p. 644, line 18, for band read bond.

On p. 660, first line, for same read some.

On p. 735, line 25, add the words: Plate V, figure 7.

On p. 785, line 3, add the words: See note, p. 161, Twenty-first Annual Report.

On p. 844, line 18, add the words: Plate III, figure 5.

N. H. W.

