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The Nineteenth Annual Report, for the year 1890.

N. H. WINCHELL,

State Geologist.

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ADDRESS.

THE UNIVERSITY OF MINNESOTA.

MINNEAPOLIS, August 1, 1891.

To the President of the University:

DEAR SIR: The nineteenth annual report of the Geological and Natural History Survey of the state is herewith presented The larger part of the year was devoted to the preparation and the publication of the report on the iron ores of the state, embraced in Bulletin No. 6, which was finally issued in April, 1891. Into this (accompanying) report are gathered therefore various reports and papers that have accumulated in the progress of the survey, and some lists of specimens and publications, the printing of which will be a great convenience.

Respectfully submitted,

N. H. WINCHELL,

State Geologist and Curator of the General Museum.

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I.

The Elements of a New Method of Chemico-Microscopic Analysis of Rocks and Minerals.

BY

DR. EMANUEL BORICKY.

(Archives of the Natural History Survey of Bohemia.)
(Vol. III, Part V.)
1877.

NOTE.

This translation is the work of several persons. Begun in 1880 by the undersigned, it was suspended because of the urgency of other duties. It was resumed and carried on in 1887 by his daughter (now Mrs. F. N. Stacy), who in turn surrendered it to Miss Mary Blanchard, and by her in 1889 was finished the first English copy. It has recently been re-compared with the original by Mr. Herbert A. Wood, and a final revision and correction have been made by the writer.

In its present form this work will be constantly useful, not only to the collaborators of the survey in its examinations of the crystalline rocks, but to numerous petrographic students in America who do not have easy access to the original. The work of Boricky must always remain the headlight of any train of similar researches which may follow it—a train which has recently received some important accessions at the hands of Fouqué, Streng, Behrens and Renard. Messrs. Levy and La Croix have, lastly, arranged all of these methods in systematic order in their late work, *Les minéraux des roches* (Chapter VIII), and to this the student is referred.

N. H. WINCHELL.

CONTENTS.

INTRODUCTION.

Like a blazing meteor appeared the microscopic examination of minerals and rocks, in the horizon of inorganology. It created surprise by the sudden insight which it afforded into the internal nature of such minerals as had been subjected in vain to manifold hypotheses as to their differences of composition; it created surprise by its unexpected disclosures concerning the existence and origin of several crypto-crystalline rocks, of the nature of which erroneous ideas had been held for nearly a hundred years before; it illuminated many a crooked way which had been pursued in the science of lithology; but it also supplied means for judging of the genetic relationships of minerals and rocks, concerning which no one before ventured to speak without apprehension of much criticism. Therefore it gave rise to the hope that in it had been found the pathway which would lead to a sure knowledge of the mineral world, though concealed by an apparently impenetrable veil.

This hope, which must have taken possession of most mineralogists and geologists, seemed to come at once into realization, inasmuch as Vogelsang's *Philosophy of Geology* [1] and Zirkel's classic work [2] on the basalts followed, as well as Fischer's critical micro-mineralogical studies, [3] and the pioneer work of Sorby [4], for from this time the investigation of

1. Bonn, 1867.
2. Bonn, 1870.
3. Freiburg, 1869 and 1871.
4. "On the microscopical studies of crystals, indicating the origin of minerals and rocks." *Quart. Journ. of the Geol. Soc. London, 1858.* The microscope had already been used toward the end of the eighteenth century for the determination of isolated portions of crypto-crystalline rocks, by Dolomieu and Flerieu of Bellevue, but powdered rock only was the object under investigation. Thereupon the "schlemm process" with an investigation of the parts separated by "schlemm," was advocated by several French geologists. And this operation employed by Cordier (1815) on an enlarged scale received an important extension in a chemical treatment of the rock-powder. But the first crystalline thin sections which were submitted to the study of their inner structure appeared to be those of chiastolite, which Gerhard (according to Fischer's statement) had investigated, but only in reflected light. William Nicol made the first investigation of a thin section in transmitted light, and proposed a method for the display of thin sections; but a searching study of the nature of the inner structure of minerals was made first by David Brewster, who interested himself particularly concerning the petrological significance of fluid inclusions, and also recognized already the importance of microscopical investigation in polarized light. Brewster may be regarded as the true forerunner of Sorby, although microscopic investigations of minerals and rocks were undertaken before Sorby (by G. Rose, Scheerer, Jensch, Knope, von Rath and others)

minerals and rocks sprang into active life. Microscope and lathe have been accepted and industriously employed as indis pensible implements in the special researches of mineralogists and geologists. Numerous minerals have been examined in respect to their internal structure, by means of this new method of investigation; in various countries the investigation of larger and smaller rock-complexes was begun according to the new method, or individual kinds of rocks united under one name, were subjected to this new test. And in three years the scientific material increased so greatly that Zirkel, in the year 1873, found himself impelled to collect, and make accessible to his co-laborers, the scattered results of these researches on the constitution of rocks and minerals, by means of a splendid text book.[1]

But the scientific effort which showed itself in so rich a degree in the direction mentioned, led soon to the knowledge that in this path there were yet large gaps which must be filled up or at least bridged over, if a sure step forward would be taken. And in response to this generally felt need, Rosenbusch[2] hastened to place a practical guide in the hands of microscopic mineralogists and geologists, in order to place before their eyes, through the well ordered collection of diagnoses of the rock-bearing minerals, as far as at that time possible, a clear picture of the territory then known, and in an indirect way to make evident to them the uncertain spots and the gaps.

The next result of these endeavors was a work in the micro scopic research of minerals and rocks, elevated high above the common level, which substantially enriched our knowledge in many directions, especially in respect to the micro-structure of rocks. It gave, however, occasion for many complications, in that often in place of positive results, only the old pillars of knowledge were overthrown and the insufficiency hitherto, of our means for new structures either public or private was shown, or in that only temporary buildings were erected upon the old foundations.

It would be reasonable—certainly in the light of the startling variety which Zirkel brought to notice in the basaltic rocks—to expect that there would be considerable difference also in other rocks heretofore united under one name, and that perhaps there would inevitably appear in respect of some

1. The microscopic structure of minerals and rocks. Leipzig, 1873.
2. Microscopic Physiography of the petrographically important minerals. Stuttgart, 1873.

kinds of rocks, a separation into many species, and in other kinds a union of species, but no one dreamed of the difficulties which arose concerning the degree of similarity which is necessary for the embracing of many groups of rocks under a common name, concerning the relations of geological, mineralogical, chemical and structural principles, upon which a natural system of rocks must be based in order to produce harmony. And the cause for these difficulties is, according to my opinion, to be found in general, in the constant extension of our petrological knowledge, in particular, however, in the deficiencies which are found in our microscopic methods, and which make their employment difficult or uncertain, often permitting only a subjective conception of the object under investigation.

Among these difficult (because incomplete) relations, Lassaulx undertook, in an excellent accurately compiled text-book,[1] devoted especially to the first work in the study of petrology, to bring the results of rock researches known up to that time into systematic order. But if one turn over the leaves of this text-book, suitable to any case, and go through the microscopic diagnosis of individual minerals and rocks, he will be led involuntarily to the above mentioned conclusion, that there is yet much to be accomplished upon the path leading to the right end, before a secure and easy advance towards it will be possible.

If we bear in mind the present standponti of microscopic rock research as it is set forth in the last mentioned text-book, and in those of Rosenbusch and Zirkel, we are obliged first of all to note great increments to the knowledge of the micro-structure of rocks, the micro-structure and other properties associated with it, of the rock-making minerals;[2] and also in the

1. Elemente der Petrographie. Bonn, 1875.

2. In regard to the knowledge of the micro-structure of minerals and rocks, Zirkel has unquestionably deserved the title of master. His works which appeared before the year 1873 are in his hand-book: "The Microscopic Properties of Minerals and Rocks, Excerped and Cited." And among his later works, those on the composition of Kersanton and the structure of Variolite (Ber. d. köngl. sächs. Ges. d. Wissensch. July 1875), and on Phyllit v. Recht im hohen Venn (Verh. d. naturh. V. d. preuss. Rhl. XXX. (1) should be mentioned. Also to Rosenbusch's above mentioned work in which his earlier works are noted, we have to add—besides his great work "Abhandlungen zur geolog. Specialkarte von Elsass-Lothringen," which I received from his friendly hand during the last few days—a valuable treatise "on the Composition and Structure of Granitic rocks," (Zeitschr. d. d. geolog. Ges. 1876) to which have been added two very important works by M. A. Michel Lévy (Structure microscopique des roches anciennes. Bull. soc. geol. France (3)III. 199-236,1874. and Mémoire sur les dévers modes de structure de roches éruptives. Paris (Dunod, éditeur) 1875, relating to the same subject. Besides Sorby's already mentioned pioneer work, the following treatises of the same

application of those optical properties which are connected intimately with the laws of individual systems of crystals, to the microscopical study of rocks there are (through the efforts

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author should be noted; On the microsc. struct. of Mount Sorrel Syenite etc., Geol. and polytechn. Soc. of the West Riding of Yorkshire 1863; on the microsc. struct of the meteorites, (Proceed. Roy. Soc. London 1864); on the structure of Rubies, Sapphires, Diamonds and some other minerals (Proceed. Roy. Soc. London, 1869).

Contributions by other investigators have been made concerning the knowledge of the micro-structure of individual minerals and rocks, of a late date: Allport (Phon. vom Wolf-Rock. Geol. Mag. N. 84; Pechstein v. Aran, Geol. Mag., 1872, IX. Brit. Dolerite. Qaurt. J. of the Geol. Soc. London, 1874), Anger (Klast. Gest. Tschermack's Mineralog. Mitth., 1875), Artopé (Trachyte der Anden. Diss. Berlin, 1872), Behrens (Grünsteine. N Jahrb. 1871; Opale. Wien. Akad. 1871), Berteles (Ein neues vulk. Gest. Diss. Wüzrburg, 1874), Cohen (Geogn. petrogr. Skizzen a. Südafrika. N. Jahrb. 1874), Credner R. (Grünschiefer v. Hainichen in Sachsen. Schieferthone u. Thone. N. Jahrb. 1875), Dana (Trap Rocks of the Connecticut Valley. Proceed. of the Amer. Assoc. for the Adv. of Science, Hartford meeting, 1874, N. J., 1875), Dathe (Diabase. Dissert. Serpentine u. Eklogite d. saechs. Granulitgebietes. N. Jahrb., 1876). Doelter (Trachyte des Siebenbürg. Erzgeb.; Trachyte v. Tokaj-Eperies. Tschermak's Min. Mitth., 1874; Melaphyre Südost-Tirols Jahrb d. geol., Reichsanst. Wien, 1874, u. Tsch's Min. Mitth., 1875), Haarmann, Melaphyre, Diss. Leipzig, 1872), Hebenstreit (Urgest. d. nördl, Schwarzwaldes. Dissert. Würzburg, 1877). Emons (Phon. d. Veley u. Westerwaldes, N. J., 1875), Fouqué (les inclusions vitrenses renf. d. l. feldspaths des laves de Santorin; une ponc de Vesuv; les nodules à oligoklas des laves de Santorin; wollastonit, fassait, grenat des laves de Santorin; les laves des dykes de Thera. Comptes rendus de l'Acad. de Sc. Paris, 1873-1876), Geinitz (Grünsteine d. Saechs. Erzg. Tsch's Min. Mitth., 1876), Gümbel (Palæol. Eruptgst. d. Fichtelgeb. München, 1874. Geogn. Mitth. a. d. Alpen. Sitzgsb. d. k. bayr. Akad., 1877), Hull (Irische Granite. The Geol. Mag., N. J., 1874; Report on the Chem. Min. and Microsc. characters of the lavas of Vesuvius, from 1631-1868. N. J., 1876), Inostranzeff (Vesuvlaven v. Spt., 1871, Maerz u. Apr., 1872; Kalksteine u. Dolomite, Tsch.'s Min. Mitth., 1872), Kalkovsky (Felsite u. Pechsteine Sachsens, Tsch.'s Min. Mitth., 1874; Felsitporphyre b. Leipzig, N. J., 1875; Salit., etc., Tsch.'s Min. Mitth., 1875; Glimmertrapp v. Melzdorf, 1875; grüne Schiefer Niederschlesiens, N. J., 1876; Einige Eruptgst. d. sæchs. Erzgeb. N. J. 1876), Kenngott (Obsidian, Petersburg, 1869 u. 1870), Koch (Donautrachytgruppe n. Budapest, N. J. 1877), v. Lassaulx (V. Gest. d. Auvergne, N. J. 1869-1872. Hemithrène d. Dep. Puy de Dôme, N. J. 1874. Eruptgst d. Vicentinischen, Z. d. d. geol. Ges. 1873), M. Lévy (Observ. sur. l' origine des roches eruptives. Variolite de la Durance, Acad.; Kersanton. Bull, de la soc. géol. de France, 1876), Liebe (Diabase d. Voigtlandes, N. J. 1870), Lossen (Porphyroide d. Harzes. N. J. 1877), Möhl (Sababurg; Scheidsberg b. Remagen; Bühl b. Weimar; Südwest. Ausläufer des Vogelsgeb; Basalte der rauhen Alp.; Bas. u. Phon. Sachsens; Bas. der preuss. Oberlausitz; Hauynbas. in Hessen; Gest. Thüringens. N. J. 1871-1875); Neminar (Erupgest, v. Banov in Mähren, N. J. 1877), Niedzwiedzki (Banater Eruptgst. Tsch.'s Min. Mitth. 1873) Petersen (Grünsteine, N. J. 1872), v. Rath (Monzoni. Bonn. 1875; Syenitgeb. v. Ditró, Trachytgeb. Hargitta., etc. Bonn. 1876. Geol. Reise n. Ungarn. Bonn. 1877), Rénard u. de la Vallíe Poussin (Mémoire sur les caractères min. et stratigr. de roches plutoniennes de la Belgique et de l' Ardenne Française. Acad. roy. Bruxelles, 1876), Rothpelz (Devon. Porphyroide Sachsens, N. J. 1877), Rutley (On some struct. in Obsidian, Perlite and Leucite. R. Microsc. Soc. 1876. Structure d. Feldsp., N. J. 1876), Sandberger (Neph. v. Katzenbuckel, N. J. 1869; Bas. u. Dolerite. N. J. 1870; Apatit im Olivinfels, Tachylyt v. Saesobühl, N. J. 1871; Kryst. Gest. Nassau's. Phys. u. Med. Ges. zu Würzb. 1873; Dolerit. Sitzb., d. k. bayr. Acad. 1873), Sauer (Phon. d. canarischen Inseln, N. J. 1876), Steenstrup (Om de Nordenskiöldske Jaernmasser og om Forekomsten af gedigen Jaern i Basalt Kjöbenhavn. 1876 u. N. J. 1887), Stelzner (Labradorit u. Pegmat. Berg-u. Hüttenm, Z. XXIX), Streng (Feldspathstudien, N. J. 1871; Porphyrite v. Ilefeld, N. J. 1875; Kryst. Gest. v. Minnesota, N. J. 1877), Törnebohm (Diabas u. Gabbrogest, Schwedens, N. J. 1877), Tschermak (Porphyrgest. Oesterreichs, Wien. 1869; Meteorit v. Lodran, Pogg. Ann. 1870. Meteorstein v. Goalpara, Wien, Acad. 1870; Pyroxen u. Amphibol, Min. Mitth. 1871. Meteoriten v. Stannern, Constantinopel, Shergotty u. Gosalpur, Min. Mitth. 1872), Umlauft (Thonschiefer, Lotos, Prag. 1876), Vogelsang (Flüssigkeitseinschlüsse in gewissen Min.

of Zirkel and Rosenbusch,) important advances to be noted.[1] There were indeed, important attempts made to determine individual species of certain groups of minerals, merely by means of optical properties. Tschermak[2] first alluded to the fact that the observation of pleochroism and light absorption rendered important service to the separation of individual branches of the amphibole and biotite groups; and later Descloizeaux showed how a member of the feldspar group can be identified with certainty by the determination of the position of the chief direction of oscillation in the known thin section of a feldspar by placing it in the maximum extinction of light between crossed Nicols[3].

Accordingly through excellent publications very important advances have been made in modern petrology by means of the employment of the morphological and optical properties of minerals; but the chemical laboratory which should reveal to us in the thin sections of the mineral its uniform and permanent characters by the results of certain tests seems—unfortunately for modern petrology—to refuse its aid. Noteworthy attempts have been made, it is true, in the latter direction and methods have been proposed for the determination of some rock-forming minerals in minute tests or thin sections, but these were either limited to a very few minerals or in their applications were of no special importance.

Indeed Zirkel, in his experiments upon the basalts has frequently proved the insolubility of the minerals in acids, by boiling the powdered rock in muriatic acid. By other investigators thin sections were boiled in muriatic acid or treated with cold muriatic acid; many important phenomena were

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Pogg. Ann. 1869; Krystalliten, hrsg. v. Zirkel. Bonn. 1874), Voldrich (Hercyn-Gneissformation, Jahrb. d. k. k. geol. Reichsanst. Wien. 1875), Vrba (Gest. Grönlands. Wien. Acad. 1875; Grünsteine, a. d. Adalberti-Sch. v. Pribram, Oest. Z. f. Berg. u. Hüttenw. 1876), Zinckendrath (Kersanton v. Langeuschwalbach. Würzburg. 1875). In conclusion, I think that my works in relation to the Basalt, Phonolith and Melaphyrgesteine of Bohemia ought to be mentioned (Archiv. d. naturwiss. Landesdurchf. v. Bohemen. 1873, 1875 u. 1876).

1. Very noteworthy are Rosenbusch's observations in his description of the new microscope for mineralogical and petrological researches. N. Jarhb, f. Min., 1876.

2. Sitzb. d. k. Akad. d. W. in Wien, B. LIX. 7 Abth., 1869.

3, Examen microscopique de l'orthose et des divers feldspaths tricliniques. Comptes rendus des séances de l'Academie des Sciences LXXXII,: seance du 1er Mai, 1876.
Memoire sur les propriétés optiques biréfringentes caracteristiques des quartre principeaux feldspaths tricliniques, et sur un procédé pour les distinguer immédiatement les unns des autres. Ann. de Chim. et Phys., IV.; 1875.—Memoire sur l'existence, les propriétés optiques et cristallographiques, et la composition chimique du microcline, nouvelle espèce de feldspath triclinique á base de potasse, suivi de remarques sur l'examen microscopique de l'orthose et de divers feldspaths tricliniques. Amn. de Chimie et de Phys., IX: 1876.

noticed, such as effervescence, separation of gelatinous silica, and the solution and removal of turbid secondary products.

Since, however, for the determination of the insolubility of a mineral in acids, no fixed law was decided upon, other than the carrying out of the same experiments under exactly similar conditions, different results were often obtained upon the same materials by different investigators, or the similar results were interpreted differently.[1] And the result was that, instead of establishing the conditions (specific gravity of the muriatic acid used, and length of treatment), under which the action of the acid should be exerted, distrust was aroused against this very reaction—which was susceptible of being used to a considerable extent, and successfully, especially upon thin sections—and thus its application became limited to the most necessary cases. So now, for example, this reaction is very little used for the approximate determination of individual members of that feldspar group, for which the comprehensive term, "plagioclase," is preferred.

Rosenbusch endeavored to introduce some operations, customary in analytical chemistry, such as the formation of precipitates, and their separation from the substances remaining in solution, by means of a filtering apparatus (under air pressure);[2] but his efforts appear to have had little result. Moreover the etchings which appear upon the various surfaces of minerals treated with dissolving reagents and which bear an intimate relation to the morphological character of the mineral, were hopefully alluded to; but,—although, except Leyden's[3] experiments upon quartz, Knopp's[4] upon xanthophyllite and Sohnke's[5] upon sodium chloride, a series of minerals[6] were investigated by Baumhauer in regard to their etchings—as to

1. In order to furnish an example, the following passage to be found on page 407, the 18th line from top, in Zirkel's Handbook, "The microscopical properties of minerals and rocks," may be cited. Through treatment with hydrochloric acid the plagioclase of diabase is strongly attacked and exhibits after this action on the polariscope no more lamellar banding. In a similar manner Senfter distinguishes the oligoklase nature of most feldspars, though he has observed (p. 692) of oligoklase, that by long digestion in hydrochloric acid it is as good as not affected.

2. N. Jahrb. f. Min. etc. 1871. 914.

3. Sitzb. d. k. Akad. d. w. in Wien XV. 1855.

4. N. Jahrb. f. Min. 1872. 785.

5. N. Jahrb. f. Min. 1875.

6. The etchings on crystals. N. J. f. M. 1875. (190).
Upon potassium-mica, granite, cobalt-quartz. N. J. f. M. 1875. (192).
Upon magnesia-mica and epidote. N. J. f. M. 1875. (420).
Upon apatite and gypsum. N. J. f. M. 1875. (746).
Upon lithia-mica, turmaline, topaz, zinc-silicate. N. J. f. M. 1876, (1).
Upon adularia, albite, fluorite, and chlorides of natron. N. J. f. M. 1876. (602).

their value in petrology no decided advance has thus far been made.

Very note-worthy also are those methods which have for their object the separation of individual minerals from the mixed crystalline rocks and their chemical analysis—such as Müller's separation of quartz and some silicates from each other by means of phosphoric acid hydrate,[1] Gümbel's "meal test"[2] and Fouque's method of separation of ferruginous portions from the non-ferruginous by means of a strong electro-magnet and by means of concentrated fluohydric acid[3]—but all these experiments are tedious and demand much material, which, when converted into powder, and the homogeneous mass of separated mineral particles is examined, admit no such minute microscopic observation as a mineral cut through in a thin section.

I consider Knopp's micro-chemical reaction[4] upon members of the hauyne family as quite simple and practicable. By this method for the first time a vaporous substance, (sulphur vapor) is converted into the constant character of a determined mineral of a thin section, viz., the blue color of a hauyne-like mineral and to the black of an iron holding mineral. Just as practical is the application of molybdate of ammonia for the proof of phosphates in thin sections, and especially for the separation of apatite from nepheline, which reaction was introduced by Streng.[5]

In conclusion Szabo's *Neue Methode, die Feldspathe auch in Gesteinen zu bestimmen*[6] deserves special notice, since by careful observation of certain experiments on small fragments of feldspar the size of a poppy seed, it makes effective the old known methods, especially those for determination of the melting point, and of the flame reaction for sodium and potassium. For the experiment by the gas flame it requires many appliances and considerable practice. According to Szabo's report, his five stages of the sodium flame show: 0.3–1 per cent, 1–2 per cent, 2–4 per cent, 4–8 per cent, 8–16 per cent of sodium, and the four stages of the potassium flame: 0.3–1 per cent, 1–4 per cent, 4–13 per cent, and 13–22 per cent of potassium.

1. Journ. f. prakt. Chemie XCV, (43) and XCVIII, (14).

2. Volcanic rock of Fichtelgebirges, München, 1874.

3. Nouveaux procédés d'analyse médiate des roches. etc. Comptes rendus 1874, XXII, (11).

4. N. Jahrb. f. Min. etc., 1875, (74).

5. Tschermak's Min. Mitth. 1876.

6. Budapest, 1876. From the Hungarian original, published by the Hungarian Academy, d. w. 1873.

Though I gladly availed myself of the chance of reading Szabo's book, when its title page met my eye, yet, after a painstaking study of it I was obliged to lay it aside unused, because my small private laboratory does not support the luxury of gas-lighting, and at the University in this place neither a laboratory nor any such means of help is at my disposal. Nevertheless, I found myself compelled to seek another way to the same end, *i. e.*, the determination of the feldspars, and the ability in my future work to eliminate the expression, so much cherished in modern petrology, "plagioclase," by means of the accurate designation of the feldspar group.

I first turned my attention to the pure feldspar, but after a series of experiments which I began in August of last year, I extended my work to all minerals which contained alkalies or alkaline earths, and became convinced that my method could be applied not only to the determination of the most minute mineral fragments, but also under the same circumstances, to the determination of minerals in thin sections of cryptocrystalline rocks.

When I had become convinced that in the most common operations in analytical chemistry, for example, the formation of successive precipitates, filtering, decanting, etc., not much is to be accomplished in the substantial investigation of minerals in thin sections, it occurred to me to cause special gaseous material (as hydrofluoric gas, chlorine gas) and such liquid substances as continually volatilize (as hydrofluosilicic acid), to act upon thin sections of minerals, and to utilize the substantial changes which present themselves upon the upper surfaces of thin sections and admit of a microscopic investigation, to the determination of minerals.

First of all I thought of the etchings of crystallographically determined mineral sections, then upon the successive removing and separate investigation of individual new-formed products, through various solvents and reagents; but the observation of beautiful, characteristic crystals which appear on some specimens, soon taught me that a far more important role is to be attributed to the new products formed from the investigated minerals—so far as they can be obtained in easily recognized crystal forms and as far as the individual chemical mineral elements, especially those of the alkalies and alkaline earths, can be investigated by these crystals and determined according to their quantitative relation—since by this means,

results are to be obtained in the shortest and most convenient way (for those who are not expert in chemical operations), while for the same results analytical chemistry requires much time and experience.

The first substance which I used was hydrofluoric gas. I was convinced that by its action upon alkaline silicates, silicic-fluorides of the alkalies would be formed, which, dissolved in boiling water, can by the evaporation of the solution be obtained in the characteristic crystals, differing for potassium and sodium. I thus saw the possibility realized of being able to separate with great readiness and in the smallest specimens all silicates containing potassium from those containing sodium, especially potassium feldspars from the soda and lime feldspars, and in general alkaline from non-alkaline silicates. Besides this there appeared some accompanying phenomena which seemed to me to be important as means of recognizing the minerals. Thus, for example, I saw that besides the alkaline silicates a long series of non-alkaline silicates is affected by hydrofluoric gas, and that all those minerals from which fluorides are formed can be easily recognized by effervescence in sulphuric acid (which can be easily observed in the microscope); I saw that in the sections of phonolite treated with HF and then boiled in water, Möhl's nepheline-glass was reduced to rather sharp edged sections of nepheline, that through similar treatment wholly turbid as well as very thin sections of porphyry became perfectly clear and bright, and thus their mineral composition and that of similar minerals could be easily recognized.

But the original problem of this work, the determination of those groups of the feldspar family which we unite under the names of oligoclase, andesine, labradorite and anorthite, could not for a long time be solved in a simple way. After I had established the fact through experiments that from the soda-lime feldspar treated with HF, all the alkalies are dissolved as silicicfluorides, by boiling away in water, while the greater part of the calcium remains behind in the specimen either as a fluoride or as an aluminous lime fluoride,[1] I struck upon several ways of reaching the desired end, that is, for determining approximately the quantitative proportions of calcium and sodium in the feldspars, which ways proved more or less suc-

1. If the silicicfluoride of calcium had been formed, it would as one of the most readily soluble silicicfluorides, have been quickly and perfectly dissolved in the water.

cessful, but none of which satisfied me on account of their minuteness.[1]

Naturally it occurred to me to produce in the form of silicic-fluorides the sodium as well as the calcium of the lime-soda feldspars, since the artificial salts of both elements showed various, easily distinguished crystal forms; then my attempt went so far as to change calcium fluoride into silicicfluoride. For this end I treated the specimens changed by HF with hydrofluosilicic acid, but I found to my sorrow that the silicic-fluoride crystals from sodium were always to be found in a considerably larger quantity than the proportion for the calcareous feldspars demanded. And for this reason I suspected that in the indicated proportions a considerable portion of the silicicfluoride of calcium crystallizes in the same form as the silicicfluoride of sodium.[2]

Since I intended to seek for the reason of the similar crystallization of substances appearing elsewhere in various forms, in the similar conditions of solution under the circumstances named, I simplified the investigation by treating the specimen directly with hydrofluosilicic acid in order to bring the very soluble silicicfluoride of calcium to formation and solution more quickly than the less soluble silicicfluoride of sodium. And these experiments had the desired result in that they demonstrated a decided difference in the silicicfluoride forms of potassium, sodium, calcium (eventually strontium), magnesium (eventually iron, manganese), occasionally also of lithium and barium, as well as made possible a quite easy separation of them. Besides this, my efforts went so far as to make known the reactions for the silicicfluorides similar in their forms to the individual elements named, in order to acquire complete knowledge of their substantial differences even in doubtful cases.

The use of chlorine gas as a reagent offered many advantages, thus: For the proof of insolubility in acids, for the proof of alkalies, for producing the characteristic etchings (in some minerals), especially, however, for establishing whether the silica which separates out of the thin section of a silicate is gelatinous or granular. And of the older methods that of

1. I reported these methods in the session of the mathematical and physical science classe d. k. böhm. Gesells. d. w., on Nov. 10, 1876.

2. From treatment with sulphuric acid were formed many of those broad monoclinic crystal needles, formerly only the peculiar silicicfluoride forms of sodium, which I took for the formtypes of gypsum crystals.

heating the specimen showed itself in most cases applicable to the recognition of the coloring metals, and to the approximate determination of the melting point, and that of the clay reaction by means of cobalt solution with microscopic investigation, to the thin sections of different kinds of rocks.[1]

Since I already use the methods explained here, though probably capable of further development, in those studies whose publication is reserved to the archives of the general scientific investigations of Bohemia, I consider this little book as an introduction to my further petrological work, and herewith venture to justify its insertion in the archives of general scientific investigation.

In conclusion the pleasant duty remains to me to express my warmest thanks to my highly esteemed colleague, Prof. Stolba, for furnishing me with a quantity of chemically pure silicic acid which was necessary for my experiments, and for his advice concerning the latter.

1. Upon all these methods I have already made communications in the session d. k böhm. Gesells. d. w. on Feb. 9 of this year.

I. General Method for the Micro-Chemical Determination of the Metals of Petrologically Important Minerals by means of Hydrofluosilicic Acid.

Principle of the Method.

With the exception of a few which offer the greatest resistance to chemical reagents, all minerals which contain alkalies, alkaline earths, heavy metallic monoxides (or analogous sulphur, selenium, tellurium, arsenic, or antimony compounds) are more or less affected by strong hydrofluosilicic acid.

The result of this action is the formation of silicicfluorides (from the metalic elements of the minerals and the hydrofluo silicic acid), which dissolve in the hydrofluosilicic acid solution and after the evaporation of the solution make their appearance in beautifully formed crystals (or of small groups of them) characteristic of the individual elements.

If the treatment of a very small piece of mineral with hydrofluosilicic acid is performed upon a spot on the object glass coated with thoroughly boiled Canada balsam, the silicicfluorides thus formed can, even in their minuteness, be studied, magnified to any desired degree.

If the silicicfluorides of the individual metals, which are formed upon the object-glass under the conditions mentioned could be separated from each other, either through the different crystal systems to which they belong, or through definite, easily recognized typical forms, or through characteristic changes when treated with new reagents, perfectly reliable means for distinguishing the individual metals would thus be afforded.

Of the silicicfluorides, thus far known, of the metals appearing in petrologically important minerals, those of potassium, cæsium, and rubidium belong to the tesseral crystal system, and those of sodium, magnesium and iron to the hexagonal or hemihedral-hexagonal system, while those of lithium, calcium and strontium (according to Marignac's statement) must be monoclinic.

In the determination of a petrologically important mineral it is hardly of importance to prove the presence of cæsium and rubidium with potassium.

The silicicfluorides of sodium, magnesium and calcium produced under the conditions mentioned show such different forms that they can, in most cases, be distinguished at the first glance. Moreover the silicicfluolithium crystals, produced from lithia-mica and lithia-iron-mica are so peculiar as to be quite easily identified; but silicicfluostrontium presents almost the same crystal appearance as silicicfluocalcium, and in nearly the same forms in which silicicfluomagensium appears; we find also silicicfluorides of iron and manganese; so that a separation of the silicicfluoride of calcium from that of strontium and of magnesium from those of iron and manganese would scarcely prove successful.

But the separation of the last named metals in the forms of silicicfluorides is not rendered impossible on this account; for by treating them with new reagents the desired end is quite easily reached.

If, for example, silicicfluocalcium and silicicfluostrontium are treated with dilute sulphuric acid, the crystals of the first are, after a few seconds, surrounded by a thick beard of monoclinic gypsum needles, while the crystals of silicicfluostrontium very slowly (in several hours) liquify into a granulous mass, or only very short (celestine?) needles, are here and there observed. In the same way can the silicicfluorides of magnesium, iron and manganese be separated by the application of various substances. The application of chlorine gas is worthy of recommendation, by means of which the silicicfluoride of iron assumes an intense citron-yellow color, while silicicfluomagnesium and silicicfluomanganese remain almost colorless: yet the manganese salt has a streak of red, and appears strongly agglutinated, and for the most part changed into a group of little tablets, prisms and melted grains, although the crystal forms of silicicfluoride of magnesium appear to be changed a little.

Also the application of sulphide of ammonium vapor for the separation of the last-named metals in the form of silicicfluorides produces exactly the same results.

From these experiments it can be seen that the metals appearing in petrologically important minerals in the presence of hydrofluosilicic acid may be easily identified. At the same time, moreover, the quantitative proportions of the several

metals existing in a mineral can in most cases be approximately ascertained.

If the mineral is readily acted upon by the hydrofluosilicic acid all the metals in their variously formed silicicfluorides make their appearance after the evaporation of the solution, and, indeed, (if they do not materially differ in their conditions of solubility) in about the same quantitative proportions in which they existed in the mineral investigated. If, however, the mineral to be analyzed is only slightly attacked by the hydrofluosilicic acid, the latter has acted on the greater part or the whole of that metal (of the respective metals) which can be most easily dissolved, while for the other metals of the same mineral only small silicicfluoride crystals or none at all are observed.

The conditions of the silicicfluorides in solution must, consequently, be considered, as well as the comparison of the quantitative proportions of the silicicfluorides, with the quantitative proportions of the metals contained in the original minerals.

If from several metals which the mineral under investigation contains, at the first treatment with hydrofluosilicic acid only one makes its appearance, then the treatment of the same portion of mineral is to be repeated with fresh hydrofluosilicic acid, which treatment usually produces the wished for result; that is the making visible of the remaining metals in the form of silicicfluorides. It is evident, however, that in this fortunately rare case the quantitative proportions of the silicicfluorides will not correspond with the proportions of the metals which the chemical analysis of the mineral demands, but that, for approximate determination of the quantitative relations of individual metals in the mineral to be examined, other methods, to be explained later, must be employed or special experiments (with hydrofluosilicic acid) must be established as rules for these individual minerals,

It may be remarked here that thin sections are more readily acted upon than cleavage particles or broken fragments.

In conclusion I think I may say that clay, and sesquioxides in general, and minerals which are free from monoxides, afford when treated with hydrofluosilicic acid, no new formed products in crystal forms.

EXECUTION OF THE METHOD.

Place a few drops of Canada balsam upon an object-glass and hold it over a spirit lamp until the little bubbles which form have passed off, and the balsam acquires, after cooling, a firm, resinous consistency. At the same time try so to turn the object-glass while the balsam is still liquid, that it will form in hardening as thin and even a coating as possible upon the glass.

In the middle of the balsam layer place the specimen or thin section of the mineral to be examined, and again heat the object-glass, but only enough to cause the specimen to adhere firmly. If the specimen is a thin section, let it be as thin as possible, because it loses something of its transparency by reason of the crust of silicicfluoride; then it must be heated cautiously (to prevent the formation of little vesicles), and carefully pressed with a penknife so that no little gas bubbles remain under it and that it may assume a perfectly horizontal position,

The size of the specimen is entirely arbitrary. It may be the size of a pea, or it may be a very much smaller piece; yet it is advisable to keep a certain relation to the size of the drop of hydrofluosilicic acid which is to be put upon it.

I usually take a specimen of mineral about the size of a pin-head or a millet grain, and place upon it a drop of hydrofluosilicic acid of about the size of a pea, If two or more pieces of minerals are taken of the above mentioned size, the drops of acid must be increased in a proportionate degree. I take a thin section of the size of 4–6 mm, taking care that the hydrofluosilicic acid placed upon it does not spread over the section, but that the drop maintains the greatest height possible, so that the greatest depth of fluid may work upon the smallest surface.

If one has to investigate a mineral dissolved in water it is advisable to take a larger amount than the above mentioned relation to the quantity of acid required, because, besides the silicicfluoride of the metal which is contained in the specimen, the crystal form of the specimen itself (either of the unchanged mineral or of its individual salts) is also brought to perfection, and one has a complete analysis of the mineral before his eyes. For example, if the specimen were a sodium salt, such as sodium-chloride, sodium-nitrate, mirabilite or borax, from each substance would be obtained short hexagonal prisms of silicicfluoride of sodium, but besides this in the first specimen little cubes of sodium-chloride, in the second rhombohedrons of so-

dium nitrate, in the third monoclinic needles of glauber salt, and in the fourth borax crystals easily recognized by their form; but from polyhalite one would find near the fluorides of the individual metals little crystals of gypsum, etc.

The hydrofluosilicic acid applied must be perfectly pure so that no silicicfluoride crystals be left upon the balsam plate of the object-glass when dried. The hydrofluosilicic acid prepared according to the direction of the analyst[1] is useless for our purpose for the reason that it is prepared and preserved in glass vessels so that it already contains various silicicfluorides, (whose metals come from the glass).

The hydrofluosilicic acid which I used was prepared by my assistant, Mr. Plaminek, by the introduction of fluosilica, obtained from fluoride of barium, sulphuric acid and pure quartz powder in a lead retort, into a platinum crucible filled with water, and this after moderate dilution was decanted in a caoutchouc flask for preservation. For transferring the drop of hydrofluosilicic acid upon the specimen (situated upon the balsam surface of the object-glass) I use a caoutchouc stick, which has a spoon-shaped rim upon the end, which may be used in dipping.

In regard to the strength of the hydrofluosilicic[2] acid, the following should be taken into consideration: If the acid is too weak most minerals are not acted upon at all, or only slightly; if it is too strong, then so many silicicfluorides will be formed, and, in addition, from the silicates so much silicious earth will be separated, that the field of vision becomes entirely dark or opaque, and no crystal forms can be distinguished—thus it is, for example, with a thin section of elæolite. In such a case the difficulty is easily remedied if one or two drops of water are added to a drop of hydrofluosilicic acid of the same size as before, for a new trial.

According to Mr. Plaminek's statement my hydrofluosilicic acid is about $3\frac{1}{2}$ per ct. strong. And this attacks thin sections of albite, orthoclase, muscovite, tourmaline, and pleonaste, and causes the formation of silicicfluorides.

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1. Anleitung zur qual. chem. Analyse. Fresenius. 1866. page 51. Und Stolba. Ueber die Bereitung der kiesel flussaure im Kleinen. Dingler's polytechn. Jour. B. CXCVII, page 336 (1870).

2. Stolba (J. f. prakt. Chemie XC, 193) has designed, upon the basis of two series of experiments, a table upon the specific gravity of dilute hydrofluosilicic acid of different values (to 3½ per ct.). He finds that the specific gravity increases regularly for every half per ct. Thus at 17.5°, for hydrofluosilicic acid of

	0.5 per ct.	1 per ct.	1.5 per ct.	2 per ct.	5 per ct.	10 per ct.
the specific gravity is	1.004	1.008	1.012	1.016	1.0407	1.0834

When the specimen has been treated with hydrofluosilicic acid, bring the object-glass (holding it always in a horizontal position) to a level place quite free from dust, and cover it with a tumbler or inverted glass under which has been placed a little cup of sulphuric acid. I place the object-glass with the specimen and acid upon the perfectly even and horizontal surface of a rather large mahogany chest, but must wait twenty-four hours for the complete drying of the drops, although in perfectly dry air only a few hours would be required.

A brief resumé of the detail of the operation may be given in the following words: The specimen placed upon an object-glass previously coated with a layer of balsam, is covered with one or two drops of hydrofluosilicic acid and allowed to lie intact and in perfect rest in a horizontal position and protected from dust until the drying of the drop is accomplished. And this entire preparatory work requires hardly five minutes time.

When the drop of hydrofluosilicic is dried the preparation is ready for microscopic examination.

MICROSCOPIC CHARACTERS FOR THE DETERMINATION OF THE SILICICFLUORIDE FORMS OF THE METALS APPEARING IN PETROLOGICALLY IMPORTANT MINERALS.

(Developed by hydrofluosilicic acid.)

The metals appearing in minerals of petrological importance are potassium, (cæsium, rubidium), sodium, lithium, calcium, strontium, barium, magnesium, iron and manganese.

The silicicfluoride of potassium (K_2SiF_6) (Plate I, Fig. 1, a, i) prepared from orthoclase, microcline (Plate I, Fig. 2 and Fig. 16), leucite (Plate II, Fig. 2), muscovite (Plate II, Fig. 5, at the right), biotite (Plate I, Fig. 1, e, m, n, r)* and some other minerals,[1] magnified to four hundred times the original size, appeared always in sharp-edged crystals with smooth surfaces and usually small. These crystals belonged to the tesseral system and always remained dark between the crossed herapatites.

1. Saltpeter, sylvine, potassium-alum.

*In this translation the English letters are substituted for the Greek, viz.: *a* for alpha, *e* for epsilon, *i* for iota, *s* for sigma, *n* for nu, *m* for mu, *r* for rho, etc.

The most common form was the hexahedron whose little crystals were occasionally united[1] in pretty chandelier-like groups; quite frequently the combination forms $\infty 0 \infty .0$; or $\infty 0 . \infty 0 \infty$ made their appearance, the latter especially when the specimen had been treated first with fluohydric gas and then with hydrofluosilicic acid.

Upon the imperfect development of the larger crystal forms the surfaces appeared in the form of steps or displayed a beautiful structure of scales.

According to Marignac[2] and Stolba[3] the silicicfluoride of potassium crystallizes in octohedrons (probably from the pure water solution).

According to Stolba's statement one part of silicic fluoride of potassium requires 833.1 parts of water at a temperature of 17.5° and 104.8 parts of boiling water.

In hydrochloric acid this silicicfluoride is the more soluble the stronger the acid is: for according to Stolba's experiments[4] HCL of the strength of 26.5, 14.1, 9.6, 2.7, 1.8 per cent. dissolves of silicicfluoride of K 237, 340, 357, 376, 409 parts, at the temperature of 14 degrees.

At 17.5 degrees the specific gravity of this fluoride is 2.6655 —2.6649.[5]

The silicicfluoride of sodium (Na_2SiF_6) (Plate I, Fig. 4), prepared from albite (Plate II, Fig. 1), pericline, the oligoclase feldspars (Plate I, Figs. 17-19), nepheline (Plate II, Fig. 3), scapolite (Plate II, Fig. 4), and several other minerals,[6] appeared always in short hexagonal prisms which were either terminated by basal planes or more frequently by a blunt pyramid, and whose vertical edges were often truncated

1. Beautiful groups of this kind were obtained from the aqueous solution of feldspathic mixed portions of syenite from Plauenschen Grunde, near Dresden, and of amazonite from Miask, when treated with fluohydric gas. (Plate I, Fig. 2.)

2. Comptes rendus, xlv, 650.

3. Jour f. prakt Chemie, xc. 193.

4. Jour. f. prakt. Chemie, ciii, 396.

5. The silicicfluoride of cæsium (Cs_2SiF_6) crystallizes from a dilute solution (through voluntary evaporation) into cubes with truncated corners. At 17 degrees it dissolves in 166 parts of water and more easily in hot water. In alcohol it is insoluble. (*C. Preis. Jour. f. prakt. Chemie.*, ciii, 410.)

The silicicfluoride of rubidium (Rb_2SiF_6) crystallizes in the combination forms $\infty 0 \infty . 0 . \infty 0$, dissolves at 20 degrees in 614 parts of water, and at 100 degrees in 73.8 parts water. In acids it is easily soluble. In spirits of wine insoluble. Its specific gravity at 20 degrees is 3.3383 (*Stolba. Jour. f. prakt. Chemie.* cii. 1).

The silicicfluoride of thallium, prepared by treating the carbonate of thallium monoxide with hydrofluosilicic acid and evaporating the solution, crystallizes in tesseral, six sided tablets, or distorted octohedrons which are easily soluble in water. (*Gmelin's Handb. d. anorgan. Chemie.*, 1875, *Bd.* 3, *p* 193).

6. Rock-salt, sodium nitrate, borax, cryolite, phosphorus-salt.

by secondary pyramids, (∞P2). Imperfectly formed crystals of silicicfluoride of sodium had barrel-shaped, oval or cylindrical forms.

Between the crossed Nicols appeared all the forms of silicicfluoride of sodium colored yellow or blue; they were all dark except those arranged at right angles with the main axis.

Marignac (Jahresb. über Fortschritte der chemie,) etc., v. Kopp u. Will, 1858, [für 1857], p. 129,) takes the crystals of silicicfluoride of sodium for holohedral forms (∞P.0P. P. ∞P2) and adds ∞P: P = 123 deg. 3 min.

According to Stolba (Jahresb. über Fortsch. d. Chem. etc., 1858 [für 1857] p. 129) one part of the silicicfluoride of sodium requires for its solution 153.3 parts of water at a temperature of 17.5 deg. and 40.66 parts of boiling water; it easily forming an oversaturated solution.

Its specific gravity is 2.7547.

The presence of a larger quantity of silicicfluoride of calcium has a noticeable influence upon the length of the hexagonal prisms of silicicfluoride of sodium. I have prepared three specimens differing in the quantity of both silicicfluorides. In the first specimen were two parts by weight of the sodium-salt, with one part, by weight, of the calcium-salt; in the second specimen equal parts, by weight, of both silicicfluorides, and in the third specimen one part, by weight, of silicicfluoride of sodium and two parts, by weight, of silicicfluoride of calcium The crystals of silicicfluoride of sodium in the second specimen were one-half longer than those in the first, and those in the third were double the length of those in the first. (Plate I, figure 7 and figure 8.)

The silicicfluoride of lithium prepared from the rose-red lithia-mica from Roznau in Moravia, and from a light lithia-iron mica from Zinnwald (Plate II, fig. 5, at the left) appeared, when magnified to 400 times, in minute, sharp-edged, six sided pyramids, which usually presented the appearance of a regular blunt, hexagonal pyramid. At times, however, a couple of surfaces were developed to such an extent, that the other surfaces of the distorted rhombic or rhomboidal forms could hardly be distinguished.

The silicicfluoride of lithium (Plate I, fig. 3) represented from the preparation of Prof. Stolba by recrystallization presented circular forms, notched or undulating at the edge, fibrous, striated within or ornamented by several concentric circles.

Occasionally. by the overlying of imperfectly formed crystal-prisms, these forms appeared to resemble cauliflower buds or blossoms and among them were found many little tablets with a regular six or eight sided appearance, sometimes also, ornamented with concentric inner circles, which remained dark between crossed Nicols. If one should consider the latter hemihedral forms of the hexagonal system, they would be regarded as combination forms of 0R.—R.∞R. and 0R. R.—R.∞R.∞P2. Besides these there were found in the preparation a few very short, hexagonal prisms.

According to Marignac (Ann. Minn. [5], XV, 221)[1] the silicic-fluoride of lithium ($Li_2 SiF_6 + 2H_2O$) is monoclinic and appears in the form of combination ∞P.0P.P̄∞.⅓P̄∞.—P̄∞. In the clinodiagonal chief section is ∞P: ∞P=83° 38′, 0P: ∞P=108° 14′, 0P: P̄∞=96° 36′, 0P:—P̄∞=139° 42′. The crystals are quite easily cleavable parallel P̄∞, less easily parallel 0P. They decompose in the air.

According to Stolba the silicicfluoride of lithium may be obtained by evaporating a solution of carbonate of lithium in a slight excess of hydrofluosilicic acid. The salt crystallizes, after voluntary vaporization, in transparent, four-sided, obliquely truncated prisms or irregular six-sided tablets which dissolve at a moderate temperature in 1.9 parts of water, also in alcohol but are insoluble in ether or benzol. Their specific gravity is 2.33.

The silicicfluoride of calcium (Plate I, Fig. 6), prepared from oligoclase feldspar (Plate I, Figs. 17–19), anorthite (Plate I, Fig, 20), wollastonite, amphibole (Plate II, Fig. 7), diallage (Plate II, Fig. 8), scapolite (Plate II, Fig. 4), epidote and other minerals[2], forms peculiar, long, pointed, thornlike crystals, branching and usually spindle-shaped; sometimes, also, in the form of rhomboidal tablets which are often united in star-like or other groups, and in most cases are recognized at the first glance. Many of the spindle-shaped forms are bounded by six lateral planes and terminated by one basal plane so that they appear like very sharp rhombohedrons truncated by basal surfaces. At times they appear very abundant in six-sided forms which resemble pointed rhombohedrons (about—2R of calcite).

A characteristic feature of these crystal forms (of silicicfluoride of calcium) produced by hydrofluosilicic acid from thin

1. Und Jahresber ü. d. Fortschr. d. Chem. 1860 (pro 1859) 107.
2. Calcite, dolomites, polyhalite, anhydrite, gypsum, fluorite-albite, titanite, scheelite.

sections or fragments of mineral is the lack of sharp rectangular edges and smooth surfaces and the presence very often of a peculiar grayish or brownish dusty character, probably because of the inclusion of delicate bubbles.

The silicicfluoride of calcium prepared by Prof. Stolba, forms mostly four-sided, rarely six-sided prisms (Plate I, Fig. 5) and needles which are terminated by an oblique terminal plane or by one prominent and several small oblique planes. These crystal needles are often united in radiated, spherical groups resembling warts.

According to Marignac (Comptes rendus XLVI—854 und Jour f. prakt. Chem, LXXIV—161) the silicicfluoride of calcium ($Ca\ Si\ F_6 + 2\ H_2\ O$) crystallizes in monoclinic, microscopic crystals which are probably isomorphous with silicicfluoride of strontium.

According to the report of my colleague Herr Stolba, and my own experiments, the silicicfluoride of calcium is readily soluble in water.

The silicicfluoride of strontium prepared from strontianite by means of hydrofluosilicic acid, and from the preparation of Herr Stolba by recrystallization, (Plate I. Fig. 9) appears in sharp-edged, smooth-surfaced prisms and needles which can scarcely be distinguished from the crystal forms of silicicfluoride of calcium produced from the preparation of Herr Stolba, except that they occasionally exhibit a greater abundance of planes.

According to Marignac (Jahresb. über Fortschr. d. Chem. von Kopp and Will 1859 [für 1858] pag. 145 u. 1860 [für 1859] pag. 107) the silicicfluoride of strontium ($Sr\ Si\ F_6 + 2\ H_2\ O$) is monoclinic. In the clinodiagonal principal section are ∞P: $\infty P = 84° 16'$ and $0P$: $\infty P = 103° 13'$.

The silicicfluoride of barium prepared from calciferous witherite (in the form of a microscopic preparation) by means of hydrofluosilicic acid, presents, when magnified four hundred times, extremely slender sharp pointed needles, whose form although sharp-edged and smooth-surfaced is very hard to determine on account of the minuteness of the crystals.

According to Stolba (Jour f. prakt. Chemie XCVI. 22) the silicicfluoride of barium presents microscopic elliptical, cruciform, divergent and roundish groups. Prepared from a dilute solution slowly evaporated it appears in slender needles.

One part of silicicfluoride of barium requires for solution, according to Stolba, 3731 parts of water at a temperature of

17.5°, 3313 parts at a temperature of 21° and 1175 parts of boiling water. It is easily soluble in acids and in salts—namely, in 448 parts 4½ per cent muriatic acid and in 272 parts 8 per cent nitric acid. Its specific gravity at 21° Temp. = 4.2741.

The silicic fluoride of magnesium prepared from humite, chondrodite (Plate I, Fig. 10), talc, biotite (Plate II, Fig. 6), rubellan, hypersthene, bronzite (Plate II, Fig. 9), and several other minerals,[1] appears in rhombohedrons whose vertical angles are usually truncated through the basal surface, or in combinations of R. ∞P2, R. ∞P2. 0R and other rather complicated rhombohedral forms.

All its crystal forms have sharp edges and smooth faces.

Upon two little crystals (of the microscopic preparation) having the combination R. 0R, which were found in an almost vertical position and remained dark between the crossed herapatites, I was able to measure the angles of horizontal projection. I found angles from 119° to 121°, therefore about 120°. In other positions between the crossed herapatites the crystals appeared colored red, yellow and blue.

Quite often the silicicfluoride of magnesium appears in rhombohedrons distorted on one edge, also in conical, cruciform, feathery and other imitative forms which sometimes have in the entire preparation the same regular arrangement, and every projection of which tends to terminate in an imperfectly formed rhombohedron.

The silicicfluoride of magnesium is quite easily soluble in water.

The silicicfluoride of iron ($FeSiF_6$ [$+6H_2O$?]) prepared by dissolving iron in hydrofluosilicic acid and evaporating the solution (in an iron crucible) in the air, usually crystallizes in pale bluish-green regular six-sided prisms (∞P2) which terminate in a rhombohedron.[2] Prepared in the form of a microscopic preparation (Plate I, Fig. 15) from the salt obtained from Herr Stolba and from siderite, it shows many individual and combined forms, also distorted forms of the hemihedral hexagonal system which appear colorless and can hardly be distinguished from the crystals and imitative forms of the silicic fluoride of magnesium.

1. Bastite, pennite (Plate I, Fig. 11), cordierite (Plate II, Fig. 10), olivine (Plate II, Fig. 11 and Fig. 12), brucite, mesitine, magnesite (Plate I, Fig. 12).

2. *Berzelius. Gmelin's handbook of inorganic chem*, 1875, *B.* 3, *p.* 403. On the appearance of the silicicfluoride of iron, see *Stolba. Sitzb. d. math. naturw. Cl. d. k. böhm. Ges. d. w. v. 27 oktbr.* 1876.

It is easily soluble in water.[1]

The silicicfluoride of manganese ($MnSiF_6+6H_2O$) appears according to Marignac (*Ann. Chem. ph.* [3], LX, 301, *u. Jahresber. ü. Fortschr. d. Chemie* 1861 [*pro.* 1860] *p.* 98) in pale reddish white crystals of the hemihedral hexagonal system, in the combination form $\infty P2.R$. According to the same investigator $R : R = 128° 20'$.

Prepared in the form of a microscopic preparation (from the salt obtained from Herr Stolba and from dialogite, through the treatment of the latter with hydrofluosilicic acid) it appears in the same forms as the silicicfluoride of iron and the silicicfluoride of magnesium so that a separation of the three silicicfluorides according to type forms would hardly be successful.

Separation of the Silicicfluoride forms of Calcium and Strontium by means of Sulphuric acid (and more particularly as a test for the presence of Calcium).

If these silicicfluorides are treated with concentrated chemically pure sulphuric acid which has been diluted with an equal volume of water the crystals of the silicicfluoride of calcium are, after a few seconds, surrounded by a thick beard of colorless monoclinic needles, (gypsum crystals), while upon the crystals of strontium only a very slow solution into little grains (among which, a very few, extremely small, short needles [celestine?] are seen in some places) is to be noticed.

After some hours the preparation containing the silicicfluoride of calcium presents an aggregated mass of striated, very long, monoclinic needles and prisms, while in the preparation containing silicicfluoride of strontium nothing new is to be noticed except a few shapeless crystals.

I perform this experiment in the following way: Upon a watch crystal by means of a very finely drawn out tube, I place a few drops of concentrated chemically pure sulphuric acid; upon a second watch glass an equal number of drops of water of the same size as the drops of acid. Now I put a few drops of the mixture of the two substances upon the silicicfluoride, formed from the specimen, and place the cover-glass upon it and bring the preparation upon the table of the microscope. At this point one must move it very carefully, that the table of

1. Silicicfluoride of iron ($Fe_2Si_3F_{18}$) prepared by dissolving ferric hydrate in hydrofluosilicic acid and evaporating the solution, forms a yellowish jelly and after complete drying a half-transparent blood-red gumlike mass, which dissolves easily in water. (*Gmelin's Handb. d. anorg. Ch.*, 1875, *p.* 403.)

the microscope may not be soiled. Later on it will be noticed that the balsam plate is colored red (blood red) by the sulphuric acid; but since it does not lose its transparency this is no hindrance to the success of the experiment.

It might be noticed here that hexagonal prisms of pure silicicfluoride of sodium had, after one and one-half hours in sulphuric acid diluted with an equal volume of water, undergone no change except that they had assumed a slight reddish color. If on the contrary—prepared openly under other conditions which will be explained hereafter— they contained calcium, they dissolved, the more rapidly the more calcium they contained. Monoclinic gypsum needles shot up and increased quite rapidly upon the sides of the hexagonal prisms. The silicicfluoride of calcium, now changed into a sulphuric acid solution, separated again gradually into short hexagonal prisms, whose mass was greatest about the third day after the experiment; but about the fifth day after the experiment these crystals of silicicfluoride of sodium formed by crystallization in the sulphuric acid (diluted with an equal volume of water) had entirely vanished.

Separation of the Silicicfluorides of Magnesium, Iron and Manganese.

a. By the action of chlorine gas.

Place the object-glass upon which are the silicicfluorides of magnesium, iron and manganese, on a low frame (for example upon an inverted porcelain crucible) contained in the chlorine gas apparatus (which will be represented and described later) and heat the apparatus gradually so that small but numerous bubbles may be developed from the manganese muriatic acid solution. After the development of gas has continued from one and one-half to two minutes, the preliminary experiment may be considered complete.

Take out the object-glass, dry it carefully and place it upon the table of the microscope. In order, however, to protect the object-glass in all possible cases against accident, the silicicfluoride treated with chlorine gas may be furnished with a cover glass.

Upon observing all these silicicfluorides under the microscope, one finds that the silicicfluoride of iron has taken an intense citron-yellow color, without having lost much of the sharpness of its crystal forms. The silicicfluorides of magnesium and manganese on the other hand, have remained almost

colorless. The first shows a streak of grey, the second of red, and while the silicicfluoride of manganese has suffered a transformation into little crystals, melted prisms, tablets and grains, or seems entirely dissolved, the crystals of silicicfluoride of magnesium have only melted a little at the corners, so that they remain almost unchanged.

b. By means of ammonium-sulphide gas.

In a beaker place an inverted porcelain crucible, upon which lay the object-glass on which are the three silicicfluorides. Pour into the beaker a little pure sulphide of ammonium and cover with a glass plate; or yet simpler, hold the silicicfluorides over the opening of a flask filled with pure sulphide of ammonium.

In both experiments it will be noticed that the silicicfluoride of iron changes quite rapidly to blackish-gray with a peculiar metallic bronze lustre; while the silicicfluoride of manganese appears reddish or brownish-white and the silicicfluoride of magnesium grayish-white. Under the microscope the crystals of silicicfluoride of iron are quite black, in the thinnest places blackish-yellow; those of magnesium grayish-white, and those of manganse a peculiar reddish-gray, the last being sometimes changed into a granular mass. Near the forms of the two last named silicicfluorides, newly formed crystals of silicicfluoride of ammonium were noticed.

Completion of the preparation for the purpose of its preservation.

If it is desirable to preserve the preparation carrying the crystallized silicicfluorides as a proof of the result of the experiment, a cover glass must be fastened upon it.

If the investigated object is a thin section whose surface acted upon by hydrofluosilicic acid show distinct etchings it is better to cover it not with Canada balsam but with a thin layer of air, which can be managed by laying the cover glass directly upon it and cementing in at the margins with Canada balsam, made viscous by previous warming.

If the specimen is a thin section, upon which no peculiar etchings are observable, it can be covered with Canada balsam in the usual way and furnished with a cover glass. Yet the following method is advisable: lest the silicicfluoride crystals may be misplaced by the application of the Canada balsam and the pressure of the cover-glass, viz: use a rather weak solution of balsam—as one part Canada balsam and two parts chloroform

—lay the cover-glass carefully upon it and press it slowly and softly.

If the object is a grain of mineral, which was not wholly dissolved in the drop of hydrofluosilicic acid, remove the remnant with clean pincers if it would prevent by its projection the application of the cover-glass, and complete the preparation in the usual manner.

Remarks upon the Investigation of some of the petrologically important mineral groups according to the foregoing method.

a. Investigation of the Feldspar group.

Among the branches of the feldspar group, orthoclase (sanidine), microcline and albite (pericline), in the form of cleavage sections, are least affected by hydrofluosilicic acid; they, therefore, usually require a repeated treatment with this acid, or better still a treatment with fluohydric gas, which will be discussed later.

But if these same minerals in the form of thin sections are treated with strong hydrofluosilicic acid, the first attempt to gain knowledge of their chemical nature is apt to be sufficient. Orthoclase and microcline (Plate I, Fig. 16) which can easily be distinguished from each other by their internal structure, offer, on treatment with hydrofluosilicic acid tesseral crystals ($\infty 0 \infty$. 0, $\infty 0$. $\infty 0 \infty$) of silicicfluoride of potassium, and near them are often found very many tiny hexagonal prisms and tablets of silicicfluoride of sodium. Albite and pericline furnish only silicicfluoride of sodium (observed when magnified to the 400th power). Oligoclase poor in calcium, treated with hydrofluosilicic acid, gives (magnified to the 400th power) the same crystals as albite and pericline, extremely small but usually numerous hexagonal tablets (and very short prisms), which sometimes crowded closely together resemble very tiny spherical forms; but near them scattered individual spindle-shaped or other crystals of silicicfluoride of calcium are usually noticed.

Oligoclase rich in calcium furnishes with similar treatment distinct hexagonal prisms and numerous spindle-shaped forms of silicicfluoride of calcium. (In regard to the latter, however, it must not be overlooked that it is often necessary to adjust the microscope very carefully till the field of vision becomes dark, when the thin section specimen is most plainly visible).

In thin sections of andesine, which have been treated with hydrofluosilicic acid, beautiful hexagonal prisms of silicicfluoride of sodium are found, besides characteristically developed forms of siliicicfluoride of calcium.

In the varieties of andesine richest in lime the forms of both silicicfluorides appear to preserve, tolerably well, their quantitative relations, while in labradorite the silicicfluoride forms of calcium are in excess. And calcium appears in just so much greater degree in anorthite as it contains less of sodium. It will not be superfluous to remark here that the smaller the quantity of sodium present which is successful in development, the more easily the feldspar specimen is decomposed by hydrofluosilicic acid.

In order to be able to determine the individual members of the feldspar family as exactly as possible let a comprehensive series of the most important of these members—for which exact chemical analyses have been made—be prepared, which will give a clear view of the various quantitative proportions of the silicicfluoride forms of calcium and sodium in feldspars, obtained by the action of hydrofluosilicic acid; and let this series of preparations be used for comparison with every new specimen. Then will one be in a position to judge with which preparation the specimen under investigation coincides most perfectly and so to which feldspar branch it stands most nearly related. Moreover the feldspar specimens represented upon Plate I, Figs. 17–20, afford some interesting points.

b. Distinction of apatite from nepheline.

For the distinction of these two very similar minerals Streng has given us[1] perfectly satisfactory methods in thin sections, founded upon the application of molybdate of ammonium mixed with nitric acid and of concentrated muriatic acid as reagents. Hydrofluosilicic acid also gives satisfactory results.

The cross sections of nepheline become darker than those of apatite through the separation of the silica and the presence of numerous crystals of silicicfluoride of sodium, sometimes also silicicfluoride of potassium, while around the apatite may be noticed clusters and groups of striated long prisms and needles of silicicfluoride of calcium with the characteristic etchings. (Plate II, Fig. 16.)

c. Distinction of the minerals: enstatite, bronzite, hypersthene and diallage.

1. Tschermak's Mineralog. Mittheilungen, 1876.

All these minerals are characterized in their thin sections by a common feature, a parallel, sharply rectilinear, very close grooving and a slight dichroism, and may therefore give cause for confounding them; but treated with hydrofluosilicic acid they can easily be distinguished by the silicicfluoride crystals of the newly formed products.

Upon diallage the silicicfluoride of calcium and also those of magnesium and iron appear numerously. In the other minerals only the silicicfluorides of magnesium and iron are to be noticed. And if these are treated with chlorine gas or with sulphide of ammonium gas the quantitative proportions of the silicicfluorides of magnesium and iron can be estimated, so that one can judge which of the three minerals he has before him.

d. Distinction of amphibole and biotite in thin sections.

Although amphibole and biotite at first sight can be easily distinguished from each other it is not always the case in thin sections. For the thin sections of both minerals have often similar outlines and are usually marked by the same color and by parallel, rectilinear grooving, and always by strong dichroism. But after treatment with hydrofluosilicic acid silicicfluorides of magnesium, iron and calcium appear upon the amphibole thin section, and silicicfluorides of magnesium, iron and potassium upon the thin section of biotite.

e. Distinction of lithia-mica, lithia-iron-mica and ordinary potassium-mica or muscovite.

These three varieties of mica can scarcely be distinguished by crystallographic or by optical properties.

If, however, they are treated with hydrofluosilicic acid, there appear upon the surface of the lithia-mica (for example from Roznau, in Moravia) very tiny, six-sided pyramids of silicicfluoride of lithium, sometimes distorted by an abnormal development of two planes, which in the second variety of mica (for example, lithia-iron-mica from Zinnwald) are accompanied by crystals of silicicfluoride of iron. Upon muscovite (for example an ordinary potassium-mica from Greenland) only solitary hexahedral crystals of silicicfluoride of potassium can be noticed. Especially do these varieties of mica belong to those minerals which are acted upon with the greatest difficulty by hydrofluosilicic acid.

II. Application of Fluohydric Gas for the Identification of Alkali Metals in Silicates, Especially in Those Which are Only Slighthy Affected by Hydrofluosilicic Acid.

Principle of the Method.

If a silicate is treated with fluohydric gas, its metals will be changed into silicic fluorides, single or double fluorides, of which one can easily become convinced by observing the fermentation[1] when the specimen is further treated with concentrated sulphuric acid.

By the action of hydrofluoric gas upon alkaline silicates silicic fluorides of the alkalies are formed, which, extracted with boiling water, can be brought to crystallization by evaporating the solution to one drop and placing this upon the object-glass, and can then be observed under the microscope. These forms are not essentially different from those produced by hydrofluosilicic acid.

In this way the most positive determination can be made for the smallest quantity of alkali in silicates, especially of potassium.

If the specimen treated with fluohydric gas and afterward boiled down in water contained alkaline earths besides the alkalies, usually only a small portion of the alkaline earths is dissolved, in the form of silicic fluorides in the aqueous solution, the larger portion remaining in the specimen.

Several experiments which I made upon feldspar specimens for the purpose of separating all the alkalies of that part of the specimen changed by the fluohydric gas as silicic fluorides and retaining in the specimen the greater portion of the calcareous earths as a fluoride, led approximately to this rule: That the specimen (of 2—6 □ ^{mm} D.) treated with fluohydric gas should be boiled upon a platinum dish (of 45 ^{mm} D,) filled with water, as many minutes as the upper surface of the specimen contains □ mm. And the calcium fluoride remaining in the specimen can then be dissolved in concentrated sulphuric acid and made visible in the form of gypsum crystals so that its quantitative relation to the alkalies can be estimated.

But if the specimen treated with fluohydric gas contains only alkalies (and no alkaline earths) then, after a complete removal of the silicic fluorides of the alkalies (by boiling away

1 As a result of the development of hydrofluoric gas and silicic fluoride at the same time.

in water), on further treatment of the specimen with sulphuric acid no fermentation and especially no devlopement of fluohydric gas is observed.

Before I was certain of the application of hydrofluo silicic acid, as the most suitable reagent for the determination of individual metals in minerals, I used fluohydric gas and sulphuric acid for the detection of single members of the feldspar family and in the following manner:

After I had taken all the silicic fluorides from that portion of the specimen changed by fluohydric gas by means of boiling with water, I allowed these silicic fluorides to crystallize upon an object glass. I then decomposed the calcium fluoride remaining in the specimen by means of sulphuric acid, and allowed the calcium sulphate to make its appearance on a second object glass in the form of gypsum crystals. By comparing the quantitative proportions of the crystals of silicic fluoride and the gypsum crystals I was able to draw a corresponding conclusion regarding the quantitative relations of the alkali metal (sodium) to calcium.

Moreover, I sometimes tried the following plan: I treated two specimens of an equal size, and equally changed by fluohydric gas, with equal drops of sulphuric acid, one piece after the other, after the boiling with water, and noted in each case (*a*) the continuance of effervescence, or development of gas, and (*b*) the quantity of gas bubbles developed, enclosed by sulphuric acid.

From the relations of the data preserved, I was able to draw a correct conclusion regarding the quantitative proportions of sodium to calcium in oligoclase feldspar; for by treatment of the specimen, changed by fluohydric gas, with sulphuric acid before boiling away with water, all the fluorides were decomposed, while by treatment after boiling away with water, only the undissolved calcium fluoride remained for separation.

Experiments made upon a specimen of chiastolite with fluohydric gas, showed through the effervescence of the specimen in sulphuric acid that the clay was also changed into a fluoride, which was dissolved in water but not crystallized.

EXECUTION OF THE METHOD.

Apparatus for the development of fluohydric gas and for the reception of the specimen.

In order to develop the fluohydric gas and cause it always to act upon the thin section or specimen of whatever kind,

I use a platinum crucible of the size of Fig. 1. In the crucible is a frame of platinum wire which supports a platinum plate pierced with an annular opening, with upturned edges; the margin of the plate and one circular opening in the center also have upturned edges. This plate serves for the reception of the specimen.

Fig. 1 represents a section of the crucible with the frame and plate, and Fig. 2 the surface of the plate.

Fig. 1.

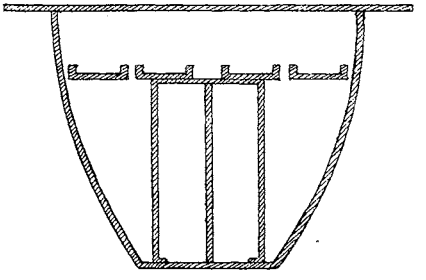
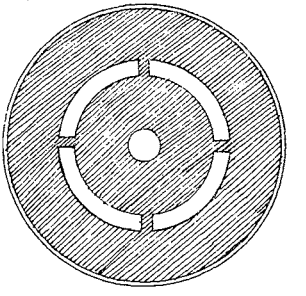


Fig. 2.



Instead of the plate a narrow strip of platinum may be used to receive the specimen.

For covering the crucible I use a circular piece of platinum which extends over the edge of the crucible, and is furnished, upon that side which is next the crucible, with a coating of wax (to be warmed before each experiment), in order to make it adhere firmly to the crucible. To assist in this, a weight is laid upon the piece of platinum acting as cover.

The thin sections or pieces to be investigated are so placed upon the platinum plate (or strip of platinum,) that little spaces are left between them so that a greater or less number (from 10 to 20) of specimens, according to their size, can be exposed at once to the action of fluohydric gas.

Only, at this point, it is necessary to note the relative positions of the specimens in order to avoid errors in subsequently confusing them.

Treatment of the specimen with fluohydric gas.

On the floor of the platinum crucible, scatter a half gram of pure finely powdered fluoride of barium,[1] place the platinum frame in position and pour upon the inner surface of the crucible enough concentrated chemically pure sulphuric acid to entirely cover the fluoride of barium; then sieze quickly (because the

1. Mercantile fluoride of barium needs to be mixed with barium chloride or sulphate of baryta.

escape of fluohydric gas has already begun) with a pair of pincers the turned up edge of the platinum plate carrying the specimens, lay this upon the frame of platinum wire, cover the crucible with the above mentioned waxed platinum cover and place a weight upon it in order to hold the platinum cover firmly over all.

The entire apparatus covered with a glass tumbler or an inverted beaker may now be left standing in any convenient place.

If a strip of platinum has been used for holding the specimens instead of the platinum plate, sufficient space must be left next the strip for the sulphuric acid to be poured in after the introduction of the specimens into the crucible, in which case it is necessary to close the crucible as quickly as possible to prevent the escape of the fluohydric gas into the air.

In order to allow the fluohydric gas to act upon the specimen as long as possible I am accustomed to leave the apparatus closed until the second day, when it is opened in a draught cupboard.

After the settling of the fluosilicium and the removal of the superfluous fluohydric gas, the platinum plate with specimen is taken out and the specimens closely examined to see if any of them are spotted by the effervescence of the fluoride of barium or by the sulphuric acid.

Boiling away in chemically pure water of the specimen changed by the action of hydrofluoric acid. Extraction and crystallization of the silicic fluorides of the alkalies. Their appearance under the microscope.

Cut from the thin section acted upon by hydrofluoric gas a specimen of 3—6 □ ^{mm}, or if the specimen acted upon was a fragment, cut a piece of the size of a small pea and lay it in a perfectly clean platinum dish, fill the latter with chemically pure water, take it up with iron tongs and hold it in the flame of a spirit lamp until the water has boiled at least as many minutes as the surface of the specimen contains □ ^{mm}. By gentle movements of the vessel take care that the specimen moves about in the water.

After the boiling remove the specimen from the water with perfectly clean pincers, wash it with water and lay it one side upon an unused object glass.

Evaporate the aqueous solution at not too high a temperature to one large drop, place this upon the thin (hard) balsam surface of an object glass and let it dry in a place free from dust.

During the drying the silicic fluorides separate in beautifully formed crystals which, after complete drying, can be examined with the microscope (most successfully when magnified to the 400th power.)

The silicic fluoride of potassium appears in hexahedrons, which, at times, form splendid cruciform or chandelier-like groups, or in combination forms of the hexahedron with the octahedron, or of rhombic dodecahedron with the hexahedron. Often these are imperfectly formed crystals of the tesseral system, distorted in the line of the axes; but their opacity between the crossed Nichols seems to easily distinguish them from the silicic fluorides of all other metals, (unless it be the similarly formed silcic fluorides of metals that occur very infrequently: cæsium, rubidium, thallium.)

The silicic fluoride of sodium appears in hexagonal prisms which are terminated by basal planes, or by a blunt pyramid, whose vertical edges are sometimes blunted by the narrow planes of a secondary prism. Yet quite often regularly formed crystals of silicic fluoride of sodium, barrel-shaped, oval, elliptical and cylindrical forms, which belong to the same silicic fluoride metal, are found near these.

From all the specimens of oligoclase feldspar, I obtained near the above mentioned forms of sodium, a small quantity of long pointed needles, or long thin four sided prisms terminated by a couple of inclined planes, which I think I may regard as silicic fluoride forms of calcium. since the above mentioned feldspar contains, besides sodium, calcium and aluminium, no other constant metal, and since from pure clay silicates (chiastolite and kaolin) no silicic fluoride appeared in such needles and prisms. yet I always found these forms in small quantities in anorthite and wollastonite.

The silicic fluoride of sodium, prepared from the specimen of oligoclase feldspar, appeared commonly in imperfectly formed, barrel-shaped, oval and cylindrical crystals, which sometimes, having pierced through the striated mass of needles and prisms of silicic fluoride of calcium, presented splendid groups.

Treatment of the specimen boiled in water with sulphuric acid

Near the specimen, freed from silicic fluorides by boiling in water, and which has been laid upon an object-glass, place one or two drops of sulphuric acid and lay over it such a cover-glass that the specimen will be covered with the acid. Now observe

(eventually also in the microscope) whether gas comes off or not. If no gas is formed then heat the object-glass gently some ten or fifteen seconds, touching the point of the flame of the spirit lamp with the edge of the object-glass.

If no gas is developed in the last named case, there are no metallic fluorides existing in the specimen boiled with water.

If, for example, the specimen was a member of the feldspar family, and if the aqueous solution has shown only silicic fluorides of the alkaline metals, then one may be certain that the specimen is a pure potassium or natron feldspar (orthoclase sanidine or microcline, or albite, or pericline, according as the silicic fluoride crystals obtained belong to potassium or sodium). If only a very weak gas development is noticed in the feldspar specimen boiled with water, and the specimen is very thinly covered with gas bubbles, or surrounded by a thin, spongy bubble-wreath, then one may assume that he has examined a member of the oligoclase series. But if a strong and continuous development of gas and of gas bubbles occurred, then one has,—according to the quantity of silicic fluoride crystals of sodium obtained from the specimen—a member of the andesine or labradorite series. Anorthite may in most cases be recognized by treating the feldspar specimen before boiling with water, since it shows no effervescence, but only a slow but strong development of tolerably large bubbles of gas is noticed, while all oligoclase feldspars treated with hydrofluoric gas effervesce in sulphuric acid, the more energetically the more soda they contain.

In order to estimate correctly the proportion of sodium which has been obtained in the form of silicic fluoride crystals, to the calcium fluoride remaining in the specimen, pour off the drop of sulphuric acid with the rest of the specimen from the object glass, into a clean platinum dish, remove the specimen and evaporate the sulphuric acid by heating the platinum cover. Dissolve the residuum which may be left in a large drop of water, place it upon a clean object glass and allow it to dry. From the quantity of gypsum crystals formed, which can now be examined upon the object glass, by aid of the microscope, in proportion to the quantity of silicic fluoride crystals of sodium, which one has obtained from the aqueous solution, a safe conclusion can be arrived at as to which series the feldspar specimen belongs to.

Remarks on the application of hydrofluoric gas for purifying turbid thin sections, bringing forth clearly the mineral outlines as well as the mineral structure, and on the identification of colorless inclusions in colorless minerals.

It frequently happens that thin sections of rocks which have attained the greatest possible thinness are still unfit for microscopic investigation by the presence of several dark mixed substances disseminated through the entire mass. In such cases the petrologist must next solve the problem of how to remove the dark substances without crumbling the section.

In my earlier work I used hydrochloric acid for this purpose. I fastened the turbid thin section to an object-glass by means of Canada balsam, and let it lie in a little cup containing hydrochloric acid several hours or days, according to the acid's action on the thin section. But since the balsam plate under the thin section became dimmed and opaque by the hydrochloric acid, I put upon the other cleaned and dried half of the object-glass some new balsam, to which I gave by heating the necessary consistency, and shoved over upon it by careful warming, the easily freed thin section. I could now cover it with a new balsam layer and apply a cover-glass, as is customary in preparing a thin section for investigation.

In this way I obtained satisfactory results. Thus, for example, I succeeded in removing the calcite from the dark thin sections (quite unfit for microscopic study) of grayish white calcareous aphanite (diabase amygdaloid) from Krusná Hora, near Beraum, and then with the thin section, now quite transparent as well as perforated, in proving that the original substance of the calcareous aphanite is identical with the greenish black heavy diabase of the same locality.

Fluohydric gas also renders similar service, if the thin section is either first boiled with water or treated with sulphuric acid according to its mineral properties. Thus the thin sections of a compact porphyry, quite opaque but thin as paper, on treatment with fluohydric gas and subsequent boiling with water, became quite clear and bright and the fragile feldspathic forms scattered through the close quartz grains were readily recognized; moreover sections of nepheline phonolite, dark but thin as paper, required besides treatment with fluohydric gas and water, sulphuric acid in order to become perfectly clear and transparent.

An interesting appearance presented itself to me in a thin section of phonolite from the Wachholder Mts. at Teplitz, where

the ground mass consisting of a homogeneous polarizing substance (without recognizable outline) is, after successive treatments with hydrofluoric gas, sulphuric acid and water, resolved into rectangles and hexagons of nepheline. And upon this section of nephline appeared a significant scaly structure of which nothing was before noticed. It is evident that Möhl's nepheline-glass was represented here in plain sections.

Before Des Cloizeaux's epoch-making works, "Mémoire sur l'existence, les propriétés optiques et cristallographiques, et la composition chemique du microcline etc." (Extrait des Compt. rendus, etc. t. LXXXII, 17. Avril 1876; and Extrait des Ann. de chimie et de Phys., 5th séries, t. IX., 1876) were by the kindness of the distinguished author placed in my hands, I had already observed the characteristic microstructure of amazonite from Miask, and of microline from Karlsbad[1] (from the systematic collection or the Bohemian museum, with the label "orthoclase [white, transparent laminated] from Karlsbad"), and upon the ground of the changes effected by hydrofluoric gas and water, I judged that internally or structurally different laminæ are present; but I also found in many oligoclase feldspars laminæ which under the influence of the above named reagents showed a substantial difference.

III. Application of Chlorine Gas for determining the Insolubility of Minerals in Acids, the Gelatinous Nature of Silicic Earths separated from the thin sections of many Silicates, and for the Determination of Alkalies, Alkaline Earths and Iron-Protoxide.

Development of Chlorine Gas, and treatment of the specimen with it.

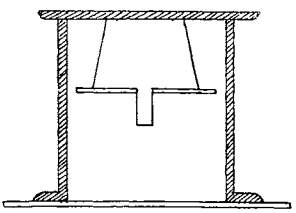


Fig. 3.

For developing chlorine gas I use a glass vessel (somewhat of the form represented in Fig. 3), upon the bottom of which is evenly scattered finely powdered manganese in the form of a ring an inch in width, and moistened with muriatic acid. Two strips of glass will serve to hold the mineral and thin-section specimens. These strips should be cemented to the upper side of a glass stopper on either side of

1. The microstructure of the Karlsbad microcline corresponds quite well with that which Des Cloiseaux in his above named works (p. 8, fig. 12) describes as a microcline from Australia (?).

the handle (as illustrated in Fig. 3), and by means of the stopper lowered into the middle of the glass vessel from whence they can be easily withdrawn when the operation is completed.

But if microscopic silicicfluoride crystals which are upon an object-glass, are to be exposed to the action of chlorine gas, then a low uncovered porcelain crucible may be used to support the object-glass.

When the frame carrying the specimens has been placed in the glass vessel and the latter closed as tightly as possible with a glass plate, whose edge has been rubbed with grease, then place the glass vessel upon a wire netting over a spirit-lamp and heat it till gas has developed rapidly for five minutes.

Special care must be taken while heating this that no large bubbles form lest by their bursting, the specimen should be soiled.

After about five minutes development of gas, the vessel should be taken from the flame and, with its cover, left standing twenty-four hours upon the work-table; but during this time the heating (for the development of a new portion of chlorine gas) may be repeated, as often as the nature of the mineral under investigation may require.

After the action of the chlorine gas has lasted about twenty-four hours, the frame, (the glass stopper) with the specimens, is taken out, each specimen laid upon another object-glass (with the side acted upon uppermost) and subjected to microscopic examination.

If the presence of (liquid) chlorides of the alkaline earths (calcium and magnesium) as new formations, is expected and it is wished to obtain them in characteristic crystalline forms, it is advisable to place the object-glass holding the specimen in a drying dish for the complete drying of the specimen, then to immediately enclose it in Canada balsam and place it under a cover glass.

If microscopic silicic fluoride crystals (upon an object-glass) are exposed to the action of chlorine gas, from three to five minutes of this action is sufficient to bring out the characteristic changes upon the silicic fluoride crystals; then the object glass is to be taken out, thoroughly cleansed and the changed crystals examined under the microscope.

Proof of the insolubility of a mineral in acids.

For testing the insolubility of certain minerals of a mixed rock in acids, the specimen in the form of powder was usually

boiled in hydro- chloric acid, shaken and left standing for some time. Then the changed specimen was investigated by microscopic observation and compared with fresh material for the purpose of establishing which minerals were wholly decomposed, which in part and which remained undecomposed.

Although the recognition of half-decomposed minerals in their tiny fragments under the microscope was often attended with difficulty, still these methods led in many cases to the desired result, provided the strength of the acid, the continuance of its action and the temperature by which the action was accompanied received proper consideration in proportion to the effect obtained upon determined minerals of the specimen.

Especially important was the fulfillment of these conditions, if the specimen was treated in the form of a thin section, since in this case a complete decomposition of the mineral had not been sought but only a clear change upon its (the thin section's) upper surface (evident mainly along the edge and in the clefts).

In the investigation of the insolubility of minerals in acids when occurring in crystalline rocks, it was found profitable to lay the thin section fastened to the object glass by Canada balsam in a little cup having a smooth bottom, in which has been placed, according to the requirements, hydrochloric acid or aqua regia; to leave it in this several days in perfect quiet, and then, after removing the acid from the specimen by careful immersion in chemically pure water, (the object glass being in a horizontal position) and drying with great care, to subject it to microscopic examination; for by this process it was possible not only to observe the decomposition of many minerals by means of the changes on their upper surfaces, but also to determine the nature and quantity of the silica separated from the silicates.

If the lower part of the specimen on the balsam plate has become, by the action of the acid, dark and opaque it can by careful heating be loosened and slipped upon a new balsam plate placed upon the same object glass.

Instead of all these methods for determining the insolubility of the several minerals in a thin section, I believe a new one may be presented as the most useful, namely, that which is based upon the action of chlorine gas upon thin sections of rocks and minerals.

According to this method the thin section specimens are laid upon the glass strips of the frame (glass stopper) in fig. 3, page 36, as close to the edge as possible but not so close to-

gether as to touch and in the manner described above (pages 36 and 37) exposed for about twenty-four hours to the action of chlorine gas. After being taken out of the apparatus each specimen is placed upon a new object-glass (arranged with the treated surface uppermost) and examined in the microscope.

If the thin section is spotted upon its upper surface with drops of chlorine water—which usually occurs with minerals which separate much gelatinous silica—the specimen may be dried in the exsiccator.

With the microscopic investigation here proposed, for which previous experiments upon determined minerals must be laid down as a guide for the determination of the decomposition of a thin section of mineral by means of chlorine gas (under the above mentioned conditions) the following points must be observed: (*a*) the nature and quantity of the silica separated out of the silicates, (*b*) the quantity of the chlorides formed upon the upper surface of the mineral, (*c*) the nature and strength of the etchings effected by the chlorine gas.

The following may be taken as a general rule: *The more the silica that has separated from a silicate, the more the chlorides that have formed and the more strongly marked the etchings, so much the greater is—under a like condition—the decomposition of the mineral.*

Determination of the gelatinous nature of the silica separated upon the upper surface of silicates.

If one has observed in the microscope the gelatinous silica separated by chlorine gas, upon the surface of some minerals, for example, nepheline, elaeolite or olivine, and has distinguished it from the powder-like silica of some minerals, he is in most cases able to determine whether the silica separated upon another mineral, is of a gelatinous or powder-like nature.

In order, however, to determine in every case with certainty the nature of the silica, the method proposed by Behrens, which is based upon the capacity of gelatinous substances for absorbing coloring matter, is strongly recommended.

I make use of this peculiarity of gelatinous substances in the following way: I cover the thin section treated with chlorine gas and placed upon a clean object-glass with a drop of fuchsin-solution, and after some time I lay the object-glass with the thin section upon it in a crucible filled with chemically pure water.

If there is no gelatinous substance upon the upper surface of the thin section, the color of the thin section vanishes in a

very short time, since the coloring matter mentioned is very easily soluble in water, but if there is gelatinous substance upon the upper surface of the thin section then every smallest part of the gelatined silica will be affected by the red fuchsin solution, which cannot be removed from gelatinous substances by water.

In this process, care should be taken that the thin sections be thoroughly cleansed before the treatment with the chlorine gas and that no portion of the silica be spilled from the surface of the thin section into the water by the movement of the object glass. While the latter condition is very easily fulfilled by a careful carrying out of the operation mentioned, the former usually requires a suitable cleansing of the thin section with alcohol or better still with chloroform, since the least trace of Canada balsam which remains imbedded in the crevices of the thin section may produce the same result as gelatinous silica.

This method is excellent *for distinguishing nepheline from apatite* and from monoclinic feldspar forms, and equally so for *distinguishing hauyne* and *nosean from leucite.*

The application of this process upon the thin sections of various kinds of rocks, especially upon the thin sections of basalt from Schlanberg and of nepheline phonolite from the Wachholder mountains at Teplitz is very satisfactory. The thin sections of the first rock, magnified to the four hundredth power, showed intense red olivine, nepheline and hauyne flakes in regular arrangement between augite groups, and numerous, colorless apatite sections, while on the phonolite thin section, the quantity of sanidine tablets remaining colorless between the red nepheline sections could be easily examined and determined.

Preparation and examination of the chlorides formed by the action of chlorine gas.

By the action of chlorine gas upon a silicate which contains alkalies and alkaline earths, and which suffer decomposition by means of the above mentioned reagent, metals of the alkalies or alkaline earths are, in the changed portions of the silicate, produced in the form of chlorides which appear upon the surface of the fragment of thin section in more or less perfect crystals.

The chloride of sodium very readily crystallizes. Its cube shaped crystals and step-like structures are best seen in those silicates which separate powder-like silica (as for example, andesine, labradorite), but far more numerous do they appear upon those silicates containing soda (as eläolite), but they lie

imbeded in the silicic gelatine and are more or less covered with it.

In order to determine the sodium chloride crystals in the last named case, it is advisable to cover the specimen with a solution of Canada balsam in chloroform and to supply it with a cover-glass; for in this way the silicic gelatine becomes strongly pellucid and shows the colorless cubes of sodium chloride. The chloroform, moreover, seems to cause the sodium chloride left in solution in the gelatinous silica to crystallize.

Less easily does the chloride of potassium, which is isomorphous with sodium chloride, crystallize. And, to cause the rhombohedral prisms (∞ R. R.—R. 0R) and tablets of calcium chloride ($CaCl_2 + 6H_2O$), and chloride of magnesium ($MgCl_2 + 6H_2O$), which liquify on exposure to air, to crystallize upon mineral thin sections by treatment with chlorine gas, is most difficult of all.

The forms of the two last named substances, which usually present distinct crystals only under the exsiccator, are generally spherical, elliptical or cylindrical, if they are successful in formation.

From the ferruginous silicates, which suffer decomposition on treatment with chlorine gas, appear often chlorides of iron. But since they belong to substances most soluble on exposure to air, they will not appear clearly in crystal forms upon the mineral thin section, but appear as a half-liquid pigment upon the mineral from which they are derived, gradually impregnating the adjoining portions of the thin section. Thus, from ferrous chloride as well as ferric chloride may proceed the intense yellowish-green or greenish-yellow color which appears upon the colorless or pale yellow olivine section, or upon other minerals containing iron protoxides, if they are exposed to the action of chlorine gas.

Judicious use of Streng's methods for the identification of apatite in thin sections, and especially after treatment with chlorine gas.

In order to determine apatite in thin sections of rock, [1]Streng has made the practical suggestion that the thin section, placed upon an object-glass, be treated first with hydrochloric acid (to dissolve the apatite) and then with molybdate of ammonia (diluted with nitric acid until the white precipitate again dissolves), then furnished with a cover glass and studied under a microscope. From the quantity of tiny but shapely formed

1 Tschermak's Mineralog. Mittheilung. 1876.

citron-yellow crystals (magnified to the 400th power) which I have usually regarded as rhombic dodecahedrons, (rarely octahedrons) of the tesseral system, the quantity of phosphate (apatite) appearing in the thin section can usually be determined in similar proportions.

Since apatite, like every other phosphate, is more or less affected by chlorine gas, the thin section treated with chlorine gas, in which one has already microscopically studied the decomposition of the minerals, can, for the determination of the phosphoric acid, be treated with one or more drops of molybdate of ammonia[1] diluted with a corresponding amount of nitric acid, and furnished with a cover-glass for microscopic examination; eventually, also, inclosed in Canada balsam applied at the edge of the cover glass.

The result is in general the same as that shown in the first paragraph; but in particular it is to be observed that if silicates which have separated gelatinous silica exist near rich apatite in a thin section, they are just as much impregnated with the citron-yellow substance of the phospho-molybdate of ammonia compound, as with the red fuchsin solution. Thus the reaction under these conditions serves a double purpose: (*a*) the proof of the existence of a phosphate in the thin section, and (*b*) the proof of the gelatinous nature of the silica separated from a silicate.

IV. The Production and Observation of Etchings, and their Importance in the Determination of Minerals in Thin Sections.

In the introduction (page 6), all those works were specified which treat of the representation of etchings upon various surfaces of many minerals and of their crystallographical significance. But at the same time the remark was made, that up to the present time no decided step had been taken to turn to account these etchings for determining the individual minerals in thin sections.

I am unfortunatelv unable to describe a large series of favorable results; for only upon the thin sections of a few minerals have I observed perfectly characteristic and, according to the above methods, easily presented etchings, which show finely the structure of the crystals of the individual minerals. But

1 The superfluous molybdate of ammonia crystallizes upon the object-glass in colorless needles.

the thin sections of most minerals treated with hydrofluo-silicic acid or hydrofluoric gas, or chlorine gas, show upon their upper surfaces changes produced by etchings, which, although hardly definable in words, present to the observer not an accidental appearance, but one closely connected with the inner structure of the mineral, so that in most cases their examination seems to be of value.

Since the nature of the etchings—by which term I believe it is allowable to indicate all depressions and protruberances in any degree characteristic, produced upon the mineral section by a chemical reagent—depends upon the crystallographical condition of the mineral section, various etchings naturally appear upon the various sections of the same mineral; and this furnishes us with a reaction which sometimes is not unimportant in the determination of a mineral.

It is to be noticed that with the appearance of the etchings on mineral sections new products also appear by the action of the chemical agents, or substances (like silica) are separated, which cover the etchings more or less wholly and must therefore be removed if the etchings are to be clearly studied.

If the new formed products are silicic fluorides or chlorides their removal from the surface of the thin section can be secured by repeated boiling in water, which can be conveniently done upon a platinum lid. And by the mechanical action of the boiling water the silica which may have separated is usually washed away from the surface of the thin section. If the new formed products are fluorides of alkaline earths which are insoluble in water they can be dissolved by sulphuric acid and then removed by water. But in the latter case it must be noticed that the action of the sulphuric acid upon the surfaces of many minerals results in additional etchings.

In order that the surface of an etched mineral section freed from new formed products and thoroughly cleansed may be conveniently observed under the microscope it should not be covered with Canada balsam but, if the section is to be preserved in the form of a microscopic preparation, a cover glass should be at once placed upon it, and the edge of this cemented to the object-glass by Canada balsam or some similar substance, the proper consistency being attained by heating on an object-glass.

1. *Etchings produced upon the surface of apatite.*[1]

1 Boricky. Sitzungsber, d. k. Böhun. Ges. d. Wissemsch, V. 9 Feb., 1877.

a. By action of chlorine gas.

By the action for twenty-four hours of chlorine gas upon thin sections of apatite from Schlackenwald, the sections being cut parallel with the basal planes, their upper surface (magnified to the 400th power) was changed into an aggregate of apparently hexagonal crystals, thickly crowded together and clinging to each other (subindividual crystal molceules) (P or P. 0 P or 0 P. P) which were placed for the most part perpendicular to the basal planes or showed only a slight inclination toward them.

In the outer zones the crystals were of various sized diameters and distinguished for the most part by prominent basal planes, but the boundary lines of the outer zone were sharply defined by crystals closely crowded together, of almost an equal size and exactly parallel to the crystal outline, running out, for the most part, into pyramidal points, so that a more splendid illustration of inner crystal structure could hardly be expected from any other chemical agent. (See Plate II, Figs. 19 and 20.)

Above the crystals there sometimes lay a mixture of short needle-shaped forms whose horizontal projections toward each other, showed for the most part an inclination of 60° or 100° and which I thought could be considered the remaining edges of the vanishing crystals of the upper layer. And these crystal-needles appeared most clearly when the thin section was covered with Canada balsam and furnished with a cover glass.[1] (See Plate II, Fig. 18). On the other hand the crystals situated beneath (the subindividual crystal molecules) could hardly be perceived through the Canada balsam.

Upon the thin section of the same apatite, crystals cut almost parallel to the prism surface (∞ P) which were boiled for a few seconds in aqua-regia, there appeared plainly in some places rhomboidal lateral angles, showing for the most part a splendid scale structure, while the rest of the thin section showed regular rhombic figures or rhombic figures long drawn out, and laterally truncated, parallel and crowded together or closely behind each other, (see Plate II, Fig. 17.)

The etchings of the apatite thin section boiled several minutes in water in a platinum dish were not injured but the tiny crystals appeared still more beautiful and clear; only the tiny needles (probably edges remaining from the upper layer) were scarcely visible.

1 Upon which bubbles of air were noticed almost continually.

Upon the natural surfaces of apatite—probably on account of greater insolubility—the abovenamed etchings were not noticed. There appeared upon the prism surfaces sharp grooves of varying lengths, and three cornered and trapezoidal forms. And upon a few places only were seen isolated rhomboidal angles (the lateral angles of tiny pyramids).

b. By action of hydrofluosilicic acid.

The etchings produced upon a thin section of apatite, cut parallel to the basal plane, by action of hydrofluosilicic acid, though only appearing plainly after the removal of the quantity of silicic fluoride of calcium formed, (removed by boiling in H_2O), showed (magnified to the 400th power), no material difference from the etchings which were described in the preceding paragraph, as being produced by chlorine gas. Yet in many places the peculiarity was to be noticed that the subindividual crystal forms of the principal basal surface with the pyramid, appeared composed of the regular crystal scales or of step-like crystals built up according to the hexagonal tablet as (0P. P) being always smaller above. Figure 16, plate II shows the silicic fluoride of calcium and the etchings produced upon the basal plane of an apatite crystal by the action of hydrofluosilicic acid.

2. Etchings upon a thin section of olivine, produced

a. By hydrofluosilicic acid.

The etchings produced by the action of hydrofluosilicic acid upon a thin section of olivine from Kozákov (at Turnau) and freed from the silicic fluorides of iron and magnesia by boiling with water (when magnified to the 400th power) are very regular crystal forms, closely crowded together and perfectly parallel to each other, of the pyramidal or tablet-shaped habitus, which latter, if they are not perfectly formed or not clearly visible, resemble rhombic figures overlying each other or clinging together.

By the individual crystals of pyramidal forms, a pinacoid or a dome may seem to be combined in the same zone with the predominant rhomboidal pyramid, while on the tablet-shaped crystals near the principal pinacoid a pyramid, prism or dome may appear not falling in the same zone with the pinacoid.

Magnified to the 400th power these subindividual crystals attain in some olivine sections the size of barleycorns; upon other sections they appear only like pinheads furnished with

two sharp and two blunt corners, and arranged regularly upon the entire section, (See Plate II, Figs. 11 and 12,) upon which the silicic fluorides are also shown near the etchings.

b. By the action of chlorine gas.

The etchings produced by chlorine gas upon thin sections of olivine from Kozákov are mostly short; not rectilinearly bounded, but usually perfectly parallel grooves, among which short pointed prisms or pointed rhombic figures were found in a very few places.

3. *Etchings upon thin sections of dichroite produced by action of hydro-fluosilicic acid.*

The etchings observed upon the thin sections of dichroite (from Bodenmais and from Orrijaerfvi in Finnland) were for the most part short rectangular depressions either parallel througout or one lying almost at right angles to another, between which were found more or less regularly laid grooves of various lengths. Only in a few places were the latter predominant; moreover among the regular some isolated depressions also appeared which showed much similarity to the crystal forms of dichroite represented in Naumann's Elements of Mineralogy (1871, p. 404). (See Plate II, Fig. 10, in which, for the most part irregular etchings are represented near the silicic fluorides).

4. *Etchings upon thin sections of chiastolite produced by the action of hydro-fluosilicic acid.*

In the thin sections of a chiastolite crystal (from an unknown locality) which were cut parallel to the basal planes, a charry substance appeared in more or less thickly packed particles, not only in the central part (along the crystallographical axes), upon the vertical lateral edges and along the diagonal of the thin section, but also in other parts of it and indeed in feather-like ramifications which ran out from the diagonal parallel to the edges of the oblique crystal section. The chiastolite substance appeared to be somewhat homogeneous, without showing anywhere a special micro structure except the imperfect cleavage crevices and a few small almost wholly colorless spots.

But after treatment with hydro-fluosilicic acid the imperfect-cleavage crevices appeared like broad spotted veins which were traversed with very broad undulating fibrous border zones, and enclosed little irregular rhomboidal, colorless spaces, so that the most important part of the thin section was marked by a strong spotted or undulatingly-fibrous structure.

Upon several points on the edge of the thin section appeared instead of the spots, promiscuously arrainged groups of long slender bands which—just like the spots and fibers produced from the chiastolite substance—presented the idea of a paramorphosis.

The colorless, somewhat less distinct rhomboidal spaces which may be considered as the residue of the unchanged chiastolite substance were cut by rare but quite perfect cleavage crevices which crossed almost at a right angle (90° 31' and 91°) and corresponded almost exactly with the cleavage directions of chiastolite (91° 4'). (See plate II, Fig. 13).

5. *Etchings on thin sections or cleavage fragments of hypersthene, broncite, diallage, augite, and amphibole produced by hydrofluosilicic acid.*

While the sections of hypersthene from Sky Island and of broncite from Graubat in Steiermark, treated with hydrofluosilicic acid, presented a union of fragile parallel fibres or very slender bands (see Plate II, Fig. 9, broncite from Graubat treated with H_2 Si F_6) the thin sections of diallage from the gabbro from Wolpersdorf showed usually two systems (cutting each other at a sharp angle) of less close but sharply rectilinear cleavage crevices between which groove-like etchings, much twisted and intertwined, appeared closely crowded together (see Plate II, Fig. 8). And these thin sections of diallage enclosed little broncite particles whose microstructure seemed uniform with that of broncite from Graubat.

Upon the thin sections of augite[1] and amphibole[2] which were cut parallel to the pinacoid face, only grooves of various lengths were noticed, which followed almost uniformly a fixed direction.

6. *Etchings on Lithia-iron-mica from Zinnwald, produced by the action of hydrofluoric gas and subsequent boiling with water.*

After treatment with hydrofluoric gas and water, there appeared upon the pale yellow or reddish white scale of this mica irregularly distributed, rusty-yellow flakes which often showed rhomboidal or six-sided incoherent outlines. And upon many places free from the rusty yellow flakes appeared very slender, more or less thickly congregated (depressed), rhombic figures, which were arranged for the most part parallel to the rhombic edges. (See Plate II, Fig. 14).

1. From Wartha on the Eger and from Kaaden.
2. From Peperin basalts from Lukov at Milleschau (see Plate II. Fig. 7).

I have measured many of the acute and obtuse angles of these rhombic figures, but obtained very different results; for the acute angles 49° 30', 50°, 56° 30', 59° and 60°, and for the obtuse, 130° 30' to 120°.

7. *Etchings upon thin sections of scapolite from Malsjö in Wermland.*

Upon the thin sections of scapolite taken nearly parallel to the main axis and treated with hydrofluosilicic acid, the etchings which were observed between the strongly appearing grooves parallel to the main axis, resembled long, much distorted and overlapping grooves which were at times united into a snake-like net-work. Chlorine gas, likewise, produced very irregular, jaggedly roundish and longish depressions and caused cleavage grooves parallel to the main axis to appear strongly.

8. *Etchings upon thin sections of elaeolite from Laurwig in Norway, produced by chlorine gas (magnified to the 400th power.)*

After removing the mass of separated gelatinous silica and the crystals of sodium chloride imbedded in it, (usually these are octahedrons,) there appeared upon the thin sections of elaeolite a parallel rectilinear grooving, besides the rare but broad rectangular cleavage crevices. And in the band-shaped spaces between the grooves appeared long rectangular depressions and protuberances, sometimes pointed at one end or many-sided, and more or less regularly prism-shaped and parallel to the grooves. Among these in some few places, tolerably regular hexagonal prisms were observed. Upon one of these prisms a secondary pyramid appeared on one of the basal planes. (See plate II, Fig. 15).

9. *Etchings on a thin section of Leucite from Vesuvius.*

(Observed when magnified to the 400th power.)

Upon the leucite there appeared, after treatment with chlorine gas, very tiny and closely crowded, round or polygonal depressions, and after treatment with hydrofluo-silicic acid a very close, delicate polygonal network (See Plate II, Fig. 2).

10. *Etchings on thin sections or cleavage fragments of feldspar.*

(Magnified to the 400th power.)

After treatment with hydrofluoric gas and then with boiling water, the most perfect cleavage planes of sanidine from the phonolite of Tannberg (at Tollstein, formerly Kingdom of Rumburg) showed either long, polygonal, sometimes six-sided

depressions (of the ordinary outline of the clinopinacoid face) or groove-like, very slender and close, parallel depressions. Those of adularia from St. Gotthard, and of pyacolite from Vesuvius, showed for the most part groups of parallel, pointed (tower like) and wedge-shaped depressions, or more rarely rows of short prisms and cones, projecting sharply out of the etched surfaces.

After a similar treatment of microcline from Miask (amazonite) the characteristic microstructure appeared upon some of the cleavage planes (which were probably parallel to the basal plane) in the most beautiful manner, since the various internal and structual bands or parts were changed in various ways. But the microstructure of microcline appeared especially beautiful upon some cleavage planes of white striated feldspar (mentioned on page —) of the Bohemian museum which was labelled "Orthoclase from Karlsbad." Upon other cleavage planes of the same microcline (which were probably parallel to the klinopinacoid faces) there appeared closely crowded together and parallel, long, slender, spindle-like, cylindrical depressions, which by a gradual lessening of length were changed into scaly etchings arranged like tiles.

Upon the most perfect cleavage planes of albite from Dauphiné, there appeared, after the above mentioned treatment with hydro fluoric gas and water, groups of slender, parallel spindle-shaped depressions crowded closely together, or of sharp edged subindividual crystal prisms or little tablets; while the etchings upon the cleavage planes of oligoclase from Ytterby were jagged, rhomboidal depressions and on the cleavage planes of anorthite from Vesuvius were polygonal, facet-like, roundish or net-shaped depressions.

Through the action of hydro-fluosilicic acid the trellis-like surfaces of the thin sections of amazonite were mostly etched in the form of delicate net-like depressions; upon the most perfect cleavage planes of albite from Dauphiné appeared peculiar sharp-edged, wedge-shaped etchings which were inclined to the plane of cleavage at a very sharp angle and were often distinguished by a regular arrangement in parallel rows, (see Plate II, Fig. 1.); and upon the oligoclase feldspar appeared either in slender grooves of diverse forms and variously placed, or lenticular, half moon-shaped, oval and quite rectangular depressions. The groove-like depressions were the more rare the less soda the feldspar contained. Upon the

thin sections of anorthite of corsite (from Corsica) only four-sided or roundish (almost rectangular) depressions of various lengths were to be noticed.

In conclusion I believe the remark would be appropriate, that the structural relations of single or twin silicate crystals as well as of many crystal groups and crystalline forms in thin sections, when treated for this purpose with hydrofluoric gas or hydrofluosilicic acid and water, are brought out in more clear significance and are more beautiful, since they present themselves unmodified.

V. Remarks upon the Application of some Older Methods for the Determination of Minerals in thin Sections.

1. *Upon the use of the red heat test for the separation of minerals containing iron (and manganese) from those free from iron (and manganese), for the proof of dichroism in the former if they offer colorless sections, and for the approximate determination of the melting point of minerals in thin sections.*

With a few exceptions all the minerals constituting the crystalline rocks may be divided into two groups, those which are free from iron (and manganese) and those which contain iron (and manganese).

In the *first* group belong chiefly the feldspathic minerals and the light varieties of mica, as well as wollastonite, apatite, calcite, dolomite and some pure clay silicates (chiastolite, andalusite, disthene, etc).

In the *second* group belong prominently minerals of the amphibole, augite and broncite series; also biotite (rubellan) chlorite, olivine, garnet, spinel, magnetite, chromite and titanic iron. And upon the borders of both groups might be placed mejonite (scapolite), cordierite and titanite, which minerals sometimes contain much, sometimes very little iron.

When the minerals of the first group appear in thin sections they present themselves in colorless, or, if they are impregnated with a pigment, in colored sections. The colorless mineral sections remain colorless even after the strongest heating or become white and slightly pellucid, while those colored by a pigment usually also appear colored after heating. But this coloring does not seem to be of a homogeneous character, is not usually evenly spread over the mineral section, but is commonly distributed in spots or intervals.

Minerals of the second group, when in thin sections, usually offer homogeneously colored sections, sometimes variously shaded in the crystal scales, but among these minerals appear also others, such that, colorless or only faintly colored, (many olivines, dichroites, epidotes, augites, diallages, enstatites), they might be mistaken for minerals of the first group. But since all minerals of this group contain more or less iron (or manganese), their thin sections can, through strong heat with the oxydation flame, be given a yellowish, reddish or brownish homogeneous coloring by which they can readily be distinguished from minerals of the first group.

The kind and intensity of color which comes by heating (of proper strength and continuance) upon the thin sections of minerals of the same species, but from different localities, sometimes determines with sufficient accuracy the relative quantity of iron (or manganese).

With the appearance of a homogeneous intense color the thin sections of many minerals of the second group acquire the peculiarity of showing a more or less strong dichroism and absorption of light. Which characteristic, before heating the minerals (so long as they were colorless or only faintly colored), could not be noticed at all, or only in a far less degree.

This process can be performed in the following way: Upon a small strip of platinum, slipped into the slit of a wooden handle, lay the thin section specimen of the size of $1\frac{1}{2}$-3 □ mm and subject it, by means of the blow-pipe, to the oxidyzing flame for from $1\frac{1}{2}$ to 3 minutes, so that for this length of time the specimen may be at a red heat; yet it is advisable to interrupt the heating after $1\frac{1}{2}$ minutes and to investigate the specimen microscopically, and, in case it is colored, it should be put to the dichroscopic test; because by a longer continuance of heat many minerals are either colored so dark (gray or grayish-brown) that they lose in great measure their transparency and are no more fit for dichroscopic study, or they are entirely melted.

If the length of heating, which thin section fragments of equal size and under the above mentioned conditions require for fusion, has been determined for certain minerals, as steps in a scale of fusibility, then the melting-point of every other mineral in thin sections can be determined approximately by comparison with these; but one must observe that the contact of a mineral difficult of fusion with one easily fusible, demands heating in the high degree of the former mineral, and especi-

ally should this be observed in such minerals as usually hold an easily fused glass cement in rich masses.

I have made experiments upon the following mineral sections in regard to the change of color produced by heating and to the possible observation of dichroism, and in regard to their fusibility.

(*a.*) Upon the colorless olivine sections of nepheline pikrite from Devin at Wartenberg, which, after about two minutes of heating, received a homogeneous dark-yellow color, and then showed as strong dichroism as the yellowish-brown amphibole sections of many basalts.

(*b.*) Upon the nearly colorless, very pale-yellow olivine sections from Kozákov at Turnau. These became by heating, in reflected light, grayish-yellow, in places grayish-brown, in transmitted light grayish yellow or grayish brown (in places darker), and less transparent. Dichroism dark grayish-yellow or grayish brown and light grayish-white with a streak of blue), and light absorption were distinctly observed.

(*c.*) Upon pale bluish-white almost colorless sections of blue dichroite from Orrijaerfvi in Finnland. These by strong heating acquired only a pale yellowish color, but, while before heating only a slight dichroism could be noticed, it appeared quite strong after the heating, when the changes of greenish-yellow, siskin-green and violet-blue were very beautiful.

(*d.*) Upon pale-bluish sections of blue dichroite from Bodenmais in Bavaria. These became, through heating, dark grayish-blue in reflected light, and in transmitted light dark grayish-brownish violet and slightly pellucid, in some places opaque. Dichroism showed itself quite strongly thus: grayish-greenish-yellow and pale smalt-blue. Moreover, it was observed that a perfect cleavage appeared.

(*e.*) Upon the almost colorless sections of scapolite from Malsjö in Wermland, which became through heating an ashy-gray in reflected light, with a streak of violet, in transmitted light grayish-blue, in some places a brownish changing streak, and were scarcely translucent. Dichroism was scarcely noticeable either before or after heating.

(*f.*) Upon the grayish-white almost colorless sections of grayish green epidote from Schwartzenstein in Zillerthal (Tirol). These, after some 1½ minutes of heating became grayish-yellow, but yet remaining literally transparent, showed a strong dichroism (change of color; pale bluish-green, emerald-

green and pale violet-brown), which was less distinctly observed before heating.

After 2½ minutes of heating the epidote thin sections became grayish-yellowish-brown very slightly pellucid, and after some 3 minutes of heating they became dark grayish-brown, opaque and with a curved distortion due to crumpling.

(*g.*) Upon thin sections of (black) augite from Wartha on the Eger (cut parallel to the pinacoid), colored brownish gray with a streak of violet. After two minutes of heating the brownish shade on these appeared stronger and a quite distinct dichroism (greenish-yellow and violet-gray), and clear distinctions in the absorption of light were noticed. These, though in a less degree, could be noticed before heating.

(*h.*) Upon the almost colorless very pale-yellow sections of bronzite from Grauthal, which by heating became bright yellow, in the crevices a pale yellowish-brown, and presented a very distinct dichroism (grayish white and light brownish-greenish-yellow), especially upon the darker places.

The thin sections of micaceous rock from Libschitz which consist of biotite, amphibole, a tetragonal mejonite mineral, magnetite, apatite, and in some places rich brown glass-cement, were, after some three minutes of intense heating, changed into greenish glass, full of bubbles and containing colorless roundish bodies thickly crowded together, in which only biotite and amphibole could be distinctly recognized.

2. *Upon the use of cobalt-solution for identification of alumina and magnesia in sections of minerals free from iron (or manganese).*

The known reaction upon alumina and magnesia by heating the specimen treated with cobalt-solution upon coal can be applied to the investigation of the thin sections of colorless minerals free from iron; yet it must be noticed: (*a*) that the thin section specimens must be moistened many times with cobalt-solution and always very strongly heated if even a partially successful result is to be obtained, and (*b*) that thin sections having become dark or opaque by heating with cobalt-solution, can be made again transparent by being boiled with water or with a very dilute nitric acid.

The blue color given to aluminous minerals by heating with cobalt-solution appears stronger in reflected light than in transmitted light, because the action of the reagent mentioned usually reaches to every part of the surface of the thin section of the

mineral. And the rougher the surface is so much the more distinct is the desired effect. It seems advisable to expose the mineral thin section, before heating with cobalt solution, to the action of fluohydric gas or of chlorine gas according to the insolubility of the mineral in acids.

I have only made these experiments upon the thin sections of two minerals: quartz-andesite from Sebesvarallya in Hungary[1], which, heated with cobalt-solution and boiled in water, caused the bluish andesine section to be clearly recognized; and amazonite from Miask which was previously treated with fluohydric gas and water. The latter thin section heated with cobalt-solution and boiled in dilute nitric acid, appeared in many places bluishly transparent, yet the blue color was more strongly noticed in reflected light.

VI. ANALYTICAL GUIDE

FOR DETERMINATION OF MINERALS[2] APPEARING IN CRYSTALLINE ROCKS, BY THE NEW CHEMICO-MICROSCOPIC METHOD.

1. The specimen is a broken fragment, cleavage lamina or thin polished section of a homogeneous mineral.

If the specimen is a broken fragment or a cleavage lamina of a homogeneous mineral, take a piece the size of a barleycorn, crumble it into many little particles, lay these in the midst of a balsam layer spread upon an object-glass and made resinous by heating, cover the particles with a drop of 3 per cent. strong hydrofluosilicic acid of the size of a pea, observe whether a bubbling[3] occurs or not, and leave the object-glass, for the specimen to dry, in a place perfectly protected from dust. (In not too moist air the drying will require from six to twelve hours). Then subject the entire dried portion of the object and the upper surface of the somewhat smooth cleavage fragment to close microscopic examination magnified from 200 to 600 diameters.

It is to be noted that a satisfactory result can be obtained with the smallest grain of the specimen, although the drop of hydrofluosilicic acid must be correspondingly lessened in size

1 Received by kindness of Prof. G. Von Rath.

2 Since not all the minerals appearing in crystalline mixed rocks offered satisfactory results in these experiments this analytical guide is useful only for such minerals as have been actually investigated in their individual characteristics, or which allowed their characteristic reactions to be developed with the greatest probability, according to their nature and the laws involved.

3 Development of a colorless, odorless gas.

If the specimen is a thin polished fragment which measures about 2–4 □^{mm}, then heat the object-glass gradually and press the specimen carefully upon it with the point of a penknife, so that it will cling firmly and no little bubbles remain between it and the object-glass, and then continue exactly as indicated in the foregoing.

The remark may be permitted here that the smallest homogeneous portion of a thin section of a mineral treated with hydrofluosilicic acid must give perfectly reliable results.

NOTE.—*The minerals named below marked with an asterisk have already been investigated with hydrofluosilicic acid.*

A) The specimen is in the form of the finest splinters or the thinnest (more or less) transparent cut section.

On treating the specimen with hydrofluosilicic acid

A′ A continuous bubbling is noticed.

The silicic fluorides formed

a belong almost exclusively to calcium (Plate I, Fig. 6.)

The cleavage crevices of the specimen show

a a rhombohedral mineral.....*Calcite.

b a rhomboidal mineral.....Aragonite.

b belong almost exclusively to magnesium (Plate I, Fig. 12.)

(The cleavage crevices of the specimen show a rhombohedral mineral).....*Magnesite.

c belong in great part to calcium as well as magnesium.

The cleavage fissures of the specimen show a rhombohedral mineral.....*Dolomite.

B′ No bubbling is noticed.

The silicic fluorides formed

d belong for the most part to lithium, in a small degree to potassium or even to sodium.

Scaly, colorless or light colored (from Roznau, peach-red) particles; for the most part thick, parallel grooved sections.....*Lithia mica.

e belong for the most part to lithium and iron[1] (Plate II, Fig. 5, left side), in a small degree, sometimes to potassium.

Scaly, light-colored particles and little leaves, for the most part thick, parallel-grooved sections. *Lithia-iron mica.

f belong for the most part to potassium (Plate I, Figs. 1 and 2), often in a lesser degree to sodium (Plate I,

1 The iron fluoride crystals are colored dark yellow by the action of chlorine gas.

Fig. 4), and sometimes a small amount to calcium also.

a The mineral specimen consists of pliant leaves or scales; most of the cut-sections show a thick, parallel, rectilinear or undulating grooving; the silicic fluoride crystals formed are small and sparingly distributed (Plate II, Fig. 5, right side.....*Potash mica.

b The mineral specimen is of very perfect cleavage; most of the cut-sections are distinguished by a *cross-banded* or *trellis structure;* the silicic fluoride crystals are larger and heaped up in quite large numbers along the trellis-like grooves.

Near the silicic fluoride of potassium appear some silicic fluoride crystals of sodium (Plate I, Fig. 16) *Microline.

g The mineral specimen is of very perfect cleavage; most of the longish-banded sections show no grooving, if they are quite homogeneous, but are sometimes composed of two long halves which in polarized light show different colors. The cut-sections, furnished with enclosures of grooved bands, offer, near the silicic fluoride of potassium, more or less silicic fluoride of sodium, at times also a little silicic fluoride of calcium ..... *Orthoclase.

d Fragments perfectly cleavable, or cut sections of glassy appearance and fissured structure. A good deal of silicic fluoride of sodium is almost always found near the silicic fluoride of potassium.....*Sanidine.

e The mineral fragments show no perfect cleavage; the roundish (polygonal) cut sections are always clear or distinguished by beautiful enclosures arranged in the forms of wreaths (Plate II, Fig. 2) .*Leucite.

g belong almost exclusively to sodium.

Treated with chlorine gas, the mineral

a is not affected.

Perfectly cleavable fragments, whose surfaces often show etchings after treatment with hydrofluoric acid (Plate II, Fig. 1; usually the cut-sections have parallel rectilinear grooves, and in polarized light give variegated lamellar colors.....*Albite (pericline).

b the mineral is strongly affected, and separates gelatinous silica which can be recognized easily by means of fuchsin solution.

aa Granular; quadratic, rectangular, hexagonal, and

trigonal cut-sections usually distinguished by a peculiar micro-structure, which (according to Knopp) become blue by the action of sulphuretted hydrogen.....Some nosean, some sodalite. (From nosean and sodalite may be recognized easily analcime.)

bb Fragments of short hexagonal prisms, rectangular and hexagonal sections often characterized by concordantly arranged outlines of microlite enclosures, which (according to Knopp become blue by sulphur vapor....Some *nepheline (elæolite). Cut-sections rectangularly cleaved, parallel barred or fibrous (Plate II, Fig. 3), which after treatment with chlorine gas show peculiar etchings (Plate II, Fig. 15).....*Elæolite

h belong for the greatest part to sodium, in a small degree to potassium.

Physical properties of the fragments and sections the same as under *g*, b, bb.....*Nepheline (elæolite).

i belong for the greatest part to sodium; but near these appear, sporadically, united silicic fluoride crystals of calcium.

The silica separated by chlorine gas in

a gelatinous. The specimen is strongly affected.

Physical properties same as under *g*, b, aa. Nosean, sodalite.

b not gelatinous. The specimen is very slightly affected. Fragments with perfect cleavage, sometimes with close and delicate parallel grooving. The majority of them in cut-sections banded, usually with parallel grooves, and showing parti-colored lamellar structure in polarized light (Plate I, Fig, 17.).....*Oligoclase.

k belong for the most part to sodium, in smaller degree to calcium, but not materially different.

The silica separated by chlorine gas

a is not gelatinous.

Fragments colorless or light colored, with perfect cleavage, sometimes with close and delicate parallel grooving. The greater part banded and in thin sections showing in polarized light variegated bands of color.....*Andesine.

b is gelatinous. The specimen is strongly affected.

Mostly blue grains; quadratic, rectangular, hexag-

onal and trigonal, cut sections usually distinguished by a blackish-blue or reddish, close trellis-work. Hauyne.

l belong to calcium and sodium, in all probability of almost equal parts, but the greater part to calcium and the lesser, though not essentially different, to sodium.

The silica separated by chlorine gas is

a not gelatinous.

Fragments colorless or light-colored, and with perfect cleavage, often with delicate and close parallel groovings; the cut-sections for the most part striated with parallel, delicate, close grooves, and in polarized light displaying parti-colored lamellar structure. (Plate I, Fig. 19).....*Labradorite.

b gelatinous.

Physical properties same as under *k*, b..Some hauyne.

m belong for the most part to calcium, in a much smaller degree to sodium, sometimes also a small quantity to magnesium and iron.

The silica separated by chlorine gas is

a not gelatinous. The specimen is strongly affected.

Fragments colorless or light colored, with perfect cleavage; for the most part the cut-sections are banded with parallel grooving, and show in polarized light a parti-colored lamellar structure. (Plate I, Fig. 20).....Some *anorthite.

b gelatinous, The specimen is strongly affected.

Most of the tetragonal and rectangular cut-sections are colorless, yellowish or brownish; the colorless ones are colored yellow by red heat, at least around the edges and in the crevices. .....*Melilite.

n belong almost exclusively to calcium (in a much smaller quantity to sodium, magnesium, iron and manganese.)

By action of chlorine gas the specimen

a is very slightly affected.

aa Blackish, sharp-angled grains, mostly with a grayish-white translucency and a sub-metallic lustre, which give a titanium reaction or cut-sections of tesseral crystals of a grayish-white (yellowish or brownish) color and dark angles.....Perofskite.

bb Reddish, brownish, blackish brown-to-black grains which give no titanium reaction; reddish or brownishcut-sections of tesseral crystals..Some garnets.

b Quite strongly affected, yet *without* the separation of *gelatinous* silica.

aa Tetragonal prisms or columnar particles; cut sections grayish-white; rectangular and tetragonal, and parallel-barred or fibrous, showing characteristic etchings after treatment with chlorine gas. (Plate II, Fig. 4).....*Scapolite.

bb Hexagonal prisms; cut-sections rectangular and hexagonal, colorless or furnished with rows of powder-grains, which after treatment with chloine gas, or with hydrofluosilicic acid, show characteristic subindividual crystals (etchings). (Plate II, Figs. 16–20).....*Apatite.

gg Yellowish, greenish or brownish, short monoclinic tablets or prisms which give the titanium reaction; cut-sections pale yellowish, greenish or brownish-gray (usually spindle-shaped) of monoclinic forms *Titanite.

dd Colorless or light colored fragments with perfect cleavage, often with parallel grooves; cut-sections for the most part with parallel rectilinear groovings, and showing in polarized light a variegated lamellar structure.....Some *anorthite.

g Quite strongly affected and *with* the separation of *gelatinous* silica.

aa Tetragonal prisms or columnar fragments; grayish-white or pale yellowish or greenish tetragonal and rectangular cut-sections or parallel-striped or fibrous particles.....*Mejonite.
Here also might belong some.....Melilite.

bb Fragments of colorless or white monoclinic crystals or bar-like to fibrous aggregates..*Wallastonite.

o belong almost exclusively to magnesium (the silicic fluorides are *not colored* by chlorine gas, or are only colored slightly an orange yellow).

a Grains, with little evident cleavage, very hard; cut-sections mostly rectangular or irregular, roundish, which after red heat show a marked dichroism (Plate II, Fig. 10).....*Dichroite.

b Pliant, very soft and flexible leaves, scales or groups of scales, white or pale colored; cut-sections mostly striped.....*Talk.

g Grains with perfect cleavage, hard, pale-greenish or

yellow; cut-sections with parallel rectilinear grooving.....Some enstatite.

p belong to magnesia, iron and potassium.

Short, dark-colored prisms with evident cleavage on the basal planes and hexagonal leaves (Plate II, Fig. 6). Some *biotite.

q belong to magnesium and iron, sometimes also in a slight degree to calcium (the silicic fluoride crystals belonging to iron are colored orange yellow by chlorine gas and are blackened by sulphide of ammonium gas.

The silica separated by chlorine gas is

a gelatinous.

Cut-sections colorless, yellowish, greenish, brownish, showing dichroism after red heat, clear or marked with non-rectilinear cleavage crevices. These sections after treatment with hydrofluosilicic acid show often subindividual crystals (etchings) (Plate II, Figs. 11 and 12).....*Olivine.

b not gelatinous; sometimes the specimen is not at all affected.

aa *Hard* grains, which present *no, or only an imperfect cleavage*; cut-sections show *tesseral* crystals upon which an imperfect cleavage, or none at all, is to be observed.

△ Grains blood-red or dark brown; cut-sections dark red and brownish....*Pyrope and some garnets.

△.△ Grains dark green, blackish-brown and blackish; cut sections greenish, grayish or brownish..... *Pleonast (picotite).

bb Greenish hexagonal tablets, of *very perfect cleavage*, soft, pliant scales, or leafy or scaly grooves; cut-sections greenish with parallel groovings or stripes, or delicate scaly spangles .....*Chlorite.

gg Grains with rather perfect or *perfect cleavage*, quite hard, greenish, blackish green or greenish-black; cut-sections grayish-white, light or dark green, with very close parallel, rectilinear or columnar groovings, or fibrous.

The silicic fluoride crystals are colored orange yellow by chlorine gas.

△ in a small part only.....Enstatite.

△△ in a greater part (Plate II, Fig. 9)*Bronzite.

△△△ in the greatest part.....*Hypersthene

r belong to calcium, magnesium and iron, or calcium and iron.

Delicate cleavage fragments or cut-sections show

aa either before or after heating a very strong dichroism. The silica separated from the heated specimen by chlorine gas.

△ is gelatinous.

Very perfectly cleavable, hard, usually grayish-green, monoclinic crystals, or barred or granular aggregates; cut-sections grayish or greenish-white, with rectilinerally parallel but very light and delicate groovings.....*Epidote.

△△ not gelatinous.

Black or blackish-green, monoclinic, columnar crystals of various lengths; cut-sections greenish, grayish, yellowish or brownish, upon which quite perfect cleavage crevices are usually seen. (Plate II, Fig. 7). These intersect in regular diagonal sections at an angle of 124°30'*Amphibole.

bb none or only slight dichroism.

△ Crystals greenish-black, black, or blackish-brown, monoclinic, short columnar; greenish, yellowish, brownish or grayish cut-sections whose cleavage crevices are often quite rectilinear. They intersect in regular diagonal sections at an angle of 87°6'..*Augite (pyroxene).

△△ Grains thick, plate-like, dark-gray, brownish or blackish, perfectly cleavable in one direction, and striped on the most perfect cleavage surfaces, or fibrous; cut-sections with parallel and sharply rectilinear but light groovings in one or two directions (Plate II, Fig. 8).....*Diallage.

s The silicic fluorides are lacking entirely or appear only very rarely.

a Cut-sections pale or colorless; changed by hydrofluoric gas effervesce in sulphuric acid..Pure alumina silicate. like *chiastolite (Plate II, Fig. 13), disthene, andalusite. etc., which may sometimes be distinguished by etchings.

b Dark red hexagons or irregular particles, or scales with tattered edges (in cut sections).....Hematite.

g Brown or yellow-brown, mostly earthy particles (in thin sections).....Limonite.

B) The specimen is in the most fragile splinters or the thinnest cut-sections.

A′ Black, opaque.

a Is distorted by heating (sometimes leaving a red portion behind it). This is

aa Amorphous.....Anthracite, coal.

bb scaly.....Graphite,

b Is not changed by treating, or only colored brownish or reddish at the edge.....Magnetite.

B′ Blackish-brown, slightly translucent.

a A rhombohedral cleavage disclosed by the cleavage crevices, and, heated with a drop of sulphuric acid, colors the latter blue at the edge (according to Sandberger).....Titanic iron.

b Is tesseral and gives chrome reaction..Chromite.

2. The specimen is a fragment or a portion of a thin-section of a crystalline rock.

If the specimen is a crystalline rock out of which the individual mineral to be investigated can be selected, in the form of very tiny but perfectly homogeneous particles, by help of strong magnifying glass; or if it is a thin section out of whose sections the smallest homogeneous particles can be cut; in either of these cases, the separate investigation of each mineral, for the proof of its real nature, should be undertaken as the surest way; but the fulfillment of all the conditions for an infallible result (namely, purity of the hydrofluosilicic acid used, as well as of the Canada balsam, and protection from dust) is to be the more carefully observed the smaller the specimen to be studied.

If the above mentioned specimen, in the form of a thin section, consists only of minerals each of which contains other metals (or one other metal) a separation and separate investigation of the individual minerals is not usually necessary, but the general treatment of it with hydrofluosilicic acid usually leads to perfectly satisfactory results. For example, if the specimen is a variety of basalt, which consists of augite or amphibole, magnetite and nepheline, or of augite and amphibole, magnetite and glass substance, (magma) and it be treated with hydrofluosilicic acid, there appear, constantly, in the first case, besides the silicicfluorides of calcium, magnesium and iron (arising from the augitic ingredient), silicicflu-

oride crystals of sodium, sometimes also, in less quantity, those of potassium, while in the latter case, the more or less rich appearance, or sometimes entire lack of silicicfluorides of the alkalies (and the insolubility in chlorine gas), sufficiently characterize the chemical nature of the glass substance (magma). If the specimen is a variety of porphyry which contains besides quartz and monoclinic feldspar, only one triclinic feldspar, and it is treated with hydrofluosilicic acid, a tolerably certain conclusion can be drawn concerning the chemical nature of the triclinic feldspar from the quantitative proportions of the silicic fluoride crystals of calcium and sodium.

These cases in which a common treatment of several minerals with hydrofluosilicic acid allows the chemical nature of the minerals to be recognized, often present themselves to the microscopical petrographer in investigating thin sections of rocks; but far more frequently the preparation of such cases lies in the hand of the investigator.

In the thin sections of most rocks particles appear in some places which allow a general treatment with hydrofluosilicic acid for the proof of the chemical combinations of their mineral mixed portions. And such particles however small they may be can be cut out of the thin sections and investigated.

If the thin section specimen of a crystalline rock, in whose minerals occur one and the same or several similar metallic elements, be treated with hydrofluo-silicic acid, the totality of silicic fluoride crystals formed affords in all cases the analogy of a partial chemical Bausch-analysis.

But in most cases more is aimed at in treating the specimen with hydrofluo-silicic acid than that a Bausch-analysis may be afforded the petrographer, since by certain precautionary measures—especially if the hydrofluo-silicic acid drop has spread only a very little over the edge of the thin section and if it is dried in a perfectly horizontal position on the object-glass and in perfect quiet,—the silicic fluoride crystals formed do not mingle regardless of order, but for the most part are formed on the upper surface of that mineral to which they belong. In such cases characteristic forms of partial chemical analyses of the individual minerals have been obtained.

VII. Remarks upon the Importance of the Explained Methods for Determinative Mineralogy and Analytical Chemistry.

Upon the basis of many analytical experiments which I have made according to the above methods upon many and various (about one hundred) minerals, I believe I may be allowed to express the hope that my elements of a new method for the chemico-microscopic analysis of rocks and minerals may offer many suggestions not unimportant to the petrologist and mineralogist, and also in some measure to the analytical chemist, and that they are worthy of a continued and broader development (by means of other valuable agents) [1]

Without mentioning the amount of time and many requisites—a favorable place for work, the necessary apparatus, and numerous reagents—which the chemico-analytical experiments undertaken upon minerals in the usual way demand, the mineralogist as well as the petrographer is obliged to experiment upon one or a few grains of the specimen, and, after one or more failures or experiments producing only negative results, must discontinue his attempts on account of lack of material. And in such a case the best chemist cannot aid him unless the spectroscope can offer assistance.

On the other hand, our "universal method" (and at times also the methods based upon the application of fluohydric gas) applied to the smallest specimen, offers a safe analysis of the metallic elements, whether they appear free or in monoxides, or in their manifold salts, in hyperoxides or their analagous sulphur, selenium, tellurium, arsenic and antimony compounds; which, with the coöperation of the physical properties, usually suffices for the determination of the mineral species. Moreover our method requires no special locality for the work, no large number of implements and reagents, but—besides Canada balsam, object-glasses and a spirit lamp—only a caoutchouc flask filled with perfectly pure hydrofluo-silicic acid of 3 per cent. strength, and a caoutchouc stick kept in a caoutchouc tube. And the whole time required for investigating a mineral—without counting the time required for drying the drop of acid—is in most cases only from five to ten minutes.

Although I have already examined more than a hundred mineral species by means of hydrofluo-silicic acid, still I consider

1 Preeminently do experiments with acids analogous to hydrofluosilicic acid, especially with borfluoric and hydrofluotitanic acid, promise favorable results.

this only a small fraction of the work yet to be completed in order to be able to publish a practical and perfectly reliable key for the determination of all minerals according to the above described methods. But I hope in a few months to reach the desired end. I will here confine myself to a few hasty remarks which indicate the foundations for the projected key for the determination of mineral substances, and which will contain the requisite directions for many cases.

(*a.*) The silicic fluorides known up to this time--besides those appearing in petrologically important minerals, and specified on pages 17 to 23—are the following:

The silicic fluoride of ammonium (plate I, fig. 1, s, t,) ($[NH_4]_2 Si F_6$) must be dimorphous (Marignac, Ann. chem. phys.,[3] *LX* —301 and Jahresb. über Fortschr. d. Chem. 1860 [pro 1859], page 107, and 1861 [pro. 1860], page 98). From the pure solution it crystallizes according to Marignac in tesseral combinations of octahedrons with hexahedrons; from solutions, on the other hand, which are rich in hydro-fluoric gas or fluoride of ammonium, in combinations of the hexagonal system: ∞P. *P*. $0P$. ∞P. *P*. $2P$. $0P$. According to Marignac's report *P*: *P*.= 139° 36′, $2P$: $2P$=127° 25′, $0P$: *P*=136° 20′, $0P$: $2P$=117° 39′. Through re-crystallization the hexagonal crystals become tesseral.

From the solutions diluted with surplus fluoride of ammonium, the silicic fluoride of ammonium crystalizes in double-folded, quadratic combination forms ($\infty P.0P$, rarely $\infty P\infty$), which many times appear cube-shaped (Jahresb. über Fortschr. d. Chem., 1860 [pro. 1859], page 107).

I obtained the silicic fluorides of ammonium (with a surplus of hydrofluo silicic acid), always in large sharp-edged tesseral forms ($\infty 0 \infty.0$), which could not be distinguished from the silicic fluorides of potassium, unless it is permissible to designate the unusually beautiful scale-structure and the step like nature of the surfaces observed on the imperfectly formed crystals of silicic fluoride of ammonium as special marks of difference.

Since the ammonium salts are, by their volatility when heated, to be distinguished easily and separated from the potassic salts, the isomorphism of their silicic fluorides is not destroyed by the investigation of the mineral substances. If, for example, a thin particle is to be tested for potassium, the specimen is heated before treatment with hydrofluo-silicic acid or with fluohydric gas.

The silicic fluoride of silver ($Ag_2\ Si\ F_6+4\ H_2O$) crystallizes in quite flat pyramids of the tetragonal system, which are liable to deliquesce in the air. (Marignac, Comptes rendus XLVI—854 and Jahresb. über Fortschr. d. Chemie v. Kopp u. Will, 1859 [für 1858], pag. 145, and 1860 [f. 1859], pag. 107).

The silicic difluoride of mercury ($Hg_2\ Si\ F_6+2H_2\ O$) prepared by the solution of carbonic oxide of mercury in fluosilicic acid and evaporation of the solution, appears in very transparent prismatic crystals.

The silicic fluoride of mercury ($Hg\ Si\ F_6+6H_2\ O$) crystallizes in water-clear rhombohedrons, arranged like stairs, and liable to deliquesce on exposure to air, and these are formed when the solution of quicksilver oxide in hydrosilicic acid is so concentrated that the crystals of the above-mentioned compound begin to separate, and also when the solution is left to itself at a temperature not exceeding 15°. (Gmelin's Handb. d. Chemie, pag. 865).

The silicic fluoride of lead: ($Pb\ Si\ F_6+4H_2\ O$) crystallizes according to Marignac, (Ann. Min. [5] XV, 221 u. Jahresb. über Fortschr. de Chemie, 1860, pag. 107), in forms of the monoclinic system, and especially in the combinations: $0P.\ \infty P,\ 0P.\ \infty P.\ \infty P2.\ P\infty .$—$P.P.\ 2P\infty$. In the clinodiagonal chief section $\infty P:\infty P = 64°\ 46'$, $\infty P2:\ \infty P2 = 103°\ 30'$, $P:P = 100°\ 2'$,—P:—$P = 101°\ 23'$, $0P:\ \infty P\ \infty = 91°\ 30'$, $0P:P = 130°\ 29'$, $0P$:—$P = 131°\ 24'$, and $0P:\ 2P\infty = 128°\ 6'$. The crystals are easily cleavable parallel to $0P$ and less easily parallel to $\infty P\ \infty$.

The silicic fluoride of lead $Pb\ Si\ F_6+2H_2\ O$ is, according to Marignac (as above), in some cases monoclinic, and usually appears in the form $\infty P.\ 0P$, rarely with $\infty P\infty$ or $P\infty$. In the clinodiagonal chief section $\infty P:\ \infty P = 71°\ 48'$, $0P:\ \infty P\infty = 103°\ 44'$, $0P:\ \infty P = 9\gamma°$, $0P:\ P\infty = 127°\ 55'$.

The large, beautiful, sharp-edged and smooth-faced crystals of *silicic fluoride of lead* (magnified to the 400th power) which I obtained from the lead-glance from Pribram, by means of hydrofluosilicic acid, had the forms: $\infty\ P.0P,\ \infty\ P.\ 0P.\ \infty P\infty, \infty P.\ \infty P\infty\ mP.\ mP\infty$. The prisms and needles were in radial groups and bore a great similarity to the aggregate forms of silicic-fluorides of calcium and strontium.

Treated with tolerably dilute sulphuric acid, they were changed into little secondary forms in a confused mass of delicate needles (anglesite?) and were soon colored grayish by hydro sulphuric gas.

The silicic fluoride of copper ($Cu\ Si\ F_6 + 6H_2O$) crystallizes according to Marignac (Ann. Min. [5] XV—221) in forms of the hemihedral hexagonal system, usually in the combination forms $\infty P2$. *R*; *R*: $R = 125° 30'$. If the silicicfluoride of copper crystallizes at 50° T, it appears as $Cu\ Si\ F_6 + 4\ H_2O$ in forms of the monoclinic system.

The rare, almost colorless crystals of silicic fluoride of copper, formed from chalkosine, bornite and tetrahedrite by hydrofluosilicic acid *being greenish-blue or bluish-green in reflected light* were usually imperfectly formed and always *deliquesced on the edges and corners.* After treatment with chlorine gas they appeared bluish-green in transmitted light.

The silicic fluoride of nickel ($Ni\ Si\ F_6 + 6\ H_2\ O$) formed by dissolving $Ni\ CO_3$ in $H_2\ Si\ F_6$, crystallizes according to Marignac (Ann. Min.[5] XV—262; Jahresb. über Fortschr. der Chemie v. Kopp u. Will, 1860, page 103, and Gmelin's Handb. d. Ch. p. 571) in forms of the hemihedral hexagonal system, and in greenish rhombohedrons and hexagonal prisms; is easily soluble in water. R: R=127° 34',—2R:—2R=97° 10', R:∞ R =116° 13', ∞ R: —2R=131° 23', 0R: R=149° 14', 0R:—2R = 130° 0'. Specific gravity=2.109 (Topsoë).

The crystals of silicic fluoride of nickel formed from ullmanite and carbonate of nickel were, magnified to the 400thpower, quite large, either prism-shaped, needle-shaped or similar to a rhombohedron combined with the basal face, very sharp-edged and smooth-faced, almost colorless in transmitted light, *grayish green in reflected light*, and usually covered with a dark-gray granular substance which is greenish-yellow and delicately granular in reflected light.

By the action of chlorine gas they acquired a more or less greenish, in some places emerald green color, and treated with dilute sulphuric acid were changed into small secondary forms in a close network of delicate, long, grayish needles; in reflected light this network appeared light grayish-bluish-green.

The silicic fluoride of cobalt ($Co\ Si\ F_6 + 6H_2\ O$), formed by dissolving carbonate of cobalt in fluosilicic acid appeared (according to Berzelius) in pale-red rhombohedrons and six-sided prisms which are easily soluble in water. According to Grailich (Kryst. opt. Unters. Wiens; u. Olmütz, 1858,75), R: R (Polk.) = 126° 59', R: ∞P2=116° 30'. The crystals are indistinctly cleavable parallel to ∞ P2. The specific gravity=2.067 (Topsoë) (Gmelin's Handbuch der Chemie, page 516).

The silicic fluoride of cobalt formed from cobaltine by means of hydrofluosilicic acid, appeared (magnified to the 400th power) in large, sharp-edged, smooth-faced crystals, which seemed to be isomorphous with the silicic fluoride crystals of nickel and iron. While the small crystals were almost colorless the larger presented a distinct, pure bluish or pale-violet color.

By action of chlorine gas the silicic fluoride crytals of cobalt were colored for the most part pale violet-brown, and dissolved largely into a violet-red liquid. Treated with rather dilute sulphuric acid, they gradually lost their bluish color, became colored pale rose-red, and about the borders merged into delicate grains.

The silicic fluoride of cadmium ($Cd\ Si\ F_6+6H_2\ O$) crystallizes, according to Marignac, (Compt. rend. *XLVI*—854, and Jahresb. ü. Fortschr. d.Chemie. 1859 [145] and 1860 [107]), in long prism-shaped, transparent forms of the hemihedral hexagonal system, which are very easily soluble in water.

The silicic fluoride of zinc ($Zn\ Si\ F_6+6H_2\ O$) crystallizes, according to Marignac (Ann. Min. [5] XV, 221 and Jahresber. über Fortschr. der Chemie. v. Kopp und Will, 1860, page 108), in hemihedral hexagonal forms, usually in the combination forms $\infty P2$. R or $\infty P2$. R. $0R$ and parallel to $\infty P2$ is distinctly cleavable. R: $R=127° 16'$. Specific gravity=2.104. Easily soluble in water.

Treated with rather dilute sulphuric acid, the crystals of silicic fluoride of zinc, which I obtained from sulphuret of zinc by means of hydrofluosilicic acid were very slowly changed.

The silicic fluoride of tin appeared in long prisms, which are very soluble in water, and by evaporation separate into oxide and silica. (Gmelin's Handbook of Chemistry, p. 153.)

The silicic fluoride of molybdenum, obtained from molybdenite by means of hydrofluosilicic acid, appears (mag. to the 400th degree) in large sharp-edged, smooth-faced colorless crystals which show greatest similarity to the combination forms of R. 0R and R. ∞ P 2. And the delicate leaves of molybdenite became transparent and of a beautiful grayish-blue color after treatment with hydrofluosilicic acid.

The silicic fluoride of platinum resembles a yellowish-brown gum. (Gmelin's Handbook of Chemistry, p. 1186).

From the foregoing it is evident that the silicic fluorides of copper, cobalt, zinc, nickel and manganese are isomorphous

(for the terminal edges of their fundamental rhombohedrons give the following values: 125° 30′, 126° 59′, 127° 16′, 127° 34′ and 128° 20′), and they appear, with the exception of silicic fluoride of copper, in very similar combination forms (mostly ∞ P2. R and R. 0R). And since these silicic fluorides are also related to those of iron, cadmium, magnesium and possibly several other metals, the series of those metals which appear in such silicic fluoride crystals as can hardly be distinguished by their same types is quite large.

But, since it is possible to separate successfully from each other the isomorphous silicic fluorides of calcium and strontium, and those of iron, manganese and of magnesia, in a very simple way, it is to be hoped that a simple and suitable reaction for all the silicic fluorides of metals of the hemihedral, hexagonal crystal series can be found.

Of the few and quickly made observations and experiments which I made with this end in view, I will mention the following: (*a*) All the specified, hemihedral hexagonal silicic fluorides were almost colorless in transmitted light if they appeared in small quantities, but, on the other hand, when they were brought forth in greater quantities or in larger crystals (from minerals easily decomposed by fluosilicic acid) a distinct, pale-violet-blue or violet-red color appeared upon the silicic fluoride crystals of cobalt; upon those of nickel, a gray color with a faint tint of brown; upon those of copper, a gray with a strong shade of bluish-green, while upon the silicic fluoride crystals of the other metals, except a grayish tint, no color was observed.

(*b*) In reflected light, of the crystals of the silicic fluoride metals mentioned under (*a*), those of copper appeared bluish-green, of nickel, greenish gray, of cobalt, bluish-gray.

(*g*) By the action of chlorine gas were the silicic fluoride crystals of copper colored bluish green, those of nickel, emerald-green or dark-grayish-green, those of cobalt, violet-brown and those of iron, orange-yellow, but in the presence of cobalt and nickel, citron-yellow or greenish-yellow. The silicic fluoride crystals of manganese contained a faint shading of rose-red, while those of zinc and magnesia remained colorless or became grayish-white.

(*d*) By sulphuric acid the silicic fluorides of most metals were gradually dissolved, though the silicic fluoride of cobalt gave a violet-red liquid. Lastly, hydrosulphuric acid and sul-

phide of ammonim gas were used; but the results were not so significant that a repetition of the experiment seemed necessary.

Since the silicic fluoride of lead appeared in monoclinic and the silicic fluoride of silver in tetragonal crystal forms, the distinction of the silicic fluorides of the two metals from each other and from the hemihedral hexagonal silicic fluorides of the above named metals, according to the form type, is possible. Moreover the silicic fluoride of lead shows itself in such a way that when treated with tolerably dilute sulphuric acid it is changed into little secondary forms in a net-work of delicate needles (anglesite?).

(b) By the treatment of minerals with hydrofluosilicic acid and by the observation and finally the further separation of the silicic fluoride crystals formed, the knowledge of the electro-positive elements of minerals is gained; therefore for determinative mineralogy (in general) a classification of the mineral kingdom—which is analogous to the classifications explained for petrologically important minerals—in groups according to the electro-positive elements, appears to be worthy of consideration.

(c) There are only a few minerals, which—like baryta, celestine and quartz—are not at all affected by the three per cent solution of hydrofluo-silicic acid; on the other hand some minerals are decomposed by it, which would hardly have been expected; as for example tourmaline, spinel in thin sections, sphalerite, and pyrite in fragments.

(d) The sesquioxides of aluminum, of iron, and as it appears of other minerals also, are quite changed into silicic fluorides by fluosilicic acid; but these *do not* appear to show themselves altogether in crystal forms. This permits the mineralogist as well as the chemist to distinguish the smallest quantity of any oxide, (for example, of iron which is easily changed into silicic fluoride crystals which remain stable in the air) in any (iron) salt, whether soluble or insoluble in acids.

(e) The quantity of silicic fluoride crystals formed under similar conditions and of the silica separated from silicates, offers an excellent means for judging the insolubility of the determined minerals in hydrofluo-silicic acid, and of estimating the importance of the determinations.

The reactions mentioned under (a) and in connection with the physical properties of the specimens should in most cases suffice for the determination of minerals.

(f) If the specimen is a simple salt soluble in water, the crystal form of the original salt, or that changed only by the percentage water of crystallization which it has absorbed, can, after the treatment with hydrofluo-silicic acid and drying of the specimen, be brought to appear in conjunction with the silicic fluoride crystals of the electro-positive elements. Thus, for example, if one should treat the larger grains of sodium chloride, Chile saltpeter, glauber salt, borax, etc., with hydrofluosilicic acid (each specimen separately), he will obtain near the hexagonal silicic-fluoride crystals of sodium (appearing in each specimen), in the first specimen little cubes of chloride of sodium, in the second rhombohedrons of sodium nitrate, in the third monoclinic needles of glauber salt, and in the fourth borax crystals recognizable through their form types. If kieserite be treated with hydrofluo-silicic acid, one obtains near the silicic-fluoride crystals of magnesium, epsomite also.

(g) If the specimen is a compound salt soluble in water, there appears near the silicic fluoride crystals of the individual metals, single salts of mineral specimens in their original crystal forms, or in these changed only by the absorption of the water of crystallization. Thus, for example, after the treatment of polyhalite with hydrofluo-silicic acid, I have also noticed at the first glance striated groups of beautiful gypsum crystals near the silicic fluoride crystals of potassium, magnesium and calcium.

(h) If the mineral specimen is a carbonate, on its treatment with hydrofluo-silicic acid, a very strong effervescence is in most cases to be noticed, by which the electro-negative elements, especially the colorless and odorless carbonic acid gas are sufficiently identified.

A more or less strong ebullition was observed, on treatment with hydrofluoric acid, of potash, soda, calcite, magnesite, dolomite, dialogite, witherite, strontianite, cerussite and azurite; on the other hand no development of gas could be noticed in the case of siderite, mesitine and smithsonite, although after the drying of the hydrofluosilicic acid drop, the formation of silicic fluoride crystals followed (less richly) from the carbonate last mentioned.

In the cases explained under (f), (g) *and* (h), *our methods offer a perfect chemical analysis of the mineral substance.*

(i) All minerals of the classes of glance, pyrite, and blende (and from the metals of pure silver) which I have heretofore investigated with fluosilicic acid, were more or less strongly

affected and gave a corresponding quantity of silicic fluoride crystals. The most beautiful and the largest crystals were obtained from iron, cobalt, nickel and lead minerals, the rarest from minerals containing copper, (chalcosine bornite, tetrahedrite). Pyrite fragments, however, form an exception since they gave only a few small silicic fluoride crystals of iron.

(k) If the material to be examined is in considerable quantity and one wishes to test the electro-negative element also, for a perfect mineral analysis, this can be done with the ordinary reagents, either upon a watch-glass (for the proof of *Cl*, *Br*, *I*, SO_3, P_2O_5, B_2O_3), or in a glass tube (for proof of *F*, *S*, *Se*, *Te*), or upon coal (for proof of N_2O_5, As_2O_5 Sb_2O_5, *As*, *Sb*), or in a salt of phosphorus lead (for proof of SiO_2, TiO_2, MoO_3, WO_3).

(l) If this be done to prove the alkalies only (even if they appear in the smallest quantity), in a silicate (for example amphibole, wollastonite), or to establish their absence, then treat the silicate specimen (in little grains) with hydrofluoric gas. Extract the silicic fluorides of the alkalies by gradually boiling in water upon a platinum cover and place this decoction reduced at a moderate temperature to one drop upon the hard plate (of Canada balsam) of an object-glass.

It is to be noticed here that in many cases the silicic fluorides of other metals contained in the specimen may appear. Thus I have always obtained from calcareous silicates rich in silicic acid (as oligoclase) a small quantity of silicic fluoride of calcuim; on the other hand, on analogous treatment of anorthite and wollastonite no needles of silicic fluoride of calcium were to be found. And the slow development of large gas bubbles on treatment of anorthite and wollastonite changed by HF was a proof that only a simple calcium fluoride had formed in the latter minerals. But by treatment of chondrodite, olivine and rhodonite with hydrofluoric gas and then with a cold drop of water, long prism-shaped silicic fluoride crystals of magnesium (iron) and manganese were produced.

Illustrations of parts of Microscopic Preparations Showing

(*a*) The silicicfluoride crystal types of metals appearing in petrologically important minerals and

(*b*) The characteristic changes which are effected upon the upper surface of thin sections or cleavage sections of petrologically important minerals either by hydrofluosilicic acid or by hydrofluoric gas.

[PLATES I AND II.]

Explanation of Plate I.

[Note. In the reproduction of the plates, some of the Greek letters employed by the author to designate the figures have become indistinct. These Greek letters, however, are confined to Fig. 4, Plate I. The reader may restore them all by noting that the small crystals in "Fig. 1," of Plate I. are designated in the original from left to right in the following order: Alpha, epsilon, iota, rho, nu, mu, sigma, tau, which in the following explanation are designated by a, e, i, r, n, m, s, t].

Fig. 1. Silicic fluoride of *potassium*, observed and represented when magnified to the 400th power: a, i, from the preparation of Prof. Stolba (by recrystallization on the object-glass); e, m, n, r, (∞ 0. ∞ 0 ∞, 0. ∞ 0∞.) from the water decoction of a dark-green biotite, changed by hydrofluoric gas. s. and t. are crystals formed by the recrystallization of silicic fluoride of *ammonium*.

Fig. 2. Silicic fluoride of *potassium* observed when magnified to the 400th power, and produced from the water decoction of amazonite from Miask changed by hydrofluoric gas.

Fig. 3. Silicic fluoride of *lithium*, magnified to the 200th power, and produced from the preparation of Prof. Stolba, by recrystallization upon the object-glass.

Fig. 4. Silicic fluoride of *sodium* (∞ *P*. *P*, ∞ *P*. 0 *P*.), magnified to the 400th power, and produced from the water decoction of albite from Zell (in Zillerthal) changed by hydrofluoric gas.

Fig. 5. Silicic fluoride of *calcium* (∞ *P*. 0 *P*, sometimes ∞ *P*. 0 *P*. ∞ P ∞ etc.), seen as magnified to the 150th power, preparation of Prof. Stolba.

Fig. 6. Silicic fluoride of *calcium* magnified to the 200th power, and produced from the hot solution of the above mentioned preparation upon the object-glass.

Fig. 7. Short, hexagonal prisms terminated by truncated pyramids of silicic fluoride of *sodium* and slender branching forms or spindle-like forms of silicic fluoride of *calcium*, magnified 200 times, and produced by recrystallization of a mixture of two parts by weight of silicic fluoride of sodium and one part by weight of silicic fluoride of calcium.

Fig. 8. Long hexagonal prisms terminated by blunt pyramids of silicic fluoride of *sodium* and thick, branching, or spindle-like forms of silicic fluoride of *calcium*, seen as magnified to the 200th power and prepared by recrystallization of a mixture of one part by weight of silicic fluoride of sodium and two parts by weight of silicic fluoride of calcium.

Fig. 9. Silicic fluoride of *strontium*, observed when magnified to the 200th power, and produced from the preparation of Prof. Stolba by recrystallization upon an object-glass.

Fig. 10. Silicic fluoride of *magnesium* (for the most part R, $R.0R$), magnified to the 600th power and prepared from chondrodite—through the successive treatments of the latter with hydro-fluoric gas and hydrofluosilicic acid.

Fig. 11. Silicic fluoride of *magnesium* (for the most part $\infty P2.R$, R, in part imperfectly formed) magnified to the 400th power and prepared from humite by treatment with hydrofluosilicic acid.

Fig. 12. Silicic fluoride of *magnesium* (for the most part imperfectly formed and regularly grouped crystals,) magnified to the 400th power and prepared by treatment of magnesite with hydrofluosilicic acid.

Fig 13. Rare crystals prepared from some calcareous silicates (corsite, tankite), by successive treatments with hydrofluoric gas and hot hydrofluosilicic acid, and observed when magnified to the 400th power. It is yet to be proven to which metal they belong. (The pyramidal crystals sometimes irregular at the middle edge, as well as the rhomboidal forms belong most probably to calcium).

Fig. 14. Tiny, short needles of silicic fluoride of *barium* and shrubby but yet delicate forms of silicic fluoride of calcium, brought out only by breathing upon them, (these forms are strongly stamped in the figure), observed when magnified to the 400th power and produced from a calcareous witherite—by treatment with hydrofluosilicic acid.

Fig. 15. Silicic fluoride of *iron* (mostly $\infty P2.R$), magnified to 400th power and obtained from the silicic fluoride of iron preparation by recrystallization upon the object-glass.

Fig. 16. A thin section of *amazonite* from Miask which was covered with a drop of hydrofluo-silicic acid[1] and after drying of the drop observed when magnified to the 400th power. The cubes of silicicfluoride of potassium and the lattice structure of the amazonite are noticeable.

Fig. 17. Portion of a polished section of *oligoclase* from Ytterby, which was covered with a drop of hydrofluosilicic acid and after drying of the drop observed, magnified to the 400th power. Tiny six sided tablets of silicicfluoride of sodium, and thin spindle-like forms of silicicfluoride of calcium are noticeable.

Fig. 18. Portion of a polished section of *labradorite*, of changeable colors, probably near a *calcareously rich andesine*, the labradorite being from Ojamo in Finnland, was covered with a drop of hydrofluosilicic acid and

[1] For all the specimens here mentioned the hydrofluo silicic acid was about 3½ per cent. strong.

observed after drying of the drop, magnified to the 400th power. Short hexagonal prisms usually surrounded by a bubble of air, of silicicfluoride of sodium and tablet-shaped, rhomboidal and thorn-shaped forms of silicicfluoride of calcium are noticeable.

Fig. 19. A part of a thin section of *labradorite* coming from the gabbro of Wolpersdorf, which was covered with a drop of hydrofluosilicic acid and observed after drying of the drop, magnified to the 400th power. The same crystal forms as in Fig. 18 are noticeable; but the spindle-shaped crystals of silicicfluoride of calcium are more numerous.

Fig. 20. A thin section of *anorthite* from the corsite from Corsica, which was covered with a drop of hydrofluosilicic acid and after drying of the drop observed, magnified to the 400th power. The same crystal forms as in Fig. 18 and 19 are noticeable; but the silicicfluorides of calcium are most numerous and the silicicfluoride of sodium most rare.

Explanation of Plate II.

Fig. 1. A cleavage fragment of *albite* from Dauphiné, which was covered with a drop of hydrofluosilicic acid and observed after the drying of the drop when magnified to 400th power. Short hexagonal prisms of silicic fluoride of sodium and wedge-shaped etchings sometimes arranged in rows were noticed.

Fig. 2. Part of a polished thin section of *leucite* from Vesuvius, which was covered with a drop of hydrofluosilicic acid and observed, after drying of the drop, magnified to the 400th power. Many cubes of silicic fluoride of potassium, two hexagons of silicic fluoride of sodium and a thin rod of silicic fluoride of calcium were noticeable, besides the polygonally etched and creviced surface of the section.

Fig. 3. Part of a polished thin section of *elaeolite* from Laurwig, in Norway, which was covered with a drop of hydrofluosilicic acid and after drying of the drop observed when magnified to the 400th power. Hexagonal crystals of silicic fluoride of sodium, a cube (in the centre of the illustration) of silicic fluoride of potassium are noticeable, and also the coherent plate, divided only by coarse veinlets of segregated silica through which the texture of the elaeolite with its delicate parallel groovings and its crossed cleavage cracks appears.

Fig. 4. A thin section of *scapolite* from Malajo, in Wermland, which was covered with a drop of hydrofluosilicic acid and observed after the drying of the drop, magnified to the 400th power. The spindle-shaped crystal forms of silicic fluoride of calcium, hexagonal tablets, often enclosed in a bubble of air, of silicic fluoride of sodium, parallel cleavage crevices, and between the latter wrinkle-like etchings are observable.

Fig. 5. *Left half. Lithium iron mica* from Zinnwald which was covered with a drop of hydrofluosilicic acid and observed after drying of the drop, magnified 100 times. Many crystals similar to a very blunt six-sided pyramid, of silicic fluoride of lithium, a crystal in the centre of the figure, of silicic fluoride of iron, a few cubes of silicic fluoride of potassium and a single spindle-shaped crystal of silicic fluoride of calcium.

Right half. Potassium mica from Greenland, which, treated like the mica mentioned above, shows besides two hexagonal prisms of silicic fluoride of sodium and two crystals of silicic fluoride of iron, only crystals of silicic fluoride of potassium.

Fig. 6. A dark-green *biotite* which was treated in a manner analogous to that of the micas given above and observed when magnified to the 400th power: showed larger crystals and slender prisms of silicic fluoride of magnesium and silicic fluoride of iron next to little cubes of silicic fluoride of potassium.

Fig. 7. A thin section of *amphibole* from Luhov (near Milleschase) which was covered with a drop of hydrofluosilicic acid and observed, after the drying of the drop, when magnified to the 400th power. Larger crystals and slender prisms of silicic fluoride of magnesium and silicic fluoride of iron, two spindle-like crystals of silicic fluoride of calcium, a cube of silicic fluoride of potassium, a hexagon of silicic fluoride of sodium and parallel, slender, wrinkled etchings are noticeable.

Fig. 8. A thin section of *diallage* from the gabbro from Wolpersdorf, which was covered with a drop of hydrofluosilicic acid and after the drying of the drop, observed magnified to the 400th power. Numerous spindle-shaped crystals of silicicfluoride of calcium, larger crystals of silicic-fluoride of magnesium and of iron and systems of parallel cleavage crevices running out in three directions are noticeable.

Fig. 9. Fragments of *bronzite* from Graubat in Steiermark, which were covered with a drop of hydrofluo silicic acid and after drying of the drop were examined when magnified to the 400th power. Large crystals of silicic fluoride of magnesium, and of silicic fluoride of iron, and the texture of the bronzite fragment with parallel groovings are noticeable.

Fig. 10. A thin section of *dichroite* from Orrijärfvi, in Finnland, which was covered with a drop of hydrofluosilicic acid, and after the drying of the drop examined. magnified to the 400th power Larger crystals of silicicfluoride of magnesium and irregularly arranged wrinkled etchings are noticeable.

Fig. 11. A thin section of a grain of *olivine* from Kozakov, treated in the same manner as is explained under Fig. 2, but delineated in all parts as magnified to the 400th power.

Fig. 12. A thin section of *olivine* from Kozakov (at Turnau) which was covered with a drop of hydrofluosilicic acid and observed when magnified from the 200th to the 800th power. The silicic fluoride crystals of magnesium and iron (drawn when magnified to the 200th power) the prominent pyramidal wholly parallel subindividual crystals, which appear magnified from 600 to 800 times, and the rhomboidal etchings of the entire surface of the sections are noticeable.

Fig. 13. The middle portion of a *chiastolite* crystal cut almost perpendicular to the main axis, treated with fluosilicic acid and examined, magnified from 200 to 400 times. Besides the central kernel with its rhomboidal outline the dark gray cross and the feather-like branchings of the coal-like substance parallel to the lateral edges of the prism, one notices only a few colorless particles of the unchanged chiastolite, while the greater part of the upper surface of the thin section presents a spotted or delicate undulatingly fibrous structure which in some places along the edge changes into net-like aggregates of parallel bars.

Fig. 14. Etchings upon *lithia iron mica* from Zinnwald, produced by the action of hydrofluoric gas and subsequent boiling away in water, and represented as magnified to the 400th power.

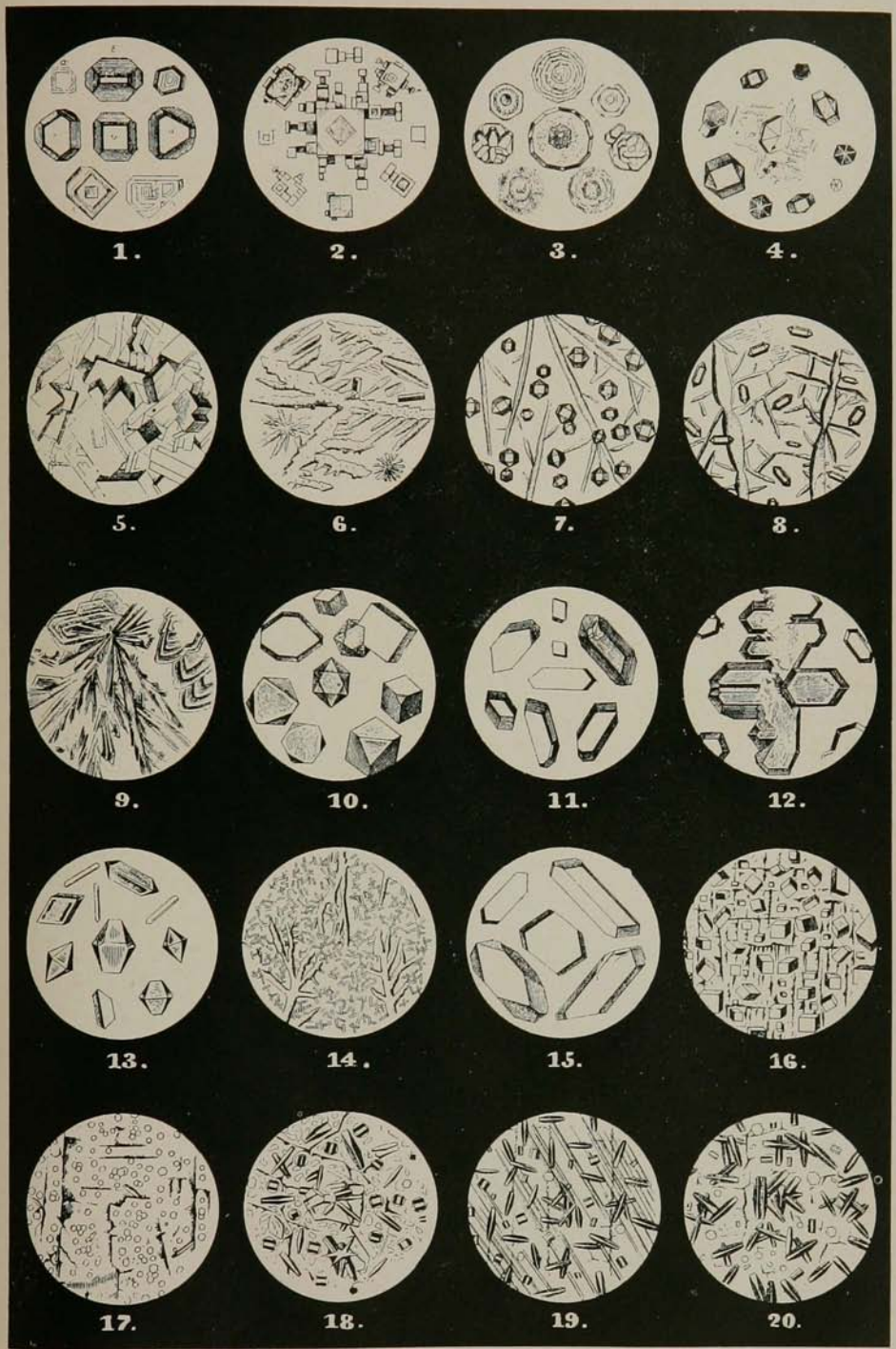
Fig. 15. A thin section of *elæolite* from Laurwig in Norway, treated with chlorine gas and observed, magnified to the 400th power. Cubes of of chloride of sodium which remain sticking in the remnant of gelatinous silica (not removed from the surface of the thin section), also the prism-shaped or long wrinkled etchings parallel to the main axis of the crystals and two large cleavage clefts running perpendicular to the main axis are noticeable.

Fig. 16. A thin section of *apatite* from Schlackenwald which was cut parallel to the base, covered with a drop of hydrofluosilicic acid and observed, after the drying of the drop, magnified to the 600th power. Striated aggregates of prismatic and acicular crystals are noticeable as well as uniform, dark particles of silicicfluoride of calcium, sometimes displaying an oblique angled cleavage and distinct hexagonal subindividuals of apatite (P. 0P.), which sometimes display a beautiful scale-structure and are parallel or a little inclined to the main axis of the crystals. After successive boilings in water, by which the silicicfluoride of calcium is removed, the subindividual crystals of apatite appear most clearly.

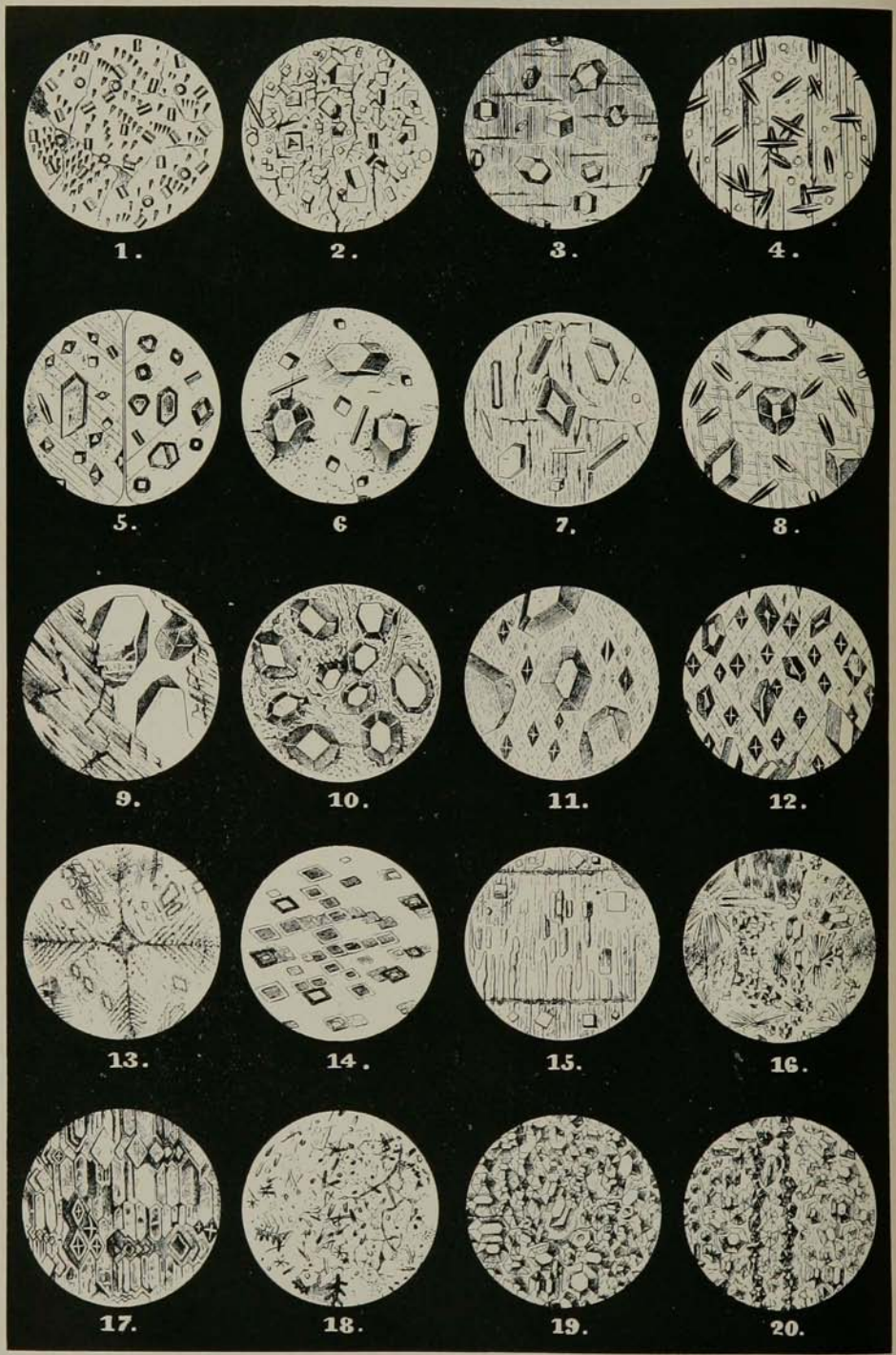
Fig. 17. A thin section of *apatite* from Zinnwald, cut parallel to the prism surface, boiled about 20 seconds in aqua regia and observed when magnified to the 600th power. Rhomboidal etchings of various lengths and solitary, prominent lateral edges of subindividual pyramid crystals.

Fig. 18. A thin section of *apatite* from Schlackenwald which was cut parallel to the base, treated with chlorine gas, covered with Canada balsam, furnished with a cover-glass and observed when magnified to the 400th power. Short, dark microlitic needles which cross each other in a horizontal position usually at an angle of about 60° and are probably to be regarded as edges remaining of subindividual crystals, of the uppermost stratum, furnished with long adherent bubbles of air. Among these, faint lateral outlines of the subindividual pyramid-crystals of the next lower stratum are visible.

Figs. 19 and 20. Thin sections of *apatite* from Schlachenwald, cut parallel to the base, treated with chlorine-gas, directly covered, not withCanada balsam, but with the cover glass, and observed when magnified to the 400th power. Both pictures illustrate the structure of the apatite crystal from little, hexagonal pyramid crystals (*P*, *P*. 0*P*), crowded closely together, sticking to each other, and almost parallel to the main axis. Upon those places of the apatite thin sections, which show no scale structure, the subindividual crystals are large and like thick tablets on account of the preponderance of the basal surfaces (Fig. 19). In the narrow scale zones, on the contrary, they are small and usually run out into pyramidal points. And the boundary lines of the scale zones consist of most extremely minute pyramidal crystals which are tolerably rectilinear and closely crowded together, as is shown by the two dark rows of crystals (boundary lines of the scale zones) of Fig. 20.



BORICKY'S MICRO-CHEMICAL METHOD.



BORICKY'S MICRO-CHEMICAL METHOD.

GEOGNOSTIC AND GEOGRAPHICAL OBSERVATIONS IN THE STATE OF MINNESOTA.

GEOGNOSTIC AND GEOGRAPHIC OBSERVATIONS IN THE STATE OF MINNESOTA

BY DR. J. H. KLOOS.

[Extracted from the the *Zeitschrift der Gesellschaft für Erd kunde zu Berlin*. Bd. XII. 1877. Translated by N. H. Winchell].

[NOTE. In two former reports, the tenth and eleventh, have been given translations of a part of the work of Mr. Kloos, based on observations and collections made by him in Minnesota before the beginning of the present survey. The following paper is not given entire, but only such additional facts and discussions as are not found in the former papers. In this connection attention may be called to the more correct description of the "Silurian" strata at St. Paul, the record of a well driven at the Northern Pacific crossing of the Red River of the North, at Moorhead, the petrographical notes on the crystalline rocks, and on the slates at Thompson, and the paleontological remarks on the Lingulæ at St. Croix Falls.

Mr. Kloos, in a communication to the translator, dated Stuttgart, Württemberg, Sep. 13, 1885, criticises the translation of his remarks on *Owen's Report of a Geological Survey of Wisconsin, etc.*, (Tenth report, p. 175), viz: "You have remarked that I said, 'a fault of the work is its petty simplicity,' which, as it seems to me, is not quite the meaning of 'Ein Mangel des Werkes ist seine geringe Uebersichtlichkeit.' Petty simplicity means, in the German language, *Kleinliche Einfältigkeit*, which is not rather flattering for an author, and which not at all expresses my opinion of Owen's work. On the contrary this work was very valuable, and almost grand, considering the time it was written, but it contains too much, and the geology is wrapped up in so many detailed topographical descriptions that it becomes difficult for a geologist of modern times to find his way through the long pages.

"I allow that it is very difficult to give the exact meaning of 'geringe Uebersichtlichkeit,' and I am only able to translate it at some greater length, for instance: 'A fault of the work is its arrangement, which makes it rather difficult to acquire a general view of its contents.' I would be pleased if in a future publication you could find an opportunity to say something on this subject, as I am afraid that the American geologists have felt hurt in reading my opinion of Owen's work." The translator is very glad of the opportunity to correct, on the authority of the author, such an error in the former translation, as it involves the opinion held by one geologist of the work of another.]

THE RED RIVER OF THE NORTH.

* * * There are present all the indications that the Red river of the North, at some earlier time, yet geologically not very far distant, has had a southerly course, and emptied into the Mississippi through the Bois des Sioux river, lake Traverse, Big-Stone lake and the Minnesota or St. Peter river. The small space of land between these two lakes last named, from which the water runs in opposite directions, is entirely flat, and rises but little above the shore of either lake. It happens frequently in spring, when the mouth of the Nelson river, in the far north, is stopped by accumulations of ice, that this strip of land, as well as a large tract of the prairie along the western border of the state, is overflowed, and that then is formed one extensive lake,—so much so that a flat-bottomed steamboat was got across the flooded water-shed, from the St. Peter river into the Red river of the North.*

For an explanation of the above-mentioned change in the direction of a part of the gathered waters of western Minnesota, it is only necessary to suppose a slight elevation of the land to the north, or which is more likely, that since the glacial epoch a sinking of a few feet has taken place.

Corroborative of this hypothesis, reference may be made also to all the rivers and creeks in the northern part of Minnesota, which, coming from the north, turn at a sharp angle toward the west and empty into the Red river of the North, having rapid and impetuous courses; while the Bois des Sioux river, with a northerly course, is a very slow flowing stream. The Red river itself also flows slow, and numberless are the curves and angles which both these rivers describe. It is only necessary here to introduce a slight change in order to give the waters of this very level prairie an exactly opposite course.

THE DRIFT IN MINNESOTA.

* * * The drift deposits through all their great extent, in their totality, remain tolerably uniform. This is specially the case with the preponderating clayey portions, which everywhere lie directly on the older formations, occupying the lowest part of the diluvium. It exhibits, in this respect, a certain analogy to the drift-clay and marl of Germany (in upper Schleswig, Pommerania, &c). These clayey parts are not always present, but the sand and gerölle, which in normal order

*This probably refers to the attempt of Capt. Davis, in 1859, which was not quite successful.—N. H. W.

overlie the clay, are still more frequently wanting. The clay, on the other hand, often reaches a thickness of 100 to 120 feet, and in its lower parts generally is of a bluish color, though of a yellowish or brown color in the region of lake Superior, and nowhere contains organic remains, although very often small rounded pieces of limestone and fragments of slate.

I found everywhere in the western part of the state, in the calcareous clays which there constitute the basis of the prairie, little rounded white limestone fragments. If these be broken they show within the structure of a pure dolomitic limestone of a yellowish brown color. Only rarely does one see small rounded fragments of granitic rock, while the limestone pieces always far predominate.

The clayey portions, (by the inhabitants called 'hardpan' on account of their firmness and hardness,) form the sub-soil throughout the prairies and the woodland, as well as the gently undulating well-watered table-lands; while the accumulations of sand and gravel form a very distinct terrane with many isolated rather high ridges. The gerölle of this latter formation exhibits a great diversity, and besides Silurian limestone in more local accumulations, consists of the crystalline rocks and slates which in the far north are found outcropping at the surface. In the sandy, very hilly tracts, are also found many large erratic blocks, which are wanting upon the prairies, though they are found in great numbers about the fresh water lakes which occupy the depressions in the sandy and stony diluvium.

Concerning the origin of this clayey deposit, with no trace of organic life, as yet no established theory has been accepted, it is very generally considered to be the material transported by glaciers, including with it the sand, quartz and gravel which is spread over it. But in what way the process was carried on, by which the fine clayey parts were separated from the granular and siliceous, is not entirely understood. In the clayey diluvium, furthermore, are those lakes the water of which has a bitter salt taste, and is unfit to drink. These are in the western part of the state, but restricted to the characteristically prairie portions. Here, and specially north from the St. Peter river, the surface of the earth is rich in salts, and for miles can be seen a white, bitter-tasting salt-crust, forming the surface, while all wells, even to a considerable depth, give bad water.*

* This bad water was largely due to the use of pine planks for curbing, the pitch in which was acted upon by the alkaline salts in the waters, and has been greatly modified since the use of pine for curbing has been abandoned.—N. H. W., Compare the Sixth Annual Report.

The above-described light colored diluvial clay with small limestone gravel, which forms the subsoil of the wide prairies on the Red river, possesses, in the interior of the American continent, a great extension. It is apparently identical with the yellow marl, or "bluff formation," which F. V. Hayden describes in his work on the geology of the upper Missouri, and which in several places has afforded the bones of the mastodon and elephant as well as land and fresh-water shells.

The extensive and thick beds of clay which cover the Huronian and the lower Silurian rocks about lake Superior, are by some geologists considered as of the same age as the above diluvial clay of the northwestern states, for example, Winchell in his geological reports. Others, however, ascribe to the light colored non-laminated clay, (the true "hardpan") containing small gravel a later date than to the dark-red clays about lake Superior, which more frequently show a bedded structure.* I have not been able to learn of any direct superposition of one over the other.

The lake Superior diluvium differs from "hardpan," by its very marked deep red color, and a greater thickness. I have seen on the lower course of the St. Louis river, a section of this clay amounting to 500 feet. It seems also to be completely free from stones, but exhibits often a plainly bedded structure, and changes often to sandy and gravelly beds.

The diluvium in southern Minnesota has a great thickness. Along the boundary of Iowa the Silurian limestone is covered only by a few feet of sandy beds, and even seems to afford a region where the drift is wanting entirely, without exhibiting any of the characteristics of its southern boundary, which are to be found much more evident in the neighborhood of the Ohio river.

Yet in the central part of the state, by means of wells, the great thickness of this post-tertiary deposit is known. From a well which was drilled a few years ago on the Northern Pacific railroad where it crosses the Red river, I obtained the following record of the layers passed through:

3 feet (English), black earth.

92 feet clay (marl?) evidently colored, with a few limestone pebbles.

10 feet gravel.

115 feet hardpan, firm clay mixed with coarse gravel.

30 feet white clay beds.

* Whittlesey on the fresh-water glacial drift of the northwestern states.

12 feet red coarse sandstone (looks like the Potsdam sandstone).

The river itself here has cut only to the depth of forty-five feet into the surface of the earth, and the shores attain nowhere a very much greater hight. It is hence questionable whether the whole thickness of 260 feet, of this section, belongs to the post-tertiary formation; rather I should be inclined to assign the deeper portion of it, and specially the 30 feet of clay-beds, to the Cretaceous formation, of the appearance of which at points not very far removed from this place, there will be a special description later. * * * *

THE LOWER SILURIAN ON THE UPPER MISSISSIPPI.

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I shall have opportunity later to return to the lower sandstone, in giving a special description of the beds on the St. Croix river. Owen has called it the "lower Silurian sandstone of the upper Mississippi," distinguishing the dolomite as "lower magnesian limestone." The characteristic fossils of the sandstone are trilobites, belonging to the genera *Dikelocephalus* and *Conocephalus*, also bivalves, *Lingula* and *Obolus*, which in the vicinity of Taylor's Falls completely fill whole layers. In the crumbling sandstones of Minnesota it is difficult to find determinable fragments of trilobites. Relying on observations in Wisconsin, Owen distinguishes six trilobite-layers, which are separated from each other by layers from ten to a hundred and fifty feet in thickness, of the existence of which, however, Hall, still later, expresses doubt. In the magnesian limestone, up to the present time, have been found only insignificant, scarcely recognizable traces of fossils. They are small *Lingulæ*, stony forms of univalves, which are the modified remains of *Euomphalus* and *Ophileta*, and fragments of trilobites similar to those in the sandstone. The geological horizon of the lower dolomite must therefore be reckoned to fall in the time between the Potsdam sandstone and the strata of the Trenton.

* * * * * * * * *

The city of St. Paul is, in general terms, built on two terraces, of which the lower consists of the St. Peter sandstone, which is covered and protected by limestone layers but a few feet thick. The upper terrace is formed by the upper part of the Trenton, and upon that lies the drift. A long-extended series of hills, composed of heavy drift, very largely made up of limestone fragments, surrounds the city on the north, the

west and the northwest, while toward the south and the south west the terraces descend abruptly. From the present river channel these are separated by a tract of low, principally overflowed land. The lower limestone layers which are often broken and removed from their original position, contain numerously the fossil *Strophomena alternata*, of Conrad. The valves of this large shell are, as in the Cincinnati limestone, chiefly accumulated in certain beds, and cover the surfaces of the layers in hundreds. These are the "*Producti*" which W. H. Keating, the geologist and historiographer of Long's expedition in 1823, mentions at Fort Snelling.

There are also in these lowest beds of the Trenton limestone, *Ctenodonta nasuta* Hall, agreeing with the figures in Dana's Geology of 1864 as well as in the geological report of Canada (in French) published in 1864, page 187, fig. 166; *Bellerophon bilobatus* Sow. (J. Hall in Palaeontology of N. Y., vol i, pl. 40, fig. 3), and a little crustacean, apparently *Leperditia fabulites*. Further up the river, at Minneapolis, I gathered from this same limestone,

Murchisonia bicincta Hall, Pal. N. Y., pl. 38, fig. 5.

Pleurotomaria lenticularis Conrad, N. Y., pl. 37, fig. 6.

Subulites elongata Conrad, N. Y., pl. 39, fig. 5, and Geol. Rep. of Canada, (French), 1864, p. 194, fig. 179.

Orthoceras juncium Hall.

Orthis tricenaria Conrad (also at St. Paul), Geol. Rep. of Canada, (French), 1864, p. 176, fig. 151.

Unfortunately the fossils that occur in the very hard rock appear only as casts, and I was obliged to undertake the examination with only such, excepting in the case of *Strophomena alternata*.

At the foot of the above-mentioned upper terrace, in the midst of the city, are the stone quarries which supply building material for St. Paul as well as for several other cities on the upper Mississippi. In these quarries the successive strata of the dolomitic limestone are disclosed to the depth of thirty or thirty-five feet. Here are firm horizontal layers of a bluish color, spotted here and there with darker, and appearing to be penetrated by evident calcite. Fossils are rare in this middle portion of the Trenton, with the exception of impressions of fucoids (*Buthotrephis*) which I saw on several of the layers. The impressions agree best with the figures of *Buthotrephis*(*Licrophycus*) Bill. *succulens* Owen, in Dana's Geology, and in Hall's Pal. of New York, vol i, pl. 22, fig. 2a. Several larger forms might

answer for *Palæophycus rugosas*; Owen thought these were too badly preserved to permit an exact determination. Besides these plant-remains I found, in my frequent visits to these quarries, only impressions of *Orthis tricenaria*, *Pleurotomaria* and a species of *Lingula*.

Above the blue limestone follow five or six feet of clayey and marly beds of a dirty-yellow color with many, though poorly preserved remains of fossils. *Strophomena* is again of frequent occurrence, as well as *Orthis tricenaria* and a species of *Murchisonia*. In color and composition these marly beds are hardly distinguishable from the lowest beds, which lie directly on the sandstone. The highest beds of the Trenton group appear in some of the bluffs of the streets in the higher parts of the city, lying directly under sixty to seventy feet of gravel and sand. These streets at the time of my residence there had been but little worked. These beds are very rich in organic remains, especially if the forms that are not very different could be known. Thin plates of dense crystalline limestone alternate with the marl beds which crumble down in the air, the latter being of a dirty-blue color. The entire slope was covered with disintegrated shale, in the midst of which were scattered thin limestone slabs of evident crystalline structure, which swarmed with beautiful coral-like bryozoa and small brachiopods. The most beautiful, most delicate forms of the palæozoic sea lie here in numberless specimens loose in the clay, or without any difficulty separable from the surface of the rock at the limestone quarries. Bryozoa, crinoid stems, head and tail shields of trilobites, with little Rhynchonellas, Terebratulas, Leptæna, Orthis and several gasteropods form the fauna.

The same fossils are found on the opposite bank of the Mississippi; only the bank is entirely wooded, and the higher beds are not exposed. But fossils can be gathered along the foot of the lower bank, where every rainstorm washes them down the numerous little gutters on the bluff. On both banks I have found the following named species common.

Stenopora (Chætetes) fibrosa Gold. spec.
Chætetes lycoperdon Say.

These bryozoa are represented as *Calamopora* in Goldfuss' *Petrefakta Germ*, plate 64, figs. 9 and 10. Hall, in Pal. N. Y. vol. i, plate 24, fig. 1, considers the branched form (*Ch. fibrosa*) and the hemispherical form (*Ch. lycoperdon*) as belonging to the same species, which opinion I can confirm by the specimens

gathered at St. Paul. The cell-structure in them is exactly the same, and transitions from both forms are quite common.

Petraia (*Streptelasma*) *corniculum* Hall, (Pal. N. Y. pl. 25, fig. 1).

Rhynchonella recurvirostra Hall, (Pal. N. Y. pl. 33, fig. 5).

Rhynchonella increbescens Hall, (*capax* Con., Pal. N. Y. pl. 33, fig. 13, a, b, c, d, p, r, s). Geol. Rep. of Canada, French, published in 1864, fig. 153.

This is the most common brachiopod in the upper strata. The very distended varieties of this species, which are so common at Cincinnati and other localities of the Trenton. I have not yet been able to find—nor *Orthis lynx*, their constant companion in Ohio.

Strophomena deltoidea Con., (Hall, Pal. N. Y. I. pl. 31, fig. 3).

Strophomena sericea Sow., (Hall, Pal. N. Y. pl. 31, B. 2).

Orthis testudinaria Dalm, (Geol. Rep. of Canada, French, published in 1864, p. 175, fig. 144).

Chonetes lata.

Schizocrinus nodosus Hall, (Pal. of N. Y. I. pl. 27). Stem joints in great numbers.

Leperditia, spec.?

Ptilodictya, spec.?

Calymenê senaria Con. (blumenbachii).

Illænus. Asaphus and Phacops. Head and caudal shields.

The remains of trilobites are comparatively rare; but there are present numerous specimens of *Calymena senaria*, though not nearly so many as at Cincinnati.

These fossils have all been collected by Logan from the Trenton beds in Canada, and by Hall from beds of the same age in New York. They are also well known, for the most part, from the Llandeilo flags of England.

Hall remarks that on the upper Mississippi and at the Falls of St. Anthony, the lower part of the Trenton group as it is developed in the eastern part of the United States, the Birdseye, Black River and the Trenton limestone proper, can also be distinguished.

So far as Minnesota is concerned, this must be wholly erroneous, and it would be difficult to distinguish in the upper magnesian limestone three parts that are palæontologically and petrographically distinct. The fossils taken together point to the level of the proper Trenton limestone, and some extend much higher in the Hudson River group, though they are not found in the lower beds in the eastern states. While the thickness of the Trenton group in New York is said to average about

300 feet, that of the limestone beds, with alternating sheets of shale, lying above the St. Peter sandstone, at different points in Minnesota, amounts only to 25 to 50 feet.

Of the Lower Silurian strata of the eastern states, only the Potsdam sandstone and the Trenton limestone have been identified on the upper Mississippi with certainty. The intervening formations, which in the east are predominatingly limy (Calciferous sandstone, Chazy, Birdseye and Black River limestone) are represented in Minnesota by the lower dolomitic limestone and the St. Peter sandstone, from the former of which, as yet, only doubtful remains of gasteropods and of trilobites have been obtained, while the sandstone is entirely destitute of fossils.

In the eastern part of St. Paul, the horizontal limestone beds are suddenly broken off, while the sandrock is entirely washed out. An interval extending up to the next range of bluff (Dayton's Bluff) about a quarter of a mile, is filled with immense heaps of debris. It is a mixture of sand and limestone *gerölle* which has been shattered and cut through by running water. On the other side of the Mississippi also the same formation is found extending out to the Silurian bluffs. To judge from the amount and the mixed nature of this gerölle, the waters from the upper plains adjoining the town must, in former times, have gathered tumultuously into this valley; and this extension to the further shore of the river certainly cannot be assigned to a date before the Mississippi had acquired its channel through the Silurian strata. Through the thickest part of this mass flow still two creeks, with a strong current, viz., Phalen's creek and Trout brook. Along the former passes the Lake Superior railroad, in order to reach the level of the surrounding country, while the St. Paul and Pacific road, coming from the west, found its only approach to the capital through the valley of Trout brook, and is compelled to describe a great curve in reaching its depot on the bank of the river. This is likewise the only route which the great Northern Pacific road had to take in order to connect with the lines to Chicago and New York, which, during the winter months, constitute its only means of communication with the east.

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THE ARCHÆAN FORMATION ON THE UPPER MISSISSIPPI.

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The massive crystalline rocks of the upper Mississippi and Sauk river show a great similarity in their composition. In the

first place are the syenitic granites (micaceous amphibole-granites*) which form sometimes long, rounded, gently ascending ridges, and sometimes low rock-crags. In these rocks a bluish-white translucent feldspar (orthoclase) is abundant, which lends to the rock a bluish color. The hornblende is of a dark-green color, and appears in irregularly outlined shapes. On the borders these are covered with mica scales, which sometimes surround the hornblendes, and sometimes stand out from them. The mica appears most generally not as an original ingredient. Quartz, in very small grains, is apparent everywhere. Plagioclase, also is not wanting. In short intervals, between the heavily wooded ranges of hills that contain these rocks, rocky knobs jut out in the swampy meadows, which consist of syenite. The feldspar is reddish orthoclase, with more hornblende Quartz and mica are sparingly present. The latter always stands in close association with the hornblende.

A very beautiful syenite granite forms the reef at the mouth of Sauk river, which here gives rise to the so-called Sauk rapids. It is a variegated rock in which sometimes a blue and sometimes a red color prevails. It contains everywhere two kinds of feldspar—besides red and blue orthoclase, a considerable quantity of greenish plagioclase showing evident striation; black hornblende, a little mica and quartz. The hornblende is sometimes in separate masses as large as a foot in diameter.

Three small parallel dykes of a dark, fine-grained rock pass perpendicular through the syenite, with sharp outlines, and also can be followed on the opposite shore. But here, singularly, the adjoining rock is not syenite but a very hard granite-porphyry with large crystals of feldspar, the relation of which to the syenite it was not possible further to discover. Under the loup the ground-mass of the dark dyke-rock resolves itself into a mixture of a feldspar and an augitic mineral. Very beautifully and finely striated feldspar-plates are distributed porphyritically. The microscopic and chemical examination of this rock has placed its relationship with the melaphyrs†.

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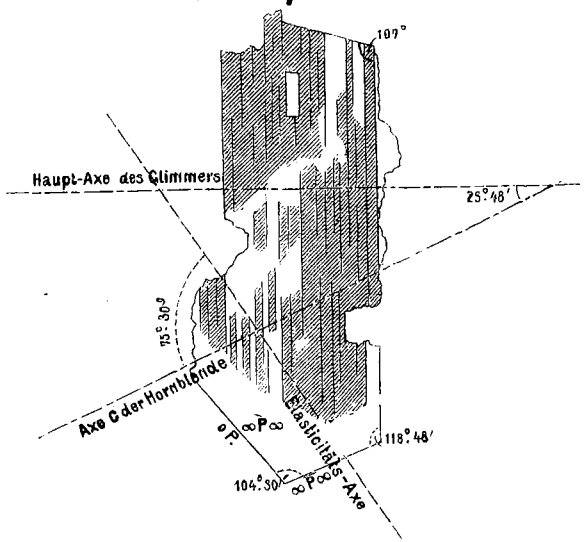
*H. Rosenbusch. *On granitic rocks*, in the *Zeitschrift d. d. Gesell*, XXVIII Bd., 2 Heft, S. 370 u. 371.

†In *Leonhard's Jahrbuch*, 1877, parts 1, 2 and 3, are set forth the complete microscopic and chemical characters of the massive crystalline rocks which I brought from Minnesota, whose investigation my esteemed teacher, Prof. Streng, of Giessen, had the goodness to undertake, some years ago; and in connection with the same are discussed the geological relations so far as it was possible to determine them, for which reason I here add nothing further on that subject. [See translation of this in the 11th report.—N. H. W].

Six miles further north, at the little town or Watab, (formerly a well-known point for trade with the Indians,) still another rock appears. The ridges here become higher and more conspicuous, but at the same time more heavily wooded and the rock outcrops less evident. The rock samples brought from Watab consist of quartz and augite dioryte along with syenite-granite and several varieties of hornblendless granite. Unfortunately the outcrops here are too few to make it possible to come to a conclusion as to the structural relations of these rocks with each other. On the spot one can only come to the conclusion that the granitic rocks outcrop as dykes in the quartz-dioryte, and that there is a greater extent of the latter than of the former.

A fine-grained rock from Watab, which is not treated of in the work in Leonhard's Jahrbuch, referred to on page 22, is abundantly pierced by blades of feldspar, and, even under the loup, shows much colorless feldspar and dull quartz along with a dark mineral (hornblende?) and a little tombac-brown mica, gave the following microscopic characters: In a clear groundmass, clouded only in spots here and there, lie the forms of green and brown crystals. Both are strongly pleochroic; the green become grass to yellowish-green, and show little absorption; the brown play from dark brown to light yellowish-brown, with strong light absorption. The regular six-sided sections



The faded portions indicate mica. The numbers and characters pertain to the hornblende.

of the latter mineral remain, at crossed Nicols, completely dark. The rectangular diagonal sections polarize brightly, and exhibit a lamellar structure. The green mineral has the cleavage of hornblende, the brown is mica. Hornblende and mica are often interchangeable, which appears here very evident by the difference of color.

Generally the mica lies about the margins of the hornblende, and surrounds it more or less regularly. In one case was to be seen a very beautiful interchange between hornblende and mica through a space of 0. 8 mm by 0. 3 mm as exhibited in the foregoing figure. By measuring the angles, and noting the position of the line of extension it was possible to determine that the principal axis of the mica forms an angle of about 23 degrees with axis C of the hornblende.

In polarized light the clear groundmass is resolved into individual grains of feldspar and quartz, the latter polarizing brightly and forming the cementing material between the feldspars. The latter are mostly twinned, sometimes clouded and sometimes not; some of them striated, others not. Often, of two or three individuals standing in the position of twins, one shows a striation and the others polarize singly or as units. Orthoclase is decidedly predominant. Quartz and orthoclase are filled with long needle-shaped microlites which are altogether colorless and pellucid, and have the aspect of apatite These needles, whose abundance is remarkable, penetrate also the hornblende and the mica. They show, under higher power of magnifying, evident polarization, are very often fractured, and for the most part are feebly bound together.

The rock is cut by feldspathic veins, which consist prevaililgly of clouded orthoclase although scattered plagioclase and irregular outlined grains of quartz also are visible. It is remarkable that here the apatite needles are wanting. Moreover the microscopic field furnished also some scattered minute reddish-brown clouded sections which are doubly refracting and may be titanite. There is a sprinkling also of pyrite.

This rock is accordingly a very finegrained magnesia-mica amphibole-granite, with more hornblende than the other granitic rocks of the upper Mississippi possess.

At Watab there are also melaphyrs which may sustain the same relation to the syenite-granite as at Sauk Rapids. Only here the formation is difficult to investigate, and the heavy forest, which afforded only isolated exposed points for observation, made it impossible in the limited time which I could devote to this

point, to determine certainly a dyke like manner of outcrop, such as is plainly exposed at Sauk Rapids. The melaphyrs brought from Watab are very hard and compact, under the loup of an entirely felsitic aspect; and the microscope has already revealed in them a triclinic feldspar, a greenish, somewhat changed augite and magnetite.*

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North from Watab the banks of the Mississippi, for a distance of twenty miles, furnish, again, no outcrop of rock. At the village of Little Falls, which is twenty-seven miles distant from the mouth of the Sauk river, the stream takes its way through a wide zone of mica schists and crystalline clay slates, which are developed to some extent as a good roofing-slate. The dip of the outcropping layers is toward the northwest, from 65° to 72° while the slates have a dip in the opposite direction from 70° to 80°.†

The rock overlying the schists consists of roofing-slates, that underlying is the mica schist next to be described. Between these lie micaceous clay-slates. Inasmuch as the schists which prevail from this place southwardly, on account of the fine distribution of the mica scales, have the aspect of a fine-grained gray gneiss, and it was of great importance, on account of its resemblance to another Archæan rock. to determine the presence or the absence of this kind of rock on the Mississippi, I had two slides made of the mica schist, one parallel with and the other perpendicular to the schistose structure. Under the microscope the predominant mica scales appear, in the former slide, in a colorless, pellucid groundmass, having six-sided outlines and a dark brown color. They remain dark at crossed Nicols; while the irregularly four-sided and the rectangular, long, diagonal sections exhibit a lighter color, a strong pleochroism and an evident lamellar arrangement. In the second slide the long, striated sections of the mica lie in a more or less parallel position, and between them are visible still a much greater number of wedge-shaped mica blades which, on account of their minuteness, appear colorless and do not afford any means of detecting any pleochroism. There are, however, also some blades which, parallel to 0P, remain dark at crossed Nicols.

In polarized light, and especially at crossed Nicols, the ground mass is resolved into clear, regular polyhedrons of

*Eleventh annual report, page 50.—N. H. W.

†The dip of the slates is given by Owen (l. c. p. 166) as the dip of the formation. The bedding lines were nevertheless plainly to be seen, and were evident, furthermore, by parallel bands of milk white quartz.

quartz, those of the same size ranked together. The appearance is much like that of a mosaic, and it is very interesting that in this respect both slides perfectly exhibit this structure. Hence it is very plainly demonstrated that the schistosity is dependent entirely on the position of the mica scales.

The quartz is relatively poor in cavities, though with a power 475 diameters I could distinguish some isolated fluid-cavities with moving bubbles.

Besides quartz and mica, the microscope brought to light in this schist only some grains of magnetite; of feldspar no trace can be distinguished, nor of apatite. The absence of feldspar shows that here we have to do with a genuine mica-schist, though this rock has formerly been conceived by me to be a gneiss, and has been so noticed.* The great roll which gneiss plays in the Archæan formation in America as well as in Europe, makes the absence of it on the upper Mississippi very remarkable, and warrants the opinion that it will still be found under the drift deposits.

In connection with this very evidently bedded mica-schist, at the place last mentioned, appear some diallage-diorytes, formerly described, which in the work referred to, were designated augite-diorytes.

South from the village the dioryte rises in the midst of the river-bluff, in low, broken cliffs, at the foot of which a stream has its entrance. Further up this stream also diorytes are again met with in the bed of the creek. These also contain diallage and are very fine-grained. The two places where these rocks outcrop are separated by low swampy ground, but are distant from each other only a few hundred paces, wherefore a continuation is probable without any intervening schist. Furthermore, in both these rocks, in hand-samples, it is possible to observe transitions in which the characteristic crystals of diallage appear surrounded by an outer band of hornblende.

Inter-stratified with the crystalline micaceous clay slates, are small lenticular masses of a granular hornblendic rock, which, both by its chemical and its microscopic characters, is found to be a quartz dioryte. These lie parallel to the schistose structure, which conforms to their contour, measure from a few inches to over two feet, and have, especially about their margins, great numbers of little garnets; while the inside is a cavity whose walls are often lined by quartz crystals.†

*See Leonhard's Jahrbuch, 1877, p. 36. *On the crystalline rocks of Minnesota in North America*, by A. Streng and J. H. Kloos. Also compare the Eleventh report, p. 34.—N.H.W.

†*On the crystalline rocks of Minnesota*, by A. Streng and J. H. Kloos. Leonhard's Jahrbuch, 1877, p. 36. Compare also the Eleventh annual report, p. 34.

North from Little Falls, the rocky strata disappear again under the sandy prairie; soon the river banks become completely wooded and afford nothing of geological interest. Rocky outcrops are first seen again at the falls of Pokegama, ninety miles further north. Here are beds of granular sandstone, or quartzyte, the age of which has not yet been determined.

THE CRYSTALLINE ROCKS OF THE SAUK VALLEY.

The Sauk river, which has already often been mentioned, cuts from east to west through the belt of crystalline rocks, of which we have already ascertained the foregoing facts, and and which outcrop at its mouth. Westward from the Mississippi, the first rock-exposure is at a distance of three and a half miles. Here are again low knobs of a red granite, having magnesia-mica and amphibole. Thence for twenty-five miles are long ridges of granitic rocks, heavily wooded. The intervening valleys are filled with drift, which has given origin to a series of ridges that rise from the sandy prairie. The most favorable exposures are at the villages of Rockville, where a very coarse-grained granite has wide extent, and Cold Spring, where in company with this is found a fine-grained porphyritic variety. The coarse-grained granite, different from any outcropping on the Mississippi, constitutes the prevailing rock at Richmond, where it is seen not to cease but to extend over the surrounding country, outcropping in the creeks and through a coarse debris which consists of orthoclase crystals, fragments of quartz and disintegrated mica. At Richmond is found again a dark, fine-grained augite-dioryte, of which the chemical composition, microscopic characters and relative position in the rocks have already been published in the work referred to.*

These rocks cannot be followed further west than Richmond. This village is situated at the border of the western prairies which the eye cannot span, where all geological investigations have to cease. Only at one point, near the village of Sauk Centre, forty-three miles west from the Mississippi, is there an upward swell or undulation, of the rock through the covering of earth. Here is a low ridge of crystalline rocks. A little quarry, opened by the German farmers for the purpose of getting stone for the foundations of their houses, has disclosed two different rocks; one a granite which for the first time exhibits a somewhat gneissic structure, and the other a quartz-dioryte. The

*Leonhard's Jahrbuch, 1877, p. 37 and 118; also, see my paper in Silliman's Journal, 1872, pp. 18-20.

whole outcrop is only sixty to seventy feet wide, and disappears in all directions under the grassy plain.

There is no doubt that the crystalline rocks of the Mississippi and the Sauk river belong to the Laurentian formation, and that the above described outcrops form only isolated points of observation in a wide belt of that formation which passes through Minnesota from north to south. The connection with the more extensive outcrops of Laurentian rocks in the northern part of the state is, nevertheless, as yet, only conjecture, and so it will remain, indeed, for a long time to come. Whether the crystalline schists at Little Falls should in like manner be placed in the Laurentian, or be considered to represent the Huronian, must likewise remain at present undecided. From the Laurentian rocks, as they are developed in Canada and Michigan, north and south of the great lake, those on the Mississippi differ notably in the lack of gneiss and crystalline limestone, although the presence of the latter in that region is indicated by great rolled fragments which I met with, particularly north of the Sauk river. With the Huronian also, as those rocks are described on the north shore of lake Huron, the schist-complex at Little Falls does not agree, inasmuch as the great conglomerates are wanting which are described by the geological reports of Canada.* The Huronian in the western part of Minnesota also is different, as we shall see below, and resembles more the beds of that age in Wisconsin and Michigan.

In a southerly direction the Laurentian zone is again met with on the St. Peter river, seventy miles distant. Owen describes from there, between the mouth of the Cottonwood river and the Redwood, granite and syenitic rocks extending over forty-five miles. These have been described more recently by N. H. Winchell in his second report. At several places they appear to take on a gneissic structure, and to pass into hornblendic schist.** The resemblance of the granite to that at St. Cloud he calls attention at several places. In the vicinity of Granite Falls and Patterson's rapids, on the St. Peter river, the granite is cut by dykes of trap and greenstone which can be followed for a distance of half a mile.†

* In the reports for 1864 of the Canadian geological commission, at the base of the Huronian system on the Thessalon river, north of lake Huron, are mentioned chloritic schists which alternate with diorytes, and therein appear to present a greater analogy with the appearances on the Mississippi.

** Prof. James Hall also has mentioned the gneissic character of these rocks.

†Second annual report on the geological and natural history survey of Minnesota, p. 160, et sequens.

The region between the Sauk and St. Peter rivers affords no outcrops. It consists sometimes of thick forest and sometimes of rolling prairie, and has a wonderful number of lakes. The connection of the crystalline rocks north and south is, nevertheless, probable, if one bears in mind the general relations of the terrane. While the first plateau along the Mississippi, west from the supposed belt of Laurentian rocks, has an absolute hight above the ocean from 750 to 800 feet, and in the west the prairies of the Red river lie at an average elevation of 850 feet, the elevation over the sea of the table lands in the strike of the granite belt reaches 1,100 to 1,250 feet according to the levels of the engineers of the St. Paul and Pacific railroad.

Whittlesey and Norwood, assistants of Owen, more especially entrusted by him with the examination of the interior of Minnesota, have likewise assumed a belt of crystalline rocks which goes diagonally through Minnesota and is crossed by the Mississippi as well as by some of its tributaries. In this, Winchell also concurs, and has exhibited on his very hypothetical map a wide zone of granitic and metamorphic rocks in immediate connection with those in the northern part of the state.

So far as our present knowledge of the geological nature of the interior part of Minnesota extends, it can only be said of it that there are present all indications of the existence of an area of Laurentian rock, but that it appears in outcrop only in the shores of the larger streams, and is covered by a very heavy deposit of drift over almost its whole extent, and is thereby hid from geological examination. Also concerning the Huronian it is only permitted to presume as yet its existence on each side of the massive crystalline rocks. As the schists at Little Falls, on one side, can be so regarded, so Prof. James Hall classes the metamorphic sandstone and red quartzyte in southwestern Minnesota, which have there a great development, and also embrace the pipestone or catlinite layers, as equivalent to the Huronian in the neighborhood of lake Superior.

Equally valid also are all the Silurian boundaries which (as well as Devonian strata) Winchell represents on his map* in beautiful order west of the granitic and metamorphic zone. As Winchell himself remarks,** this supposition rests entirely

*This map appears as a "preliminary geological map of Minnesota," with his first report.

** Pages 94 and 109. of the first report.

and only on the fact that Prof. Hind, of the Canadian geological commission has exhibited on his map of the British possessions, north from Minnesota, similar portions of the Silurian and Devonian in belts running from north to south along the Red river, and that these extend to the 49th parallel of latitude, the boundary line of the United States.*

But they are ideal there also, inasmuch as the southern part of the Winnipeg district is covered, like the northwest part of Minnesota, by a heavy sheet of drift below which the deepest wells penetrate only into the clay shales of the Cretaceous formation. So far as I know, there is no instance of outcropping old rock along the Red river throughout its course in the United States, and the same is true of its course for sixty miles further northwest. It is true Owen mentions that he found an outcrop of limestone with Silurian fossils two to three feet above the level of the water, on the upper course of the Red river. I have, nevertheless, sought for this place in vain, and am strongly inclined to believe that the American geologist mistook a limestone boulder with fossils of the Trenton formation for outcropping rock *in situ*. The existence of a great thickness of transported drift in this region (an out-running portion of the Leaf Hills, which will be mentioned below,) makes this the more probable.† Should later investigations establish the correctness of Owen's statement, there would be reached then a long stopping-place in the progress of our knowledge concerning the structure of the earth's crust in this difficult portion of North America.

THE CRETACEOUS FORMATION IN THE SAUK VALLEY.

At the village of Richmond on the Sauk river where the granitic and dioritic rocks of the Laurentian zone disappear entirely under the drift deposits, the river has cut a valley into the prairie the depth of thirty feet. In the steep banks I found strata of rock such that I had not as yet encountered in Minnesota, and which caused me to infer that I had here to do with strata of a younger formation. They are plastic clays of a prevailingly dark-blue color, with isolated lines of what appears to be white and yellow. Below the dark clays is a layer of kaolin

*The report of Professor Hind on the Assiniboine and Saskatchewan district of British America appeared in 1849.

†This statement of Owen is on page 173 of his *Report of a geological survey*, etc. According to his description this spot lies 50 miles distant from Otter Tail lake, measured by the river, and hence ten to twelve miles above Breckenridge, the end of the St. Paul and Pacific railroad. On his map this place is given at least fifteen miles further up the river.

with fragments of rock broken from the granite, and a few feet above the kaolin can be seen a band of very impure brown coal. The beds lie about horizontal, except that the kaolin layer has an entirely irregular outline, and presents to the beholder the appearance of a cloak-like covering of the underlying rock, which everywhere is granite as this appears in outcrop a short distance away.*

The river bluffs afford only scanty indications of the age of this formation. In spite of eager and continued search the plastic clays afforded me, besides several small fragments of shells, only a single small tooth of *Corax* or *Galeus*, which cannot be considered very reliable in determining the age of the beds. A few steps from the point at which these were found, shortly before my arrival, a shaft had been sunk, and in it a drill-hole carried further in hope of finding coal, which for several years has been reported in this region. By means of this mining work, though indifferently carried on, and by means of wells in the vicinity, have been discovered only some clay shales with impressions and fragments of fossils which show most conclusively that the beds which here lie directly on the granite belong to the Cretaceous formation, and indeed to the Benton group, or No. 2 of the series of the Missouri basin as it has been described by Meek and Hayden.** Not only are the bivalves, cephalopods, fish-teeth and scales identical, but the clays and shales are the same, at these distant points, and make it possible to establish an exact parallelism. Dark, plastic clays predominate. These alternate with fragile schists, with impure brown coal and clayey ironstone. The plasticity and the dark-blue to lead-gray color of these clays are so characteristic of the Benton group that they are distinguished easily from the sandy and marly portions as well as from the calcareous clayey beds of the upper members of the Missouri-Cretaceous.***

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*Winchell found later in several places on the St. Peter river, that a kaolin layer lies between the granite rocks and the clay beds, and sand deposits which here also are probably Cretaceous, (second annual report, 1874, p. 163, etc.) My observations upon the Cretaceous formation in Minnesota were first published in January, 1872, in Dana and Silliman's Journal of Science.

**Meek and Hayden's Palaeontological report of Lieutenant Warren's expedition to the Upper Missouri.

F. V. Hayden: On the Geology and Natural History of the Upper Missouri, in the Trans. Am. Phil. Soc., vol. xii, new series, part I.

***It is possible that the Fort Pierre group, only, could be confounded with it. This, however, holds a higher horizon, and likewise sometimes contains dark-colored plastic clays; but according to Meek and Hayden, the *Inoceramus problematicus* (=*In. labiatus* Schloth), the most abundant shell at Richmond, has not yet been afforded by these beds.

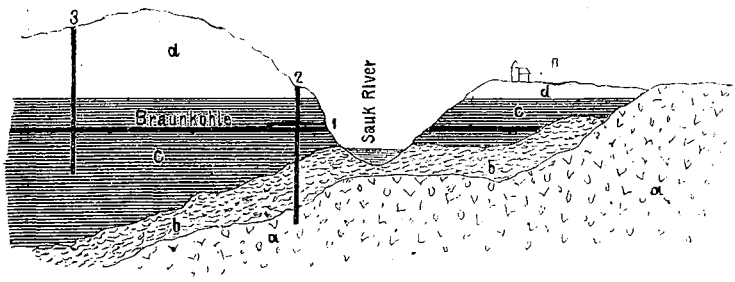
The above mentioned drill-hole, unfortunately, was made by men in whom all geological knowledge is wanting, and who neither kept a register of it nor were they in condition to give any reliable information concerning the nature of the layers penetrated. I was compelled, therefore, to depend on the material that had been piled up about the shaft.

The first search for coal was undertaken several years before by a farmer who had discovered the soft brown coal layer in the banks of the river. He ran a drift a distance of about sixty feet into the southerly bank, but a sudden rise of the water flooded his works and he then gave up the search.

The same farmer found coal three miles north from Richmond, in the midst of the forest, and dug three or four shafts in order to discover the supposed stratum. These also he was obliged to give up on account of the increasing waters. After that the matter remained unnoticed till 1870, when several merchants in St. Cloud rented the land in and around Richmond for the purpose of exploring for coal. There were sunk thereupon several shallow shafts in the neighborhood of the former experiment.

At the time of the experiment a streak of coal was said to have been followed of the thickness of four inches. The coal remained, nevertheless, very impure, and consisted, indeed, for the greater part of bituminous shale, which even now can be seen in the little mound thrown up near the opening of the pit. The dip amounted to four feet over the whole distance of sixty feet, and hence for the whole clay-complex a slightly inclined position was shown of about four degrees toward the south. At the opening of the shaft could be seen blue, white and yellow plastic clays with a little gravel and much clay shale. The shale contains here some scales of cycloid fishes as well as many fragments of *Inoceramus* and *Ostrea*, but unfortunately not a single entire specimen of any determinable species. The adjoining profile shows the appearance of the Cretaceous beds at Richmond.

It is worthy of note, still, that in an old pit in the neighborhood of the trial pit small quantities of a very clear petroleum had gathered, and that the water of a brook in the neighborhood carried with it some petroleum.



a. Granit,
b. Kaolin,

c.c. Plastic clay and clay shale with a thin layer of impure brown coal.

d.d. Diluvium.

1. The above mentioned small test drift.

2. Shaft and drill of a hundred and twelve feet in which the granite was reached. The drill-hole entered the granite eight feet, and the auger brought up small pieces of feldspar, quartz and pyrites, apparently derived from a pegmatite like the same that I have met with frequently as viens in the granitic rocks of the region.

3. Shaft and drill a hundred and eighty feet deep in which the granite was not reached.

Afterward having learned that in the digging of wells at several farm-houses south from Richmond, fossils had been discovered, I set out on a search in that direction. On the surface nothing more can be seen of the easily distinguishable clays and clay-shales. The land is very rough, heavily wooded, and the sandy drift in some places very significantly disappears. Two miles south from the village I came to a farm-house where a well had raised to a high pitch the wonder of the whole region about. The well was dug thirty feet deep, and then by means of boring had been carried ten feet still deeper. At eight feet below the natural surface of the ground a dark plastic clay was encountered, which gradually changed to clay-shale with numerous large shells. The water of this well smelled strongly of sulphuretted hydrogen, but the odor was lost after it stood a little time in the air, and it was then used as drinking water. At that time I could obtain at the place only small fragments of shells, from which the clay shale had crumbled, and the valves had been broken. Of the relation of

these fragments to *Inoceramus* but little doubt could be entertained. The well was soon afterward sunk somewhat deeper (always with the hope of encountering the coal stratum,) and the owner sent me several good specimens of the organic remains that were thus brought to light.

Besides the same fish-scales as on the Sauk river, were the valves of a large *Inoceramus* in great numbers, sometimes with the pearly interior perfectly preserved. Prof. Meek, at Washington, had the goodness to name these, and declared them to be the *Inoceramus problematicus* of the American geologists, adding further that this shell is identical with the *Inoceramus pseudomytiloëdes* which Dr. Schiel has figured in the second volume of the Pacific railroad reports, plate III, fig. 8.* I also got fragments and impressions of *Ammonites percarinatus*, Meek and Hayden, known from the Benton clays on the Missouri, very likely the same as *A. woolgari* Mant, and a *Scaphites* which Prof. Meek identified as his *Scaphites larvæformis*, or a closely related form of it, and which can scarcely be distinguished from *Scaphites æqualis* Sow.**

According to these fossils the clay and shale beds on the Sauk river correspond to the Lower Chalk, of England, the middle plains of Saxony, and the lower Turon of France (Turon Frankreichs).

According to the latest reports that have reached me, the well had been sunk, in a vain search for coal, still forty feet deeper, and that altogether it had reached the depth of 80 feet. The following statement shows the nature and thickness of the strata penetrated:

	Feet.
1. Gravel and sand	8
2. Dark-blue, plastic clay, occasionally with a tendency to the form of shale; numerous valves of *Inoceramus problematicus* and crystals of gypsum	30
3. Hard, sandy clay, and shale of lighter color, with pyrite, mica scales, and numerous scales of cycloid fishes. Fragments of *Inoceramus*. At the depth of forty feet a thin stratum of brown coal	8

*Probably this *Inoceramus* is identical with *Inoceramus mytiloëdes*, Mant. and *Inoc. labiatus*, Schloth. (Goldfuss, Petrefakta Germaniae, pl. II, p. 118, fig. 4.)

**At that time I sent the fossils and figures of the fragments which had crumbled, to the immortal professor Meek, at Washington, for determination. It has been impossible for me, however, to institute any later comparisons with European forms though the above determinations by so thorough a student of the Cretaceous formation of the interior of North America are sufficient to establish the horizon of the Minnesota beds and their full identity with the Fort Benton group on the Missouri.

4. The same clay with more layers of shale from three to four inches thick. Very large specimens of *Inoceramus problematicus*, as well as *Scaphites* and *Ammonites*. The valves sometimes retain their color and luster. At the depth of 50 feet a second thin bed of brown coal.... 10
5. Dark blue plastic clay without layering; the color still darker than the last thirty feet above, and sometimes entirely black. At the depth of 65 feet it was necessary to bore through a hard bed of grayish-black color..... 15
6. Clay, with thin scales and layers of pyrites..... 10

Total..... 81

The well was begun about 30 feet above the level of the water in Sauk river, and therefore at the same level as the prairie at Richmond, which shows the nearly level position of the strata. In a low meadow which in time of high water in the river, is connected with the river, I found the same unusual plastic clay at the surface. The locality where the above fossils were found lies two miles nearly south from Richmond, at the residence of a German farmer named Sieverding. The formation here certainly attains a very great thickness.

Besides the region about Richmond, I have also found the blue plastic clay on the shores of White Bear lake, in Pope county, [now Minnewashta lake—N. H. W.] at Glenwood, a village which lies 42 miles west from Richmond, and is 75 miles in a right line west from the Mississippi.* Here the clay appears under a covering of about two hundred feet of drift. This place is, therefore, the only positive evidence which I can cite for the extension of the Cretaceous beds towards the west, although I do not doubt such an extension, as will be further shown below; and hence, I believe it is correct to assume that these beds are continuous with the Missouri Cretaceous.

In the southern part of the state, Prof. Hall had ten years before described an impure, worthless bed of brown coal, which was associated with crumbling sandstone and sandy clays. In these beds appear leaves of dicotyledonous plants which point to an equivalence with the lower, or Dakota group, of the Missouri Cretaceous. They rest directly upon red-quartzytes which

*White Bear lake is one of the most beautiful lakes in Minnesota. The water-level lies about 150 feet below the level of the surrounding prairie. The shores are steep and as usual are covered with great boulders which are derived from the sandy drift. The blue plastic clays come to light at a spot, a few feet above the surface of the water, where a spring gushes out of the bank whose clear water must have been gathered between the yellowish sandy loam and the blue clay.

Hall, as above mentioned, assigns to the Huronian formation. From Nobles county, on the border of Iowa, some years ago several fragments of *Baculites* were brought to St. Paul and were preserved in the collection of the Natural History Society. They were alleged to have been found in beds of clay several feet below the surface. In late years, N. H. Winchell has accurately described* as Cretaceous, the beds that are to be seen along the lower course of the St. Peters river, in southern Minnesota. Unfortunately he has found no fossils, except a few remains of leaves, and, therefore, the age of the sands, clays and marl-beds which lie on the Silurian rocks can be announced, as yet, only as conjectural. Not to mention that without the aid of fossils it would be difficult to decide whether a portion of these younger beds be not diluvial, yet, on account of the frequent appearance of an impure brown-coal, it is possible to suggest for them a Tertiary age, and to conceive them as contemporary with the beds which have been described by Hayden and Meek as the Great Lignite formation of the Missouri. Therefore it must remain for later research to furnish more light on this point.

Although all these localities are three hundred miles distant from the Missouri, the natural surface of the intervening region (the eastern part of Dakota territory and of western Minnesota) affords no objection to the supposition that the above-described Cretaceous beds and perhaps the still later brown-coal and sand are connected with the Cretaceous and Tertiary formations of the Missouri. There is no exposure of older strata, in this latitude, between the belt of Laurention rocks in the interior of Minnesota and the above formations on the Missouri. The several low hill ranges, the Leaf hills in Minnesota, and the Coteaux des prairie in Dakota, are nothing but great accumulations of sandy and stony drift. The Leaf hills, a succession of long ridges curved like a horseshoe, situated between the Red river and the sources of the Mississippi, I have crossed myself in several places, for the purpose of finding a suitable route for a railroad to the British possessions. Nowhere, not even in the deepest cuts, were any outcropping rock beds seen.

The southern sides of the hills are very steep while to the north their slopes are very gradual. The strongly marked terrane is in width from six to ten miles and is composed of long parallel ridges joined by smaller transverse ones. Boulders of

*First and second reports on the geological and natural history survey, 1873, 1874.

various sizes of crystalline and sedimentary rocks lie scattered in wild confusion with numerous and very large erratic blocks.

Personally, I did not visit the Coteaux of Dakota but every opportunity was embraced of becoming acquainted with it through the engineers and surveyors. I was assured that at least between the 45th and 47th degree of latitude, here considered, there was seen no outcrop of sedimentary rocks of any kind either along the water-courses or on the hillsides. This region, like the Leaf hills, appears to be made up of unstratified stony and sandy material.

Under this supposition both of these elevated ranges are of later origin than the deposits of Cretaceous age and were not present at the time when the almost completed level upland formed the bottom of the Cretaceous sea. For this reason there is less need of admitting the existence of a number of small Cretaceous seas and particularly since the discovered fossils are absolutely identical. The various divisions of the Cretaceous formation along the Missouri show in their thickest development a thickness of nearly two thousand feet and it is therefore probable that during Cretaceous times a large ocean covered the interior of the North American continent.

On the maps included in the works of Hayden and Meek, the eastern boundary of the Missouri-Cretaceous sea is not given and professor Meek has assured me that this is totally unknown. The formation disappears towards the east under the great diluvial covering.

So far as I am acquainted nothing has heretofore been discovered of the eastern extension of the Missouri-Cretaceous sea. It seems to me from the above information and observation that the conclusion will be granted that the described strata of Sauk river near Richmond formed a portion of the eastern shore line of the Missouri-Cretaceous sea; however, I do not wish it to be understood that this correlation is established as a positive fact.

The Lower Silurian and the Huronian Melaphyr of the St. Croix Valley.

The same difficulties met with in geological explorations west of the Mississippi Valley are also met with along our route through the state east of this great river until we reach the valley of the St. Croix. This river has its origin in the vicinity of the western arm of lake Superior and flows southerly

towards the Mississippi and joins it after having formed the boundary line for 90 miles between the states of Minnesota and Wisconsin. In this entire distance the shores are covered with a dense primeval forest generally of pine, with a light sandy soil, while west of the Mississippi the forest is of deciduous trees and consists of oak, ash, maple, linden, walnut, etc., that grow in a heavy clayey soil. Only along the southern course of the St. Croix there extend sandy prairies interrupted by small forests of bur-oak to the vicinity of St. Paul.

Immediately after leaving the shores of the Mississippi on one side and the St. Croix on the other all possibility of geognostic observations on the surface are at an end. I have already stated that the first plateau of the Mississippi is from 750 to 800 feet above the ocean level. At this elevation the surface remains eastward from St. Paul to the St. Croix river. One rides for hours over rolling prairies and passes several large lakes in which the sandy and abundant diluvium with large erratic blocks cover all of the older sedimentary rocks. Suddenly the broad deeply eroded valley stretches out before the observer and a surprising view is given. With the greatest regularity several terraces rise one above the other and on the Wisconsin side at the same altitude can be readily followed as a step-like descent to the bottom of the valley.

The upper terraces are washed out of the diluvial formation; the lower ones lying partly in the Lower Silurian dolomyte, partly in the Potsdam or St. Croix sandstone which was formerly distinguished by American geologists as an older member of the Lower Silurian. Along the upper St. Croix are added the great eruptions of melaphyr and melaphyr-porphyry which form the base of the Silurian system in the vicintiy of lake Superior and which I shall have opportunity during this work to revert to more in detail.

* * * * On a geological map of Wisconsin published in the year 1869 by I. A. Lapham of Milwaukee, in place of these four formations [referring to Owen's map of 1851] there is but a single formation "trap," which branches from the southwestern point of the granitic and metamorphic rocks of Wisconsin. This comprehension is the proper one, as we shall see shortly that the crystalline rocks of the St. Croix are older than the Silurian sandstone. Similar formations of that which American geologists call "traprock" are found plentifully embedded in and on the edge of the Archæan

formation in Wisconsin, particularly in conjunction with quartzytes and conglomerates of Huronian age.

Owen regarded these rocks of the St. Croix as "porphyritic trap" and compared them with the Norwegian porphyry as found on the western side of Christiana-fjord at Bogstadt.* I also regarded it originally as a porphyry or a porphyry without quartz, under which name I first introduced it in 1871. Now, however, professor Streng found not only in the matrix of this rock but also in the porphyryritically disseminated crystals, besides the plagioclase only augite and its decomposition products (chlorite, or viridite and epidote) with very little orthoclase; and for this reason this rock is decidedly more basic than porphyrite, and should be rather placed with the melaphyrs†. The character of this rock upon the whole is nearly uniform; only in places are the porphyritic and amygdaloidal structures more abundant than in others. The matrix is cryptocrystalline and of a dark-green color; under a magnifier can be distinguished dark-brown to black banded feldspars and a transparent yellowish-green mineral, which has proved to be epidote, and probably was transformed from augite. Instead of placing it with the melaphyrs one could probably refer this rock of the St. Croix valley with equal correctness to diabase since the microscopic examination has shown both the constituents of diabase and the particular alteration peculiar to it, and further, that olivine and an amorphous matrix are totally wanting. Diabases of Huronian age south of lake Superior in Wisconsin and Michigan are besides of common occurence.

* * * * Besides Lingula and probably Obolus-valves I found in these Silurian strata only glabellas of trilobites the size of peas (*Conocephalus* cf. *minutus*). Of Lingula there is a form with a long pointed beak associated with much shorter and broader ones. Examples of the first attain a length of 15^{mm}. At first view one thinks he sees the well known *Lingula antiqua* and *Lingula prima* but of much larger size than those we are accustomed to meet with. The nature also of their association leads at once to the supposition that we have here the differently formed valves of but one and the same species. The large form with pointed beak Owen described as *Lingula pinnaformis*. His illustrations, however,

*Owen's Geological Survey, page 161.

†Ueber die Krzstallinischen Gesteine von Minnesota, von A. Streng und J. H. Kloos, in *Leonhard's Jahrbuch*, 1877, pp. 49-51. [See translation of this in the Eleventh Annual Report. N. H. W.]

do not allow of its being distinguished from the *Lingula acuminata* Conrad* and in the description he does not point out the differences between it and the earlier described forms of the oldest Silurian. Later James Hall recognized the species *Lingula pinnaformis* Owen, noting, however, that the muscle impressions of all these valves, so far as he had observed, showed sufficient differences from true *Linulae* to elevate the St. Croix form into a distinct genus and to which he gave the name *Lingulepis*†. At the same time he refers the shorter and broader form to *Lingulepis* but leaves it in doubt whether they belong to one or two species. Owen also cites from this locality *Lingula ampla* and *Orbicula prima*, both named by him, as well as *Lingula antiqua* and *prima* (?).

So far as the occurrence of all these species at St. Croix Falls is concerned it is positive that these identifications, as shown already by Hall,‡ with *Lingula ampla*, rests partly on mistaking one thing for another and erroneous identifications. Owen's figures are too poor to admit of comparisons being made with other localities, and Hall, who had a large amount of material from St. Croix Falls at his disposition, admitted that he could not make out Owen's species.

The material which is at my command is unfortunately insufficient to thoroughly work out the fauna of this oldest Silurian stratum, and I am compelled in this to wait until I shall again have the opportunity of visiting these localities. Besides *Lingulepis pinnaformis* Owen, there can probably also be identified an *Obolus* which particularly occurs in the pyritiferous marl-slate, but also in the limestone layers associated with *Lingulepis*. Externally it very much resembles the *Obolus appolinis* Eichwald, of Russia, and it is only, upon the whole, larger, attaining a length and breadth of 11 mm. The thin valves are irregularly concentrically striated and show an exfoliation of the outer layers, particularly towards the anterior edge, also a fine longitudinal lining. The greatest breadth lies somewhat below the middle, the lateral margins converge towards the beak and there form an angle of about 50°. On a single example only was it possible to uncover the muscular-impressions; they do not entirely agree with the drawings of *O. appolinis* as

*From the Potsdam sandstone of Canada, compare Geolog. Report of Canada for 1864, p. 109.

†See Cont. to palæontology in the sixteenth Ann. Rep. of Regents of the University of New York, Appendix D. p. 129. Albany 1863. This work of the American palæontologist unfortunately came into my hands long after my visit to these localities

‡L. C., page 125.

given by Davidson, in that the adductors instead of having an oblique direction and converging downwards towards the middle, are disposed in a straight line and stand perpendicular on the axis of the shell. With the small *Obolella* species from the Cambrian strata of England, the muscular impressions have also only a distant resemblance; agreeing no better with true *Lingulas* and with the illustrations of *Lingulepis*. It would be risky to found a new species upon this single example, and I prefer not to decide the question as to the proper disposition of those St. Croix brachiopods not belonging to *Lingulepis pinnaformis**

THE UPPER HURONIAN SLATES OF THE ST. LOUIS RIVER.

A third river which in central Minnesota demands the closest attention of the geologist is the one already named in the introduction, viz., the St. Louis river. It also offers for a great distance the only possibility of a view of the geognostic relations. Still more than on the St. Croix and on the upper Mississippi are here all explorations made more difficult, on account of the enormous forests and the extensive swamps. One reaches the St. Louis river now more easily by the railroad between St. Paul and lake Superior which was completed in the year 1869. This railroad follows at a small distance the course of the St. Croix and rises gradually from 700 feet at St. Paul to 1170 feet above the ocean level. Here it crosses the water-shed between the tributary streams of the Mississippi and those flowing in a northerly direction into lake Superior. This point is 120 miles distant from St. Paul and 35 miles from the western arm of lake Superior.

Outside of a few cuts in the Trenton limestone in the vicinity of St. Paul, the region along the Lake Superior railroad affords no exposures of the underlying rocks until one reaches the water-shed. Extended forests composed mainly of pines, firs, etc., stretch out on both sides. The country is flat and swampy, the brooks and water courses are cut but little into the surface. In the cedar-marshes, through which the railroad has been built on the hights of the water-shed, the first rocks project.

*Although the material still in my possession is not sufficient to positively determine the proper relationship of the St. Croix river linguloid, yet the rich material at hand from other regions and in the Göttinger collection which my highly honored teacher professor Von Seebach, with the greatest willingness placed at my disposal, has assisted much to settle earlier wrongly-formed opinions, for which I should not neglect in this place to express publicly my thanks as well as for his general readiness to help and teach me.

They are steeply inclined, darkish slates whose stratified knobs are elevated but a few feet above the marsh. Where the railroad company has built a high bridge over the river in the vicinity of the new village Thompson, we there have the first opportunity to study more closely these slates. Here the water has broken through these steeply inclined slates and has formed over it a series of falls and rapids which in a few miles descend 370 feet and are known as the "rapids of the St. Louis river."

Particularly fine are the slates exposed in the railroad cuttings at the junction of the Lake Superior R. R. with the Northern Pacific. One can here follow the strike for a distance of half a mile without interruption as well as the dip of the strata which the slatiness proves with accuracy. The strike is nearly direct east and west, while the dip varies between 30° and 50° toward the south. Strata of a crystalline clay-slate alternate very regularly with a rock which on first view reminds one of many German grauwacke-slates such as one often meets with in the Kulms-grauwacke of the Upper-Hartz. This simply crypto-slaty rock I am now led, since the microscopic examination, to regard as a horn-slate.

The protrusions of the clay-slates are jagged and rough, while the intermediate layers, which in contrast with the clay-slates that have been wrought variously as roofing-slates, must be regarded as very imperfectly slaty, are smoothed off and more or less excavated in such a way that when one walks over the slate-complex perpendicular to the strike, the clay-slates form the ridges and the horn-slates the troughs. The thickness of the different strata is various; on the railroad I measured several clay-slate strata from 25 to 30 feet thick, while the intermediate beds of horn-slate are in general somewhat less in thickness. In other places however the thickness is considerably greater, and there are places where large quarries have been opened for the obtaining of roofing-slates. The transverse slatiness, which warrants this, passes through the entire clay-slate strata and shows in connection with the changeable dip of the strata a constant direction from 75° to 77° toward the south. Crevices filled with quartz, calcspar and feldspar are of common occurrence throughout the entire strata-complex.

For a long time uncertain where to place the rock here named horn-slate, I received my clue from a microscopic examination of it. A detailed description is therefore necessary. The color can be called a light green. This rock to the naked eye appears entirely compact although with many minute white and

luminous dots which under a magnifying glass prove to be very small quartz and feldspar crystals, or grains, and which are imbedded in a felsitic matrix with a splintery fracture. Under the microscope there appears an irregular aggregation of quartz-grains and feldspar-crystals, and this is traversed in all directions by a dirty-greenish granular substance through which the whole receives the appearance of an irregular mesh or network. In quantity the quartz is predominant; the feldspars are prevailingly striated.

Where the green-colored substance is massed in somewhat greater quantities between the quartz and feldspar-crystals one can plainly observe that it shows no pleochroism between crossed nicols on rotating the preparation, as it remains totally dark. Under stronger magnification it dissolves itself into greenish, pipe-like bodies, flakes, pellicles and in still smaller, short, apparently colorless microliths, which however by turning the micrometer screw also become green and are therefore sections of flakes lying in the various strata of the preparation. Where the pipe-like bodies, filled with a greenish pigment, lie between neighboring quartzes and feldspars, a parallel arrangement among them can be detected, and they are placed at right angles on the edges of the crystals. They also penetrate into the quartz and feldspar and sometimes completely fill the latter while the quartz usually appears clear and does not show many cavities or dark-edged bubbles. Rarely was I able also to discern moving bubbles. Yet the quartz could be sufficiently recognized by its clearness, smooth surface and active polarization. Magnetic iron appears in small, separated accumulations which by the strongest magnification dissolves only along the edges into small grains. The similarly formed particles of a dirty-brown color originate apparently from the decomposition of the magnetite.

We therefore have here an imperfectly slaty, crypto-crystalline rock composed of quartz, plagioclase, a greenish chloritic mineral and magnetite, with a sub-crystalline clay slate regularly interstratified, which agrees in its construction and nature with the horn-slates as it was recently described by R. Credner* from the older slate-formation of Saxony and which was formerly called felsyte-slate. This rock apparently was regarded by Norwood as well as by Eames as green stone. Its regular alternation with the roofing slate in thin beds but in a very

*Compare G. R. Credner das Grünschiefer system von Hainichen im Kgr. Sachsen, in der Z. f. d. Ges. natur Wiss, 1876, B. XLVII. S. 25 ff.

thick and widely distributed slate-complex, points however decidedly against the acceptation that we have here to deal with a massive rock.

For comparison with the horn-slate I also undertook a detailed microscopic examination of the roofing-slate. The following description is based on a thin section made parallel with the cleavage-planes. Only under strong magnification does this exceedingly fine-grained slate-rock resolve itself and then into the same greenish substance which to some extent forms the cement in the horn-slate between the quartz and feldspar crystals; only that in the roofing-slate it has a far greater share in the composition; one sees, besides this, but comparatively few sections of an anomalous nature which are first brought out by polarized light.

The pale-green substance is throughout not columnar and fibrous but chloritic and decidedly scaly; one distinctly recognizes the same flakes and pellicles as in the clay-slate and can observe how the flakes partly cover and are superimposed on one another. In polarized light they show no change but remain dark in turning the thin section between crossed-nicols. Of the larger sections there are two kinds: light, slightly colored and dark. Some of the light-colored ones give distinct evidence of mica scales. They polarize very lively, have a very irregular shape and are mostly fringed, also often creased and bent over on the edges. They are, however, to be regarded as clastic particles. All these nearly or altogether colorless sections cannot, however, be referred to mica, as a part of them appear to be quartz. The dark sections are sometimes almost square, occasionally rhomb-shaped and often wholly irregular in form. Their color appears in polarized light light-yellow, yet they are generally filled with a black untransparent substance which often causes them to appear as opaque particles. In direct light they appear in the dark field as faint yellow in color; in rare instances they attain the size of 0.1mm. the majority, however, remain below 0.01mm. in the largest section. The appearance signifies that these bodies are epidote.

Besides these larger sections one discerns, however, under a magnification of 400 diameters, still more numerous smaller needle-shaped forms which under crossed-nicols appear in the dark chloritic matrix as bright, shining, short threads. In turning the section they become light and dark and also exhibit faint colors; rarely do they attain a length of 0.5mm. with great thinness; generally, however, they are not over 0.005mm. long,

and when compared to their length, somewhat broader. Magnetic-iron can be observed in somewhat large dust-like accumulations. Only with great effort, and after many failures, was it possible also to prepare a thin section transverse to the cleavage of the roofing-slates sufficiently thin and transparent to distinguish the various particles. This showed, first of all, that in contrast to the above observed mica- slates the slatiness is not dependent upon the position of the scales of a single element (in that case of the mica), but on the contrary that all particles have a stretched layering. With this there also appears a net-like stucture, in which the colorless, pellucid elements in parallel lentile-shaped aggregates are surrounded by a green chloritic substance. These now appear in transverse section between crossed nicols different from the picture presented in the longitudinal section. There is namely a polarization appreciable and at the same time a lamellar or fibrous structure in the sheets, parallel with the cleavage. These are shown plainest when the direction of the layers forms an angle of 45° with the principal sections of the nicol-prisms; when it coincides with one of the principal sections, the green scales appear totally dark. Thin splinters of the roofing-slate can with the aid of a blow-pipe be melted into a dark-green glass; the thinest splinters of the horn-slate, however, can only be rounded on the edges; after heating the pale green of the transparent edges of the splinters changes to an opaque brown-green. Muriatic acid had no effect upon the sections of the roofing-slate even after heating; powdered it was not appreciably affected by sulphuric acid.

After all this the difference between the horn-slates and the interbedded roofing-slates appears in the greater content of quartz and feldspar, while the latter contains more chloritic properties, and microlites the proper reference of which remains uncertain.

Midway between Thompson and Fond du Lac, a small village on the St. Louis river and up to which point this stream is navigable, the above slate system is uncomformably overlain by sandstone layers of the Lower Silurian. Lake Superior, as is known, forms a basin in these strata and repeats the same interrelations along the whole south shore*. Everywhere the Potsdam sandstone lies in undisturbed deposits upon the slate knolls

*Compare the above mentioned geological map of Wisconsin and H. Credner's: Vor silurische Gebilde der "Oberen Halbinsel von Michigan" in der Zeit. der deut. geol. Gessel., 1869, pages 531 and 550.

of the great clay-chlorite-talk slates and quartzytes which together form the Huronian formation. Although I found no organic remains in the sandstone strata of the St. Louis river yet they undoubtedly belong to the Potsdam sandstone as one can conclude with reasonable certainty from analogy with its widely distributed and often repeated stratigraphic relations along lake Superior, and that these roofing and horn slates must be assigned to the Huronian.

A local disturbance of the inter-relations of the strata does not exist on the St. Louis river. The position of the slates of the older strata is similar, so far as opportunity to observe them has been afforded, everywhere in the regions of the Archæan slates. I also did not find in the vicinity any crystalline rocks to whose influence Norwood had earlier ascribed the position of the bedding, even though it may have been possible for him to give the direct proof of it. I do not doubt but that further examination of this portion of Minnesota will show a similar development of the Huronian system as that already described in detail for northern Michigan. * * *

The Silurian Melaphyr and Gabbro of Lake Superior.

The great clay masses already alluded to in the description of the diluvium which on lake Superior is distinguished by its prevailing red color, along the lower course of the St. Louis river conceal the older formations from the view of the observer. This certainly very young formation, which has never furnished organic remains, rises above the water level from 600 to 700 feet. It is on account of these deposits, that the relations between the Lower Silurian and the crystalline rocks cannot be determined and which on the western arm of lake Superior forms the shore.

At the terminus of the Lake Superior railroad near the steep cliffs where a few years ago the new city of Duluth originated, at several places these rocks are well exposed. They form almost the entire left shore of St. Louis bay and the bay of Superior. The former is a widening of the mouth of the river; the latter is formed by a narrow extension of the land separating a portion of the lake, and because of its protected position it forms a harbor much sought after.

The configuration of the western end of lake Superior is a most remarkable one. Narrow points branch off from the shore

parallel with one another, and meet similar extensions from the opposite shore of Wisconsin. They still have between their extremities narrow openings affording entrance to the inner waters. The outer of these land extensions "Minnesota point" is six miles long and has a general width of only 600 feet. It consists of coarse pebbles (*shingle*) and is elevated but few feet above the water-level. The pebbles have a longish, flattened shape and consist mainly of melaphyrs and amygdaloids with larger and smaller calcspar amygdules, which one finds contiguous in the immediate vicinity.

Connor's point in Wisconsin and Rice's point in Minnesota divide St. Louis bay from the bay of Superior. Between them there is a 50 feet deep channel through which the waters of the St. Louis river flow into the lake. Superior bay has its greatest depth along the Minnesota shore. In Wisconsin the inhabitants had to build out into the bay several hundred feet to procure a depth of nine feet, while on the Minnesota side the water has a depth of 15 to 18 feet. A street of Duluth now follows along Minnesota point; the railroad company has cut the same near its junction with the land and has made an artificial water-way protected by a strong breakwater. The natural entrance six miles farther south is variously exposed to filling up with sand; this entrance is being continually improved by the inhabitants of Wisconsin and more particularly by the city of Superior, a competitor with the new town Duluth.

In the cliffs near the city of Duluth at the time of my visit, the soil and red clay had been removed in places by the building of streets. There appear essentially two totally unlike crystalline rocks. One of these, which was particularly well exposed at the railroad depot, I have already given in my first notice of Minnesota as a gabbroid or hypersthene rock. Since the examination by Prof. Streng it has actually proven to be gabbro; the preponderance of labrador-plagioclase with equal quantities of hornblende and diallage led him to regard it as hornblende-gabbro. Noticeable in this rock is the enormous wealth of feldspar and the great paucity of other elements, which are, except the titanic magnetic iron, difficult to detect between the feldspar-crystals and can only be distinguished with sufficient clearness in thin sections. The distinct twinning-striation, the plainly marked cleavage planes, the lustre and beautiful changeable colors, and the results obtained in the analysis of this rock all point to the labrador nature of the feldspar.

The pecular formation of this rock lends probability to the surmise that it is stratified—opposed to which, however, is the general distribution which it occupies on the cliffs along the St. Louis river. Unfortunately it was not possible to observe the contact relation with the other rock series. Its last appearance is several miles away from the Lower Silurian strata, and towards lake Superior the dense primeval forests conceal it from observation.

This rock, erroneously named Duluth granite, has recently found a common use in monumental work as it receives a very high polish.

A short distance beyond the gabbro (i. e. toward the east) the beautiful porphyry-like melaphyr forms the first rocky masses on the shore of lake Superior. In contrast with the gabbro above described is a green rock of similar composition, which forms on the St. Croix river the support of the Potsdam sandstone, and has here a prevailingly brown color and greater tendency to embrace amygdaloids. The latter are therefore on the western shore of the lake widely distributed and pass gradually into the compact rock. Under a magnifier one soon recognizes that the prevailingly brown muddy coloring is due to a profound separation of the individual elements, and the examination of a thin section shows particularly the feldspar to be impregnated with a granular substance which in the greatest magnification is no more definable. The presence of epidote, which mineral is secreted in various forms on the hills, and appears in conjunction with calcspar, laumontite, and a dusty iron-and-a-manganese-rich substance, as if impregnating the matrix of the melaphyr, points likewise to the change which the original elements have suffered.

At one place only was there a slight break in this rock, and there it seemed to appear fresher, having a dark green-to-black color. Here it appeared in connection with fine non-porphyritic melaphyr ; whereas the immediate passage into the brown, epidotic, melaphyr-porphyry, which has a much larger distribution, was not discernible.

In the amygdaloids, into which the brown melaphyr passes insensibly in several places, the decomposition of the matrix has gone on considerably further. The longish cavities are filled with quartz, calcspar, a chlorite-like mineral and the above mentioned dark, dusty substance. There are also long crevices attaining several inches in size which are filled with large calcspar leaves, laumontite and epidote. Of a filling of the amyg-

daloids and crevices with copper or salt of copper, as it occurs on the north and south shores of lake Superior in the trap-like rocks of the Huronian and the Lower Silurian. not a trace was discovered at Duluth.

Although it cannot with certainty be stated what relation the melaphyr and gabbro of Duluth have with the sedimentary rocks, yet where the above described formation appears on the St. Louis river, the succession appears to me to allow the conclusion that the shores of the western arm of lake Superior are made up of beds in the Potsdam sandstone, and that they probably consist of dike-like intrusions. From the descriptions of Owen, Whittlesey, and others, we know that trap-like rocks, *i. e.* melaphyrs, play a great part on the north shore of lake Superior, and that they appear partly in a conformable position with the strata of the Potsdam sandstone and partly as dykes.

A ridge continues along the northern shore, and is composed of crystalline slates and other Archæan rocks. It extends from four to six miles into the land, with its greatest elevation from 600 to 1,000 feet above the water level. From the crest of this ridge the rocks descend gradually towards lake Superior, and here lie against the Silurian strata with a southerly dip. A number of winding streams have their origin on this ridge, rapidly descending through the various massive and stratified rocks, affording numerous exposures of the relations of the often very complicated strata. Some of these by their indications of copper have obtained a certain notoriety, and are still regarded as rich in copper by many people ; this is particularly so in the French and Knife River districts, which are also within the limits of Minnesota.

To similar intrusions the above mentioned land-projections, which extend in front of the St. Louis river in a manner similar to the low ground in front of the river-mouths of northern Germany, point; but here they have a totally different origin.

Whittlesey has set up the proposition that the trap-like rocks, which contain metallic copper, are of the age of the Potsdam sandstone, while those containing sulphides belong to the Huronian.* And also that the copper bearing dykes become barren as they pass from the "trap" into the sandstone. The first portion of this proposition if proven would be of great importance to Lake Superior copper mining, still I believe I am forced to doubt its general accuracy. The dia-

*Whittlesey's Report of 1866, page 5.

base-like melaphyr of the St. Croix river, which is older than the Potsdam sandstone, is numerously traversed by dikes, in which of course now and then occur sulphides. Constantly, however, I found with it also pure copper in soft leaves and segregations or in threads, thin sheets, even in wire and button-shaped masses.*

On the other hand, a dike-rock from the horizon of the Potsdam sandstone of the Knife River district, about 30 miles east of Duluth, had, besides pyrite, only sulphuret of copper in slight segregations, without a trace of pure copper.

At most localities where Huronian or Silurian melaphyrs appear, traces of copper have been found in the crevice-fillings. On the surface of the melaphyr of the St. Croix river one often sees feldspar veins of but few inches thickness which become wider at greater depths. One of these veins which could be traced on the surface for several hundred feet had at a depth of twenty feet a thickness of nearly $2\frac{1}{2}$ feet. The samples from this depth consisted of a much decomposed rock rich in feldspar and lime, traversed with pure copper and sulphurets, however, only in small segregations and not in sufficient quantities to undertake large trial workings.

The larger masses of pure copper which up to this time have occasionally been found in Minnesota, come from the boulder-strewn hills of the diluvium. I also met with them along the river beds of the St. Croix and the Kettle rivers, and also from the eastern portion of the city of St. Paul. As similar copper drift has been found much farther south, even in the state of Ohio, in the "drift formation" one is justified in looking for their origin in the vicinity of lake Superior, and it is certainly to be deplored, as still often happens, that such foundlings awaken an expectation of finding a great richness of copper in the vicinity.

A short resumé of the results obtained and a condensed view of our present knowledge of the geognostic relations of Minnesota may conclude these observations.

Within the limits of this state there have been determined with accuracy: the Archæan series; the strata of the Lower Silurian and Middle Cretaceous ages. In the southern part of the state there can probably also be added the Upper Si-

*Compare J. Kloos Geol. Notizen aus Minnesota, in der Z. d. deutschen geolg Gessel, 1871, page 445.

lurian strata, which, however, soon thin out and have as yet furnished no characteristic fossils.

The Archæan group in the middle portion of the state is particularly represented by massive crystalline rocks, chiefly composed of non hornblendic and hornblendic granites (syenite granites), diorites (augite diorytes) as well as melaphyr-like rocks. Upon these succeed the crystalline slates, namely mica-slates, horn-slates and chloritic slates, which are usually formed as roofing slates and in which gneiss is observably wanting or at least very inconspicuous. In the north the crystalline, massive and slaty rocks have a very large distribution, and there it can be shown that the sequence of the Laurentian and Huronian systems is analogous to that of Canada, Michigan and Wisconsin. The Archæan slates through lateral pressure are similarly elevated over great areas, as can be observed everywhere along the edges of the massive Laurentian. On the knolls of the younger Huronian, preponderateingly chloritic-slates, or on the diabase-like melaphyrs, which belong to the same age, lie in a horizontal position the Lower Silurian sandstone strata. The latter have a great distribution and join directly the strata of the same age in Wisconsin. They are similarly traversed there as in western Canada by melaphyrs; melaphyr out-pourings have also spread over them and now alternate with them while they are again traversed by copper-bearing dikes. As probable inclusions in the Potsdam sandstone can also be added the hornblende-gabbro of Duluth.

A rock with hardly less areal distribution than the Potsdam sandstone is the following member of the Silurian—the lower dolomyte of the Mississippi; it is a constant associate with the sandstone. Of far less importance, however, are the younger strata; as the disintegrating nature of the St. Peter sandstone has caused the disappearance of this as well as the superimposed destructible strata of the Trenton limestone over great areas in the central portion of the state, and it now appears in several separated regions. The Silurian strata apparently lie everywhere horizontal but have a slight dip which in the southern part of the state is southerly while beyond Mountain lake it is toward the north.

Above the Silurian the various formations are wanting up to the Cretaceous period, at least none have been seen up to this time. It appears, therefore, that this middle portion of the North American continent during this enormous time was elevated above the ocean surface. In the wide valleys of the

Mississippi and St. Peter rivers there can also be seen evidences of great erosion, and at St. Paul on both sides of the stream it is apparent in the vast accumulation of boulders composed almost entirely of Silurian limestone, how powerfully these strata have been affected.

First during Cretaceous times was the western portion of the state again covered by the sea, and it formed a portion of the great Cretaceous ocean whose deposits can be studied along the Missouri in the most complete manner. The eastern shore of this great salt-water basin lay within the present region of the Mississippi. Whether Tertiary deposits were present, and later have disappeared through erosion to a few outliers, is uncertain. The predominating clayey and sandy Cretaceous formations have at least again suffered great erosion.

Diluvial formations are represented in great thickness and cover the southern and middle portions of the state, making it very difficult to investigate the lower formations. These youngest deposits can be separated into two natural groups,—the clayey-marls and the sandy gravel diluvium; and, further, the latter covers the unstratified clay and marl beds where the two come together.

The diluvium determines the configuration of the ground and forms adjoining step-like successions of table lands. The largest and deepest river valleys penetrate the diluvium to the Silurian and Huronian strata; the majority of the water-courses, however, have cut down only to the clayey diluvial deposits. The massive rocks of the Archæan group in the vicinity of the Mississippi and in the valleys of the Sauk and St. Peter rivers project above the diluvial formation. These are also for the greater part removed from observation by the plateau like diluvial deposits and only in the presence of a higher plateau, which on the St. Peter and Mississippi rivers joins with that of the northern part of the state, give evidence of the existence of a tongue of Laurentian rock transversely traversing the state. The restricted hill ranges towering above the table-land consist mainly of accumulations of boulders and presumably had their origin in currents or by the action of later erosion. Of high interest are the hydrographic relations of the low watersheds separating the great river systems. The waters now flow from a central high plateau in three directions; it is, however, probable that the northerly direction of the western stream, the Red river of the North,

was first given to it in recent times, and that at an earlier date all waters found an exit either towards the south through the Mississippi valley or easterly through the great lakes.

III. CHEMISTRY.

REPORT OF PROFESSOR JAMES A. DODGE.

UNIVERSITY OF MINNESOTA,
Minneapolis, Nov. 30, 1891.

Professor N. H. Winchell.

DEAR SIR: I hereby submit to you, for publication in the report of the State Geological Survey, a copy of the results of the chemical analyses of minerals, etc., made for the survey by the Chemical Department of the University since the last report.

CHEMICAL SERIES NO. 194.

A sample of black sand. Analysis by J. A. Dodge.

Silica	SiO_2	5.19 per cent.
Alumina	Al_2O_3	2.95 " "
Lime	CaO	traces
Magnesia	MgO	.35 " "
Oxide of titanium	$Ti'O_2$	36.77 " "
Protoxide of iron	FeO	32.29 " "
Magnetic oxide of iron	Fe_3O_4	22.10 " "
Phosphorus		none.
Sulphur		none.
Chromium		none.
Total		99.65

This sand was but little attracted by the magnet.

CHEMICAL SERIES NO. 195.

A sample of iron ore. Analysis by J. A. Dodge.

Metallic iron		47.07 per cent.
Phosphorus		.09 " "
Oxide of titanium	TiO_2	traces.

CHEMICAL SERIES NO. 196.

A dark gray crystalline rock. Analysis by J. A Dodge.

Oxide of titanium	TiO_2	none.

CHEMICAL SERIES NO. 196'.

Supposed gold ore. Assayed by C. F. Sidener.

Gold, none. Silver, none.

CHEMICAL SERIES NO. 197.

A hematite ore. Analysis by C. F. Sidener.

Silica	SiO_2	8.25 per cent.
Alumina	Al_2O_3	traces.
Lime and magnesia		traces.
Ferric oxide	Fe_2O_3	92.08 " "
Manganese		none.
Titanium		none.
Sulphur		none.
Phosphorus		.09 " "
Total		100.42

CHEMICAL SERIES, NO. 198.

A sample of ore. Analysis by C. F. Sidener.

Silica,	SiO_2	39.70 per cent.
Arsenical pyrites		60.30

CHEMICAL SERIES NO. 199.

A sample of kaolin. Analysis by C. F. Sidener.

Silica	SiO_2	63.64 per cent.
Alumina	Al_2O_3	24.95 " "
Ferric oxide	Fe_2O_3	4.90 " "
Lime	CaO	1.02 " "
Magnesia	MgO	.20 " "
Soda	Na_2O	.66 " "
Potassa	K_2O	.31 " "
Water and organic matter		4.32 " "
Total		100.00

CHEMICAL SERIES NO. 200.

A reputed ore of silver, from the "Silver Star Lode," near Cable, Wis., sent by Mr. F. L. McKusick, of Stillwater, Minn. Assay by J. A. Dodge.

Gold	very slight traces.
Silver	none.

CHEMICAL SERIES NO. 201.

A sample of water from a deep well at Stillwater, Minnesota. Analysis by C. F. Sidener.

Chlorine	30420 parts per million.
Bromine	240 " " "
Reduced to grains per gallon U. S.	
Chlorine	1,774.4 grains.
Bromine	14.0 "

CHEMICAL SERIES NO. 202.

An olivinitic magnetite. Analysis by C. F. Sidener.

Silica	SiO_2	11.39	per cent.
Alumina	Al_2O_3	traces.	
Magnetic oxide of iron	Fe_3O_4	85.55	" "
Lime	CaO	.22	" "
Magnesia	MgO	3.44	" "
Oxide of titanium	TiO_2	none.	
Sulphur		traces.	
Phosphorus		.02	" "
Total		100.62	

CHEMICAL SERIES NO. 203.

A titaniferous magnetite. Analysis by C. F. Sidener.

Silica	SiO_2	11.37	per cent.
Alumina	Al_2O_3	1.32	" "
Magnetic oxide of iron	Fe_3O_4	53.33	" "
Protoxide of iron	FeO	14.42	" "
Oxide of titanium	TiO_2	16.03	" "
Lime	CaO	.10	" "
Magnesia	MgO	2.73	" "
Sulphur		traces.	
Phosphorus		.01	" "
Total		99.31	

CHEMICAL SERIES NO. 204.

A green siliceous rock. Analysis by C. F. Sidener.

Silica	SiO_2	50.47	per cent.
Alumina	Al_2O_3	18.48	" "
Ferric oxide	Fe_2O_3	2.13	" "
Ferrous oxide	FeO	7.74	" "
Lime	CaO	6.61	" "
Magnesia	MgO	6.90	" "
Soda	Na_2O	2.58	" "
Potassa	K_2O	.30	" "
Water	H_2O	2.34	" "
Phosphorus		traces.	
Total		97.52	

CHEMICAL SERIES NO. 205.

A magnetic iron ore. Analysis by C. F. Sidener.

Silica	SiO_2	11.85 per cent.
Alumina	Al_2O_3	.34 " "
Magnetic oxide of iron	Fe_3O_4	87.00 " "
Lime	CaO	.20 " "
Magnesia	MgO	.80 " "
Oxide of titanium	TiO_2	none. " "
Sulphur		traces. " "
Phosphorus		.056 " "
Total		100.246 " "

CHEMICAL SERIES NO. 206.

A limonite ore. Analysis by C. F. Sidener.

Silica	SiO_2	3.52 per cent.
Ferric oxide	Fe_2O_3	87.10 " "
Lime	CaO	traces. " "
Magnesia	MgO	traces. " "
Sulphur		traces. " "
Phosphorus		.023 " "
Water	H_2O	9.70 " "
Total		100.343 " "

CHEMICAL SERIES NO. 207.

A sample of borings from a well at Mankato, Minn., consisting mainly of magnetic oxide of iron. Analysis by C. F. Sidener.

Oxide of titanium	none.

CHEMICAL SERIES NO. 208.

A sample of rock, showing black mica, feldspar and quartz, reputed to contain silver. Assay by J. A. Dodge.

Silver	none.

CHEMICAL SERIES NO. 209.

An iron ore. Analysis by C. F. Sidener.

Silica	SiO_2	10.90 per cent.
Alumina	Al_2O_3	5.83 " "
Ferric oxide	Fe_2O_3	70,39 " "
Ferrous oxide	FeO	8.75 " "
Lime	CaO	1.20 " "
Magnesia	MgO	1.50 " "
Sulphur		.47 " "
Phosphorus		.022 " "
Oxide of titanium	TiO_2	none.
Total		99.062 " "

CHEMICAL SERIES NO. 210.

An iron ore. Analysis by C. F. Sidener.

Silica	SiO_2	3.62 per cent.
Alumina	Al_2O_3	traces.
Ferric oxide	Fe_2O_3	95.76 " "
Lime	CaO	traces.
Magnesia	MgO	traces.
Sulphur		none.
Phosphorus		.093 " "
Total		99.473

CHEMICAL SERIES NO. 211.

A siliceous material with a somewhat foliated appearance Analysis by J. A. Dodge.

Silica	SiO_2	60.05 per cent.
Alumina	Al_2O_3	27.55 " "
Ferric oxide	Fe_2O_3	1.30 " "
Lime	CaO	.38 " "
Magnesia	MgO	.77 " "
Soda	Na_2O	.31 " "
Potassa	K_2O	4.26 " "
Phosphoric oxide	P_2O_5	.11 " "
Water	H_2O	5.30 " "
Total		100.03

The material is to be regarded as a kaolin mixed with some undecomposed feldspar.

CHEMICAL SERIES NO. 212.

A sample of quartz and pyrite. Assay by J. A. Dodge.

Gold	traces.
Silver	none.

CHEMICAL SERIES NO. 213.

A sample of quartz and pyrite. Assay by C. F. Sidener

Gold	none.
Silver	none.

CHEMICAL SERIES NO. 214.

A green mineral. Analysis by C. F. Sidener.

Silica	SiO_2	43.96	per cent.
Alumina	Al_2O_3	16.03	" "
Ferric oxide	Fe_2O_3	10.50	" "
Ferrous oxide	FeO	8.74	" "
Lime	CaO	9.54	" "
Magnesia	MgO	6.56	" "
Soda	Na_2O	1.62	" "
Potassa	K_2O	.27	" "
Water	H_2O	1.84	" "
Total		99.06	" "

CHEMICAL SERIES NO. 215.

A dolomitic rock. Analysis by C. F. Sidener.

Silica	SiO_2	2.70	per cent.
Alumina	Al_2O_3	.35	" "
Ferric oxide	Fe_2O_3	17.23	" "
Ferrous oxide	FeO	8.35	" "
Carbonate of lime	$CaCO_3$	49.80	" "
Carbonate of magnesia	$MgCO_3$	19.65	" "
Soda	Na_2O	.20	" "
Potassa	K_2O	.04	" "
Water	H_2O	.47	" "
Total		98.79	" "

CHEMICAL SERIES NO. 216.

A sample of crystalline rock. Analysis by J. A. Dodge.

Silica	Si_2O	67.42	per cent.
Alumina	Al_2O_3	15.88	" "
Ferric oxide	Fe_2O_3	1.37	" "
Ferrous oxide	FeO	1.14	" "
Manganese		traces.	
Lime	CaO	3.49	" "
Magnesia	MgO	1.43	" "
Soda	Na_2O	6.42	" "
Potassa	K_2O	2.65	" "
Phosphoric oxide	P_2O_5	.07	" "
Oxide of titanium	TiO_2	none.	
Water	H_2O	.05	" "
Total		99.92	

Very respectfully yours,
JAMES A. DODGE, Prof. Chemistry.

NOTE.—The foregoing substances were derived as follows:

Chem. Series 194.—Iron sand, fine, a few of the grains being magnetic. Birch lake beach, one mile west of the mouth of Dunka river.

Chem. Series 195.—Iron ore, Geol. Survey No. 1024, from J. Bausman's. Schistose ore, east of Garden lake.

Chem. Series 196.—Olivinitic ore, Geol. Sur. No. 976. From SW. ¼ Sec. 10, 62-12.

Chem. Series 196'.—Supposed gold ore 258 (H) submitted by H.V.W., Aug. 22, '87.

Chem. Series 197.—Iron ore, Prairie River Falls, Geol. Sur. No. 260 A. (H). Foot of the lower falls.

Chem. Series 198.—A heavy, white, metallic ore, said to have been found on White Iron lake. (Dovonan).

Chem. Series 199. —Kaolin, from near Brownsdale, Minn. From Mr. W. M. Jones, of C., St. P. & K. C. Ry.

Chem. Series 200.—Ore from Silver Star Lode, Cable, Wis. For F. L. McKusick, to compare with report of "Lehnen" in St. Paul.

Chem. Series 201.—Brine from the Stillwater deep weell.

Chem. Series 202.—Olivinitic magnetic, Geol. Sur. No. 408 (H). SE. ¼ Sec. 30, 62-10.

Chem. Series 203.—Titaniferous magnetic, Geol. Sur. No. 414 (H). SE. ¼, NE. ¼ Sec. 36, 63-10.

Chem. Series 204.—Green rock, Geol. Sur. No. 538 B. (H). Diabasic rock, ten feet from contact with jaspityte, SW. ¼, NW. ¼ Sec. 4, 63-9.

Chem. Series 205.—Magnetic iron ore, Geol. Sur. No. 369 A. (H). SW. side of Iron lake, NE. ¼ Sec. 23, 60-13.

Chem. Series 206.—Limonite, Geol. Sur. No. 354 (H). Mallmann's working, Sec. 29, 59-14.

Chem. Series 207.—Magnetic particles from the Mankato well, (at Minneopa). First rock below the red quartzite, (No. 10 of the section).

Chem. Series 208.—Sample of gneiss, from Auditor Braden. Said to have silver—so reported by "Lehnen," from his explorers on state lands in the northern part of the state.

Chem Series 209.—Magnetic iron ore, from the north side of Long lake, from the Vermilion series of rocks, Geol. Sur. No. 543 (H).

Chem. Series 210.—An amorphous hematite, from the Mesabi (Animikie) east of Grand Rrpids; the Warner-Griffin location.

Chem. Series 211.—White kaolinic "soapstone" Geol. Sur. No. 1449, stone mine.

Chem. Series 212.—Pyritifereous quartz, Eagle lake. Geol. Sur. No. 1501. Supposed to contain gold.

Chem. Series 213.—Pyritiferous quartz, and slate, supposed to represent the "gold ores" of Vermilion gold extitement in 1870. Geol. Sur. Nos. 395, 396, 397, 398, 400, 423, 428. All used as one sample.

Chem. Series 214.—Kawasachoug rock, Geol. Sur. No. 356.

Chem. Series 215.—Dolomitic or sodoric rock, from the Animikie, on Gunflint lake, Geol. Sur. No. 312.

Chem. Series 216.—Porphyritic conglomeritic rock, from Kekekebic lake, Geol Sur. No. ——?

N. H. W.

IV.—THE WOODS OF MINNESOTA.

By H. B. Ayres,

Agent of the Forestry Division, Department of Agriculture, Washington, D. C.

Among the natural stores so placed as to encourage the pioneer and develope the manly hardihood characteristic of the woodsman, the explorers of Minnesota found one of the grandest forests in one of the most accessible locations.

The conception first formed of the condition of the existing woodlands, is that all possible conditions are formed, and that they cannot be classified. Yet after the ceaseless variations have passed before the mind general classifications group themselves, and several portions of the wooded area stand out as having characteristics that distinguish them and separate the whole into groups. These groups are:

(1) The brush prairie bordering the first elevation above the plains on the south and west. The growth here is rose, hazel, thorn, plum, choke cherry, scrub oak, poplar, etc., with a stunted growth of the hardwood timber trees.

(2) The hardwood belt of oak, maple, basswood, elm, birch, poplar and ironwood on fertile undulating land dotted with lakes and broken by prairie openings. This land is now mostly in the hands of private owners, farmers, who are as a rule doing well.

(3) The jack pine and norway belt marking in general the border of a second elevation, a beach formation of sand and gravel, mostly non-agricultural, except in Hubbard Co., almost annually burned over, sparsely timbered, yet saved from denudation by the wonderful reproductive power of the scrub pine (P. banksiana), under shelter of which the norway pine (P. resinosa), develops rapidly into a valuable timber, and by the poplar under which the white pine is apt to start. This belt is well developed north west of Brainerd and no the east grades into the pine barrens of Wisconsin. It is frequently broken by areas of poplar and white birch, while much white pine exists here and there on the heavier soils.

(4) The white pine region, infinitely varied with hardwoods, norway and jack pine, cedar and tamarac swamps, and open or spruce bogs bordering the numerous lakes or occupying their old beds. In general, this region is brushy where not heavily

timbered, and so well watered with so little fall that but little white pine is more than five miles from drivable streams.

Nearly all of the streams of this region head in the open bogs, which, where partly shaded by spruce, make enormous growth of sponge-like spagnum moss holding the ice of winter until June and July and preserving a supply of water that the explorer may find under some upturned root, well into if not throughout the drought of August and September.

The soil here is usually loam or clay and supports a considerable growth of hardwood, among which the white pine reaches its most perfect development.

Much of this whole area has been stripped by fire even before the loggers increased the liability to fire by the tops they leave in the woods; and by the greater drying of the forest floor by exposure to sun and wind, in the openings they have made.

It has been estimated that thirty years ago over 40,000,000,000 feet of pine were standing on the 25,000,000 acres of forest in the state. Since that time busy milling towns have started up here and there as if by magic and loggers and choppers have swarmed into the forest until the average number of men now employed in preparing forest products for market reaches about 17,000, and the value of the product as placed upon the market amounts to about $31,635,000.

Must the industry soon decline?

The answer is a prompt and positive—No.

If timber were a deposit, like beds of iron ore, with no power to reproduce itself, we could readily estimate the time of the end.

In such a case we could see that with the present supply of standing timber—say 20,000,000,000 feet, 17 years more would leave the state stripped.

But where fire is kept out forests reproduce themselves, and the accretion by growth, while small and of comparatively little value in woods cut without any view to reproduction, in woods cut at such a time and in such a manner as to give the seedlings and sprouts the best chance to make a rapid "second growth" the annual increment under the best forest management in Europe has averaged about 55 cubic feet per acre; one-third of which should be estimated as log timber.

To produce an annual growth of 1,200,000,000 feet B. M.—(the latest annual cut)—would at this rate require 5,500,000 acres.

In mournful contrast with these results obtained in Prussia, stands the estimate, though roughly made and presented with some hesitancy, yet approximating the fact, that the 24,960,000 acres of wooded area in the state did not, last year, grow more than 200,000,000 feet B. M. of log timber. In other words 50,000,000 acres of such forest as ours in its present condition would be required to grow the amount grown on 5,500,000 acres of well managed forest. and our forests are thus only producing less than one ninth of what they might.

We must not, however, forget that of the 24,960,000 acres now wooded, probably one-half will eventually prove more valuable as agricultural than as forest land, and suould be partly cleared. This would leave the area that should always be kept in forest, i. e. the lands unprofitable for agriculture as compared with forestry, about 12,500,000 acres, which, as above, should, under management, produce twice our present annual cut of log timber, and 400,000,000 cubic feet of other material for woodworking, fuel, etc.

Every considerable tract of forest in the state is more or less depleted by fire and can only be brought into full productlon after many years of renovation; but should any reader be tempted to cast these estimates aside as overdrawn, I must ask him to not do so without a careful study of the subject, such as I have given it during four years of exploring that have taken me all through the wooded region and formed in me a deep conviction that, while these estimates are necessarily rough, they are based on sound principles and at least point toward and approximate the truth.

Theoretically, therefore, it seems possible that the present yield of log timber alone may be doubled permanently and that a vast increase of manufacturing industries would follow the assurance of a constant supply, and, locating themselves throughout the woods, would in every way tend toward the greatest development of the state.

Practically, however, the difficulties in the way of attaining this ideal state of affairs are so great as to try the determination and skill of our best citizens.

The difficulties attending the question of ownership before operations of any kind can be commenced are the greatest that are to be met in the whole subject. In Europe, however, where claims of private owners were everywhere to be ajusted before anything could be done, this great barrier has been overcome satisfactorily to all.

In this country, where so much of the lower grade of agricultural land is owned by the government, there should be great hesitancy in making a beginning, beyond the caution necessary to make sure that the course be the right one.

In Europe the great difficulty has been just as here, the prejudice against anything but the free use of public property and against interference of the government in the business of individuals.

But they have, first in the moumtains where the general welfare most plainly demanded it, by condemnatory proceed ings, and later, on the poorest lowlands, where the direct profits of forestry are greater than those of agriculture, by bounties to the owners of the land, made such progress during the past century that the wisdom of the movement is plainly shown, and all men who have the chance to know, combined with a desire for the public good, write in sustaining the governmental policy of securing the perpetual cultivation of forests on all the poorest lands.

OUR LAND OFFICE SYSTEM.

While the giving of from 300,000 to 4,000.000 feet of standing pine to a poor pioneer seems a paternal act on the part of the government, the actual result is putting nearly all the value of the timber into the pocket of the lumberman, to whose plant the tract may be tributary.

The settler, even when honest, can, as a rule, afford to live on a pine claim merely long enough to comply with the homestead or pre-emption law, and when he sells his pine, often gives title to the land also, when it starts upon the routine by which it is, eventually, advertised for taxes, non-productive, idle, worthless.

If we continue, as we have done, the 17,000 men now employed in reaping the great natural harvest will soon leave the country, as they have left the older lumber states; for the lumberman, under the present system of disposing of public lands, cannot think of waiting for a second growth while he can acquire new forests of standing pine at a nominal figure. His only sensible course, as far as his own interests are concerned, is to strip off the timber and abandon the land.

The time to decide upon the use to which timbered lands should be put is, undoubtedly, before they pass into the hands of individuals. They should be examined and the question decided whether they should be thrown open for settlement as

farm lands, or whether it would be best for the general welfare to have them kept in timber.

There are still in the state some 6,000,000 acres of more or less wooded land belonging to the federal government. To one looking the situation fairly in the face, would it not seem best to have all this area withheld from settlement until the soil be examined, and its adaptability determined?

The direct profits that may be expected from forestry, are not large after the virgin timber has been cut. In Europe, seldom over 5 per cent. is realized, and the American lumberman cannot be expected to act contrary to his notable common sense and shrewdness and stay and do a business that brings in 5 per cent., while he may by entering a new field, under the present land office system, get from 10 to 200 per cent. Only in exceptional cases, most favorable to growth and convenience to market, is forestry profitable to the individual. To a corporation of wood-workers the profits may be greater, but it is only the state or the general government that will be able to reap all those other benefits, such as permanency of industries, support of greatest population, etc., which, added to the direct profits possible to the individual, would bring the sum of gains well within the percentage of fair business profits.

Forest lands should therefore, as a rule, be managed by the state or by the federal government.

In Minnesota, the federal lands now vacant, and more or less wooded, amount to some		6,000,000 acres.
The state lands	600,000	
The university lands	470,000	
The school lands	231,000	
		1,301,000
Total public forest lands		7,301,000 acres.

The question as to what would be the best management of these lands has been studied and studied faithfully by many, if not by all the men upon whom their care devolved, and no doubt they have found the difficulties that they, single-handed, were unable to overcome. It is necessary that all the people be so well informed that they may, at least, be able to appreciate the efforts their chosen representatives in the local, state or federal government may make in their behalf; and while it is the plain duty of these representatives to study all the questions bearing upon the welfare of their constituent regions,

these questions are so numerous that they cannot be expected to master them all, unless those who have made special study, aid them by digests of their work.

FORESTRY IN PRUSSIA.

While some of the forestry that is practiced in Europe is for protection purposes on steep mountain slopes, where erosive torrents, destructive floods, landslides, falling rocks and avalanches make the work imperative, most of the forests there are managed for the revenues there are in them.

Some quotations from an article by Mr. Gillford Pinchot, before the American Economic Association, referring to forestry in Prussia, may be of interest here.

"All forest management may be said to rest on two closely related facts which are so self-evident that they might almost be called axioms of forestry, but which, like other axioms, lead to conclusions of far-reaching application. These are, first, that trees require many years to reach merchantable size; and, secondly, that a forest crop cannot be taken every year from the same land. From the last statement it follows that a definite, far-seeing plan is necessary for the rational management of any forest, from the first; that forest property is safest under the supervision of some imperishable guardian, or, in other words, of the State." * * * * * *

"Holding it as a duty to preserve the wood lands for the present share which they take in the economy of the nation, the State has recognized as well the obligation to hand down its forest wealth unimpaired to future generations. It has recognized and respected equally the place which the forest holds in relation to agriculture and in the economy of nature and hence feels itself doubly bound to protect its woodlands. In a word, it has been seen that in its direct and indirect influence the forest plays a most important part in the story of human progress, and that the advance of civilization only serves to make it more indispensable."

It has, therefore, steadily refused to deliver its forests to more or less speedy destruction by allowing them to pass into the hands of shorter lived and less provident owners

Even in the times of the greatest financial difficulty, when Prussia was overrun and nearly annihilated by the French, the idea of selling the State forests was never seriously entertained.

But the government of Prussia has not stopped here. Protection standing alone is irrational and incomplete. The cases where a forest reaches it highest usefulness by simply existing are rare. The immense capital which the State wood lands represent is not permitted to lie idle, and the forest, as a timber producer, has taken its place among the permanent features of the land. The government has done the only wise thing by managing its own forests through its own forest officers.

"Donner, now Overland first-meister, in a work which carries all the weight of an official document, says:

'The fundamental rules for the management of State forests are these: First, to keep rigidly within the bounds of conservative treatment; and secondly, to attain, consistently with such treatment, the greatest output of most useful products in the shortest time.' * * * * * * *

"The State believes itself bound, in the administration of its forests, to keep in view the common good of the people, and that as well with respect to the lasting satisfaction of the demand for timber and other forest produce, as to the numerous other purposes which the forest serves. It holds fast the duty to treat the government wood lands as a trust held for the nation as a whole, to the end that it may enjoy for the present the highest satisfaction of its needs for forest produce and the protection which the forest gives, and for all future time, at least an equal share of equal blessings." * * *

"The forest is a trust handed down from former times, whose value lies not only in its immediate production of wood, but also essentially in the benefit to agriculture of its immediate influence on climate, weather protections in various ways, the conservation of the soil, etc. The forest has significance not only for the present nor for its owner alone; it has significance as well for the future and for the whole of the people."

"With respect to the second class of forest property, that belonging to towns, villages and other public bodies, it is again impossible to speak for the whole of Germany except upon the broadest lines. The State everywhere exercises oversight and a degree of control over the management of these forests, but the sphere of its action varies within very wide limits. Even within the individual states it does not remain the same. Thus far, however, the action of the government is alike not only throughout Prussia but in all parts of Germany. It prevents absolutely the treatment of any forest of this class under im-

provident or wasteful methods; nor does it allow any measure to be carried into effect which may deprive posterity of the enjoyment which it has a right to expect." * *

The relations of the State to the third class of forests, those belonging to private proprietors, are of a much less intimate nature. The basis of these relations is, however, the same. To quote again from Donner: "The duty of the State to sustain and further the well being of its citizens regarded as an imperishable whole, implies for the government the right and the duty to subject the management of all forests to its inspection and control." This intervention is to be carried, however, "only so far as may be necessary to obviate the dangers which an unrestrained utilization of the forest by its owners threatens to excite, and the rights of property are to be respected to the utmost consistency with such a result." Prussia, of all the German countries, has respected these rights most highly, and the government exerts practically no restraining influence except where the evident results of deforestation would be seriously dangerous. Here it may and does guard most zealously the wood lands, whose presence is a necessary safeguard against certain of the more destructive phenomena of nature, and which have been called in general "protection forests". Of their many sided influence so much has been said and written of late in America—both truly and falsely—that no farther reference to the subject seems needful.

"The State leaves open a way of escape for the private proprietor who finds himself unwilling to suffer such restriction of his rights for the public good, and shows itself willing to buy up areas not only of protection forests but also of less vitally important wood lands. On the other hand, it is ready, with a broadness of view which the zeal of forest authorities sometimes unfortunately excludes, to give up to private ownership lands which, by reason of their soil and situation, will contribute better to the commonwealth under cultivation than as forest.

"In this way the forests whose preservation is most important are gradually passing into the hands of the State; yet the total area of the wood lands is increasing but slowly.

"The policy of State aid in the afforestation of waste lands important through their situation on high ground or otherwise is fully recognized (a notable example exists upon the Hohe Venn near Aix-la-Chapelle) but the absence of considerable mountain chains has given to this branch of government influ-

ence very much less prominence than in the Alps of Austria, Switzerland and France, where its advantages appear on a larger and more striking scale.

"In closing this brief sketch of forest policy in Prussia, you will perhaps allow me to refer for a moment to the erroneous ideas of German forest management which have crept into our literature. They have done so, I believe, partly through a desire of the advocates of forestry to prove too much, and they injure the cause of forestry, because they tend to make forest management ridiculous in the eyes of our citizens. The idea has risen that German methods are exaggeratedly artificial and complicated, and not unnaturally the inference has been made that forestry in itself is a thing for older and more densely populated countries, and that forest management is inapplicable and incapable of adaptation to the conditions under which we live. It is true, on the contrary, that the treatment of German forests is distinguished above all things by an elastic adaptability to circumstances, which is totally at variance with the iron-clad formality which a superficial observation may believe it sees. It is equally true that its methods could not be transported unchanged into our forests without entailing discouragement and failure, just as our method of lumbering would be disastrous there; but the principles which underlie not only German, but all rational forest management, are true all the world over. It was in accordance with them that the forests of British India were taken in hand and are now being successfully managed, but the methods into which the same principles have developed are as widely dissimilar as the countries in which they are being applied."

So forest management in America must be worked out along lines which the conditions of our life will prescribe. It never can be a technical imitation of that of any other country, and a knowledge of forestry abroad will be useful and necessary rather as matter for comparison than as a guide to be blindly obeyed. It must be suited not only to the peculiarities of our national character, but also to the climate, soil and timber of each locality, to the facilities for transportation, and relations of supply and demand, and the hundred other factors which go to make up the natural character of a hillside, a county or a state. Its details cannot be laid down *ex cathedra*, but must spring from a thorough acquaintance with the theory of forestry, combined with exhaustive knowledge of local conditions. It will necessarily lose the formality and minuteness

which it has acquired in countries of older and denser settlement, and will take on the character of largness and efficiency which has placed the methods of American lumbermen, in their own sphere, far beyond all competitors.

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
162	Sept.. 1875	Geol. Survey...	Streptelasma corniculum Hall.	1
207	1875	"	Streptelasma corniculum Hall.	1
231	Oct., 1875	"	Orthis testudinaria var. meeki Miller.	1
236	Oct., 1875	" ...	Orthis testudinaria var. meeki Miller.	1
263	Sept., 1875	"	Schizotreta pelopea Billings.	1
272	Oct., 1875	"	Orthis testudinaria var. meeki Miller.	Indef.
273	"	"	Orthis (Dinorthis) proavita W. and S.	1
274	"	"	Orthis (Dinorthis) subquadrata Hall.	Indef.
278	"	"	Orthis (Dinorthis) proavita W. and S.	2
279	"	"	Orthis subæquata var. circularis Winchell.	3
294	Sept.. 1875	"	Climacograptus typicalis Hall.	1
295	Sept., 1875	"	Climacograptus typicalis Hall.	1
302	1875	"	Diplograptus putillus Hall.	1
318	Oct., 1875	"	Streptelasma corniculum Hall.	1
321	Oct., 1875	"	Orthis subæquata Conrad.	2
346	1872	"	Orthis subæquata var. circularis Winchell.	3
364	Oct., 1872	"	Streptelasma corniculum Hall.	1
390	Oct., 1872	"	Climacograptus typicalis Hall.	1
396	Oct,, 1875	"	Orthis (Dinorthis) subquadrata Hall.	2
433	Oct., 1875	"	Streptelasma profundum Hall.	2
651	Aug. 1875	"	Orthis subæquata var conradi Winchell.	1
664	Aug., 1877	"	Streptelasma profundum Hall.	1
672	"	"	Orthis (Dinorthis) deflecta Conrad.	3
707	"	" ..	Orthis (Dalmanella) subæquata Conrad.	3
710	"	"	Streptelasma profundum Hall..	1
712	"	"	Rauffella filosa Ulrich.	1
713	"	"	Rauffella filosa Ulrich.	2
720	"	"	Orthis (Dalmanella) subæquata Conrad.	2
734	"	"	Rhynchonella ainsliei Winchell.	9
753	"	"	Orthis subæquata var. conradi Winchell.	5
766	"	"	Orthis (Dalmanella) subæquata Conrad.	Indef.
3487	1879	"	Streptelasma profundum Hall.	"
3488	1879	"	Streptelasma profundum Hall	"
3489	1879	"	Streptelasma profundum Hall..	"
3491	1879	"	Rauffella filosa Ulrich	1
3493	1879	"	Rhynchonella capax Conrad.	2
3504	May, 1879	"	Lingula cobourgensis Billings.	1
3513	Aug., 1877	"	Orthis subæquata Conrad.	2
3515	April, 1879	"	Orthis subæquata var. circularis Winchell.	2
4031	Sept.. 1880	"	Rhynchonella ainsliei Winchell.	9
4032	"	"	Orthis (Dalmanella) subæquata Conrad.	Indef.
4034	"	"	Orthis tricenaria Conrad.	5
4035	"	"	Orthis (Dalmanella) testudinaria Conrad.	2
4038	"	"	Streptelasma profundum Hall.	1
4042	"	"	Crania setigera Hall.	1
4049	"	"	Orthis subæquata var. circularis Winchell	Indef.
4053	"	"	Rhynchonella capax Conrad.	1
4055	"	"	Orthis (Dinorthis) meedsi W. and S.	Indef.
4056	"	"	Orthis (Dalmanella) subæquata Conrad..	"
4057	"	"	Streptelasma profundum Hall.	"
4061	"	"	Rhaphistoma lenticularis Conrad.	"
4076	"	"	Orthis (Dinorthis) subquadrata Hall	"
4078	"	"	Orthis testudinaria var. meeki.	"
4079	"	"	Orthis (Dinorthis) subquadrata Hall.	"
4081	"	"	Hindia sphæroidalis Duncan.	17
4085	"	"	" " "	4
4092	"	"	Rhynchonella capax Conrad.	6
4094	"	"	Orthis (Plectorthis) whitfieldi Winchell.	1
4097	"	"	Diplograptus putillus Hall	1
4935	1882	"	Orthis subæquata var. circularis Winchell.	13
4944	1882	Presented	Receptaculites oweni Hall.	3
4946	1882	"	Rauffella filosa Ulrich.	2
4948	1882	"	Platystrophia biforata Schlotheim.	1
4999	1882	Geol. Survey...	Rhynchonella capax Conrad.	10
5001	1882	"	Orthis (Dinorthis) pectinella var. sweeneyi Winchell.	2
5053	1882	Presented	Streptelasma profundum Hall.	6
5079	1876-1879	Geol. Survey...	Streptelasma profundum Hall.	9
5148	1881	Presented.....	Orthis subæquata var. perveta Conrad.	1
5149	1881	"	Orthis subæquata var. circularis Winchell.	1
5305	Aug., 1883	"	Streptelasma profundum Hall.	5
5307	"	"	Platystrophia biforata Schlotheim..	1
5476	Aug., 1877	Geol. Survey...	Rhynchonella capax Conrad.	9
5478	"	"	" " "	4
5479	"	" ...	" " "	1

ADDITIONS.

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks,
Sec. 17, Rochester, Olmsted Co., Minn.	Galena	M. W. Harrington (Garrick's quarry)
" " " " "	"	"
Spring Valley, Minn	Cincinnati	N. H. Winchell.
" "	"	"
Mantorville, Minn	Galena	M. W. Harrington.
Spring Valley, Minn	Cincinnati	N. H. Winchell.
" "	"	"
" " "	"	"
" " "	"	"
Minneapolis, Minn	Trenton	"
Mantorville, Minn	Galena	M. W. Harrington.
" "	"	"
Forestville, Minn	Maquoketa?	N. H. Winchell.
Minneapolis, Minn	Trenton	"
" "	Hudson River	"
Rochester, Minn	Trenton	"
Near Rochester, Minn	Galena	"
Mantorville, Minn	"	"
Spring Valley, Minn	Cincinnati	"
Chatfield, Minn	Trenton	"
Fountain, Minn	"	"
Pleasant Grove, Minn	"	"
Minneapolis, Minn	"	C. L. Herrick.
" "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
Near Cannon Falls, Minn	"	N. H. Winchell.
" " "	"	"
" " "	"	"
" " "	"	"
" " "	"	"
Minneapolis, Minn	"	H. V. Winchell.
" "	"	C. L. Herrick.
Oxford Mills, Goodhue county	"	N. H. Winchell.
Near Lanesboro, Minn	"	"
" " "	"	"
" " "	"	"
" " "	"	"
" " "	"	"
Lanesboro, Minn	"	"
Near Fountain, Minn	"	"
" " "	"	"
" " "	Galena	"
" " "	"	"
" " "	Trenton	"
" " "	"	"
Spring Valley, Minn	Cincinnati	"
" "	"	"
" "	"	"
" "	Niagara	"
" "	"	"
" "	"	"
" "	Cincinnati	"
" "	"	"
State St., East Minneapolis	Hudson River	"
Near Marion, Minn	"	Cora E. Goode
" " "	Trenton	"
" " "	"	"
Mineola, Goodhue county, Minn	"	N. H. Winchell.
" " "	"	"
Minneapolis, Minn	"	H. V. Winchell.
" "	"	C. L. Herrick.
" "	"	J. C. Kassube.
" "	"	"
Cannon Falls, Minn	"	W. H. Scofield.
" "	"	"
Minneapolis, Minn	Green shale	C. L. Herrick.
" "	"	"
" "	"	"

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
5480	Aug., 1877	Geol. Survey	Rhynchonella ainsliei Winchell	31
5481	"	"	Rhynchonella capax Conrad	12
5483	"	"	" " "	17
5484	"	"	Rhynchonella ainsliei Winchell	10
5485	1879	"	Rhynchonella capax Conrad	4
5488	1879	"	" " "	14
5489	1879	"	Rhynchonella ainsliei Winchell	3
5490	1879	"	Rhynchonella capax Conrad	1
5491	1879	"	" " "	3
5492	1879	"	Rhynchonella ainsliei Winchell	4
5493	1879	"	Rhynchonella capax Conrad	6
5495	Sept., 1880	"	" " "	2
5496	"	"	" " "	3
5497	"	"	" " "	3
5498	"	"	Rhynchonella ainsliei Winchell	1
5500	"	"	Crania setigera Hall	2
5505	"	"	Rhynchonella ainsliei Winchell	2
5506	"	"	Rhynchonella capax Conrad	1
5508	"	"	" " "	12
5509	"	"	" " "	4
5512	"	"	Rhynchonella ainsliei Winchell	3
5513	"	"	Rhynchonella capax Conrad	1
5515	"	"	" " "	4
5516	"	"	" " "	1
5517	"	"	Rhynchonella ainsliei Winchell	1
5518	1873	"	Rhynchonella capax Conrad	2
5519	1880	"	" " "	5
5521	1880	"	Rhynchonella ainsliei Winchell	1
5522	1880	"	Rhynchonella capax Conrad	1
5547	1880	"	Rhynchonella perlamellosa Whitfield	4
5548	1880	"	Platystrophia biforata var. crassa James	1
5668	1884	Purchase	Lingula elderi Whitfield	1
5839	May, 1885	Geol. Survey	Ischadites iowensis Owen	1
5840	"	"	Streptelasma corniculum Hall	9
5848	"	"	Rhaphistoma lenticularis Sowerby	7
5852	"	"	Rhynchonella capax Conrad	12
5856	"	"	Orthis (Dalmanella) testudinaria	2
5860	"	"	Orthis meedsi W. and S.	4
5861	"	"	" " "	2
5862	"	"	Platystrophia biforata Schlotheim	2
5865	"	"	Cryptozoon minnesotense Winchell	Indef.
6070	Sept., 1885	"	Orthis remnicha Winchell	7
6758	June, 1888	"	Receptaculites oweni Hall	1
6760	"	"	Ischadites iowensis Owen	3
6774	Sept., 1888	"	Streptelasma profundum Hall	1
6775	"	"	Orthis (Dalmanella) subæquata Conrad	1
6801	"	"	" " "	2
6802	"	"	Orthis tricenaria Conrad	3
6803	"	"	Orthis (Dalmanella) subæquata Conrad	1
6804	"	"	Orthis subæquata var. circularis Winchell	2
6805	"	"	Orthis	7
6806	"	"	Orthis (Dalmanella) testudinaria Dalman	3
6808	"	"	Streptelasma profundum Hall	1
6828	Jan., 1889	"	Rusted, coarse, quartz sand	Indef.
6829	"	"	Gray siliceous shale, or "slate"	
6830	"	"	White sand, with some yellowish shale	
6831	"	"	Fine white sand, giving first water	
6832	"	"	Green shale	
6833	"	"	Fine white sand, with globules of pyrites	"
6834	"	"	Green shale or sand, with some white sand	"
6835	"	"	White sand with some specks of green sand	"
6836	"	"	Mainly white sand, of a grayish aspect	"
6837	"	"	Quartz sand, with some gray grains, all rounded	"
6838	"	"	Rounded white sand, with some gray grains & pyrites	"
6839	"	"	Gray shale, slightly greenish	"
6840	"	"	White sand, with some fragments	"
6841	"	"	White sand, rounded	"
6842	"	"	Shale or clay, with quartz sand	"
6843	"	"	Coarse quartz sand, almost pebbly	"
6844	"	"	The same. Here the water all ran out	"
6845	"	"	Red slate or shale, with white kaolinitic grains	"
6846	"	"	White sand, with reddish grains and shale pieces	"
6847	"	"	Red clay (shale) unwashed, hardened in drying	
6848	"	"	Dark red, or brown feldspathic sandstone	

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
Minneapolis, Minn	Green shale	C. L. Herrick.
" "	"	"
Fountain, Minn.	"	N. H. Winchell.
Minneapolis, Minn	"	C. L. Herrick.
Near Cannon Falls, Minn	Hudson River	N. H. Winchell.
" " "	"	"
Minneapolis, Minn	Green shale	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
Near Lanesboro, Minn	"	"
" " "	"	"
" " "	"	"
" " "	"	"
Near Fountain, Minn	"	"
" " "	"	"
" " "	"	"
" " "	"	"
" " "	"	"
Minneapolis, Minn	"	"
Holden, Goodhue Co., Minn	"	"
Kenyon, Goodhue Co., Minn	"	"
Minneapolis, Minn	"	Chas. Kassube.
" "	"	"
" "	"	N. H. Winchell.
" "	"	H. V. Winchell.
Near Lanesboro, Minn	"	N. H. Winchell.
" " "	"	"
Spring Valley, Minn	Trenton	"
" " "	Cincinnati	"
Minneapolis, Minn	Trenton	Wm. Howling.
Cannon Falls, Minn	Galena	N. H. Winchell.
" "	"	"
" "	"	"
" "	Trenton	"
" "	Galena	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	Shakopee	"
Red Wing, Minn		"
Holden, Minn	Galena	"
" "	"	"
Minneapolis, Minn	Trenton	"
" "	"	"
St. Paul, Minn	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
Stillwater, Minn	Drillings from Stillwater deep well.	N. H. Winchell, taken at 18 feet.
" "	"	" " 103 "
" "	"	" " 142 "
" "	"	" " 162 "
" "	"	" " 203 "
" "	"	" " 215 "
" "	"	" " 271 "
" "	"	" " 302 "
" "	"	" " 312 "
" "	"	" " 322 "
" "	"	" " 349 "
" "	"	" " 380 "
" "	"	" " 450 "
" "	"	" " 460 "
" "	"	" " 540 "
" "	"	" " 630 "
" "	"	" " 688 "
" "	"	" " 701 "
" "	"	" " 706 "
" "	"	" " 717 "
" "	"	" " 796 "

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
6849	Jany., 1889	Geol. Survey	Dark red, or brown feldspathic sandrock	Indef.
6850	"	"	Somewhat darker, otherwise same as last	"
6851	"	"	Same as last	"
6852	"	"	Same as last	"
6870	April, 1889	Presented	Gold bearing quartz	4
6871	"	"	" " "	3
6872	"	"	" " "	2
6873	"	"	" " "	2
6874	"	"	Granite containing garnets	1
6875	"	"	Potsdam sandstone	1
6876	"	"	"Cosmic material"	4
6877	"	Geol. Survey	Selenite	Indef.
6879	June, 1889	"	Yellowish blue pebbly clay	"
6880	"	"	Slightly darker pebbly clay	"
6881	"	"	Same as 6880	"
6882	"	"	" "	"
6883	"	"	" "	"
6884	"	"	" "	"
6885	"	"	Gravel and sand bearing gas	"
6886	"	"	Same as 6880, pebbly clay	"
6887	"	"	" " "	"
6888	"	"	" " " "	"
6889	"	"	" " " "	"
6890	"	"	" " " "	"
6891	"	"	Drift gravel and sand with fragments of lignite	"
6892	"	"	Drift gravel & sand with fragments of gray limestone	"
6893	"	"	Fine quicksand	"
6894	"	"	Magnesian limestone	"
6895	"	"	Magnesian limestone drillings	"
6896	"	"	Gray limestone	"
6897	"	"	Same as last, but with some drift	"
6898	"	"	Same as last	"
6899	"	"	Coarse drift pebbles	"
6900	"	"	Dolomitic limestone	"
6901	"	"	Same as last, but nearly white	"
6902	"	"	Gray aluminous limestone	"
6903	"	"	Gray limestone	"
6904	"	"	" "	"
6905	"	"	" "	"
6906	"	"	" "	"
6907	"	"	" "	"
6908	"	"	Gray limestone, finely crystalline	"
6909	"	"	Gray limestone, with siliceous grains	"
6910	"	"	Gray limestone	"
6911	"	"	" "	"
6912	"	"	" "	"
6913	"	"	Gray shale, with quick effervescence	"
6914	"	"	Gray limestone	"
6915	"	"	Bluish gray shale; slight effervescence	"
6916	"	"	Bluish gray shale; pebbly	"
6917	"	"	Fine bluish shale	"
6918	"	"	Coarser shale	"
6919	"	"	Fine homogeneous gray shale	"
6920	"	"	Blue and gray shale and limestone	"
6921	"	"	Same as last	"
6922	"	"	Fine bluish gray shale	"
6923	"	"	Blue shale	"
6924	"	"	White sandstone	"
6925	"	"	" "	"
6926	"	"	" "	"
6927	"	"	White, fine sand	"
6928	"	"	Magnesian limestone	"
6929	"	"	White sandstone	"
6930	"	"	Magnesian limestone	"
6931	"	"	Mottled green and reddish shale	"
6932	"	"	Green shale and magnesian limestone	"
6933	"	"	Mainly magnesian limestone	"
6934	"	"	Much like last, but more siliceous	"
6935	Aug., 1889	"	Yellow loam, or clay	"
6936	"	"	Yellow clay—lacustrine	"
6937	"	"	Very fine lacustrine blue clay	"
6938	"	"	Drift gravel with some clay	"
6939	"	"	Drift gravel, much limestone	"
6940	"	"	Coarse drift gravel, much limestone	"

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
Stillwater, Minn	Drillings from Stillwater deep well.	N. H. Winchell, taken at 892 feet.
" "	"	" " 923 "
" "	"	" " 952 "
" "	"	" " 2,250 "
Nova Scotia, Canada	.....	Brookfield mine, Anderson, Douglas & Co.
" "	.....	Neptune mine, " " "
" "	.....	Malaga district, " " "
Salmon River, N. S.	.....	From Prof. J. S. Clark.
"Garnet Hill" N. H.	.....	From Prof. J. A. Dodge.
Port Henry, N. Y.	Potsdam	From W. H. Benedict.
Nininger, Minn	?	From Ig. Donnelly.
Minneapolis, Minn	.....	O. W. O. Contact of limestone and sandstone.
Freeborn, Minn	Drillings from Freeborn gas well.	No. 1. depth 20 feet.
" "	"	" 2, " 30 "
" "	"	" 3, " 40 "
" "	"	" 4, " 50 "
" "	"	" 5, " 60 "
" "	"	" 6, " 70 "
" "	"	" 7, " 74 "
" "	"	" 8, " 80 "
" "	"	" 9, " 90 "
" "	"	" 10, " 100 "
" "	"	" 11, " 110 "
" "	"	" 12, " 120 "
" "	"	" 13, " 130 "
" "	"	" 14, " 140 "
" "	"	" 15, " 145 "
" "	"	" 16, " 150 "
" "	"	" 17, " 160 "
" "	"	" 18, " 190 "
" "	"	" 19, " 200 "
" "	"	" 20, " 210 "
" "	"	" 21, " 220 "
" "	"	" 22, " 230 "
" "	"	" 23, " 240 "
" "	"	" 24, " 250 "
" "	"	" 25, " 260 "
" "	"	" 26, " 270 "
" "	"	" 27, " 280 "
" "	"	" 28, " 290 "
" "	"	" 29, " 300 "
" "	"	" 30, " 310 "
" "	"	" 31, " 320 "
" "	"	" 32, " 330 "
" "	"	" 33, " 340 "
" "	"	" 34, " 350 "
" "	"	" 35, " 360 "
" "	"	" 36, " 370 "
" "	"	" 37, " 380 "
" "	"	" 38, " 390 "
" "	"	" 39, " 400 "
" "	"	" 40, " 410 "
" "	"	" 41, " 420 "
" "	"	" 42, " 430 "
" "	"	" 43, " 440 "
" "	"	" 44, " 450 "
" "	"	" 45, " 460 "
" "	"	" 46, " 470 "
" "	"	" 47, " 480 "
" "	"	" 48, " 490 "
" "	"	" 52, " 535 "
" "	"	" 53, " 710 "
" "	"	" 54, " 840 "
" "	"	" 55, " 880 "
" "	"	" 56, " 900 "
" "	"	" 57, " 920 "
" "	"	" 58, " 930 "
" "	"	" 59, " 950 "
Moorhead, Minn	Drillings from Moorhead well.	" 2, " 5 "
" "	"	" 3, " 55 "
" "	"	" 4, " 110 "
" "	"	" 5, " 115 "
" "	"	" 6, " 125 "
" "	"	" 7, " 135 "

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
6941	Aug., 1889	Geol. Survey	Drift gravel and sand	Indef.
6942	"	"	Sandy and gravelly clay	"
6943	"	"	Sandy clay—blue	"
6944	"	"	" " "	"
6945	"	"	Gravelly and sandy clay	"
6946	"	"	Boulder; hard gray gneiss	"
6947	"	"	Boulder; quartzose	"
6948	"	"	Bluish, sandy clay	"
6949	"	"	" " "	"
6950	"	"	Quicksand	"
6951	"	"	Quicksand, with some clay	"
6952	"	"	Green shale or clay	"
6953	"	"	Soft reddish chlorite-granite or gneiss	"
6954	"	"	" " "	"
6955	"	"	" " "	"
6956	"	"	" " "	"
6957	"	"	" " "	"
6958	"	"	The same, but more like 6946	"
6959	"	"	Same, but more green from chlorite	"
6960	"	"	" " "	"
6961	"	"	" " "	"
6962	"	"	Same, but finer	"
6963	"	"	Same, but coarser	"
6964	"	"	Same, but darker colored	"
6965	"	"	Same, fine drillings	"
6966	"	"	" "	"
6967	"	"	Soft, greenish, red-mottled felsyte	"
6968	"	"	Same, with some calcite	"
6969	"	"	Mainly water-worn sand	"
6970	"	"	Mixed granitic rock	"
6971	"	"	Mainly light chloritic granite	"
6972	"	"	Mostly white feldspar and quartz	"
6973	"	"	Brownish-red rock	"
6974	"	"	Gray, epidotic, finely granular gabbro	"
6975	"	"	Same as 6974	"
6976	"	"	" "	"
6977	"	"	Apparently the same, but finer	"
6978	"	"	Essentially quartzose	"
6979	"	"	Same as 6978; pyritiferous	"
6980	"	"	Drillings; gray, pulverulent	"
6981	"	"	Drillings brown, fine-grained	"
6982	"	"	Essentially a brown felsyte	"
6983	"	"	Conglomerate with brown felsyte	"
6984	"	"	Pink and gray conglomerate and quartzyte	"
6985	"	"	Granular white quartz	"
6986	"	"	Same, a granular quartzyte	"
6987	"	"	Same, but showing gray also	"
5988	"	"	Same, but more gray, also pink	"
6989	"	"	" " " " "	"
6990	"	"	Dark gray, pulverulent; similar to 6980	"
6991	"	"	Trap-rock, epidotic diabase	"
6992	"	"	Gray diabasic trap-rock	"
6993	"	"	" " "	"
6994	"	"	Apparently the same, very fine	"
6995	"	"	Brown-gray diabasic rock	"
6996	"	"	Drillings of two sorts	"
6997	"	"	"Black slate" or argillyte	"
6998	"	"	" " "	"
6999	"	"	Same, but with a greenish tinge	"
7000	"	"	Same as 6998	"
7001	"	"	Same as 6999	"
7002	"	"	Essentially the same, not so slaty	"
7003	"	"	Same, rather light gray	"
7004	"	"	Gray slate, slightly pyritiferous	"
7005	"	"	" " "	"
7006	"	"	Drillings of two kinds	"
7007	"	"	Drillings very fine, light yellowish	"
7008	"	"	" " " " " "	"
7009	"	"	" " " " " "	"
7010	"	"	Same as last, but also some of the next	"
7011	"	"	Gray, compact, fine, diabasic rock	"
7012	"	"	Same as 7011, with some gray slate	"
7013	"	"	Same as 7011	"
7014	"	"	Same, gray rock predominates	"

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
Moorhead, Minn.	Drillings from Moorhead well.	No. 8, Depth 145 feet.
" "	"	" 9, " 155 "
" "	"	" 10, " 165 "
" "	"	" 11, " 185 "
" "	"	" 12, " 195 "
" "	"	" 13, " 200 "
" "	"	" 14, " 220 "
" "	"	" 15, " 240 "
" "	"	" 16, " 300 "
" "	"	" 17, " 345 "
" "	"	" 18, " 360 "
" "	"	" 19, " 375 "
" "	"	" 21, " 400 "
" "	"	" 23, " 475 "
" "	"	" 24, " 600 "
" "	"	" 25, " 635 "
" "	"	" 26, " 745 "
" "	"	" 27, " 765 "
" "	"	" 28, " 800 "
" "	"	" 29, " 900 "
" "	"	" 30, " 1,000 "
" "	"	" 31, " 1,010 "
" "	"	" 32, " 1,050 "
" "	"	" 33, " 1,065 "
" "	"	" 34, " 1,090 "
" "	"	" 35, " 1,120 "
" "	"	" 36, " 1,195 "
" "	"	" 37, " 1,205 "
" "	"	" 38, " 1,265 "
" "	"	" 39, " 1,280 "
" "	"	" 40, " 1,325 "
" "	"	" 41, " 1,425 "
Duluth, Minn.	Drillings from Duluth deep well.	" 3, " 243 "
" "	"	" 4, " 276 "
" "	"	" 6, " 417 "
" "	"	" 7, " 448 "
" "	"	" 8, " 463 "
" "	"	" 9, " 468 "
" "	"	" 10, " 473 "
" "	"	" 11, " 490 "
" "	"	" 12, " 506 "
" "	"	" 13, " 508 "
" "	"	" 14, " 511 "
" "	"	" 15, " 513 "
" "	"	" 16, " 514 "
" "	"	" 17, " 516 "
" "	"	" 18, " 520 "
" "	"	" 19, " 524 "
" "	"	" 20, " 528 "
" "	"	" 21, " 530 "
" "	"	" 22, " 554 "
" "	"	" 23, " 574 "
" "	"	" 24, " 590 "
" "	"	" 25, " 598 "
" "	"	" 26, " 613 "
" "	"	" 27, " 619 "
" "	"	" 28, " 680 "
" "	"	" 29, " 880 "
" "	"	" 30, " 1,080 "
" "	"	" 32, " 1,175 "
" "	"	" 33, " 1,235 "
" "	"	" 34, " 1,340 "
" "	"	" 35, " 1,370 "
" "	"	" 36, " 1,375 "
" "	"	" 37, " 1,400 "
" "	"	" 38, " 1,435 "
" "	"	" 39, " 1,437 "
" "	"	" 40, " 1,445 "
" "	"	" 41, " 1,448 "
" "	"	" 42, " 1,450 "
" "	"	" 43, " 1,452 "
" "	"	" 44, " 1,454 "
" "	"	" 45, " 1,455 "
" "	"	" 46, " 1,456 "

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
7015	Aug., 1889	Geol. Survey	Same, gray rock predominates	Indef.
7016	"	"	Same, but lighter colored	"
7017	"	"	" " "	"
7018	"	"	Gray quartzyte, very fine; same as 7014	"
7019	"	"	" " " "	"
7020	"	"	Same, but more cleavable	"
7021	"	"	Same gray rock, slaty	"
7022	Jan'y, 1890	Exchange	Spirifer pennatus Owen	2
7023	"	"	Spirifer keokuk var	3
7024	"	"	Spirifer cameratus Morton	3
7025	"	"	Spirifer mucronatus Conrad	5
7026	"	"	Spirifer whitneyi Hall	4
7027	"	"	Spirifer hungerfordi Hall	18
7028	"	"	Spirifer orestes Hall and Whitfield	3
7029	"	"	Orthis impressa Hall	7
7030	"	"	Atrypa hystrix Hall	2
7031	"	"	Atrypa reticularis Linn	13
7032	"	"	" " "	3
7033	"	"	Atrypa aspera Schloth	3
7034	"	"	Rhynchonella alta Calvin	10
7035	"	"	Rhynchonella capax Conrad	3
7036	"	"	Athyris ambigua Sowerby	6
7037	"	"	Athyris subtilita Hall	4
7038	"	"	Productus costatus Sowerby	3
7039	"	"	Hemipronites crassus Meek and Worthen	7
7051	"	"	Zaphrentis spinulifera Hall	1
7064	"	"	Blue limestone	1
7065	Feb'y, 1890	"	Apophyllite	1
7066	"	"	Iron, apophyllite and other minerals	1
7067	"	"	Chacopyrite and pyrite	1
7068	"	"	Pyrite on calcite	1
7069	"	"	Magnetite (crystals)	1
7070	"	"	Calcite and apophyllite	1
7071	"	"	Byssoiltic calcite	1
7072	"	"	Pink orthoclase	1
7073	"	"	Pyroxene	1
7074	"	"	Sphalerite	1
7075	Ma'ch, 1890	Presented	Graphite	1
7076	"	"	Concretions in slate	3
7077	"	"	Kaoline	Indef.
7078	"	"	Lignite	"
7079	"	"	Asaphus canadensis Chapm	2
7081	1876	"	Fossil bones from S. America	Indef.
7082	June, 1890	"	Pyroxenite var. "Websterite" 1st type	1
7083	"	"	Pyroxenite var. "Websterite" 2d type	1
7084	"	"	Coquina	2
7085	"	"	Asbestos, artificial	Indef.
7086	"	Exchange	Limestone, No. 1	2
7087	"	"	" (above No. 1) No. 2	2
7088	"	"	" No. 3	1
7089	"	"	" No. 4	1
7090	"	"	"	1
7091	"	"	"	1
7092	"	"	Marshall sandstone	2
7093	"	"	Limestone	2
7094	"	"	Conglomerate	2
7095	"	"	Green mica	2
7096	"	"	Feldspar	1
7097	"	"	Magnetite in granite	7
7098	"	"	Selenite	8
7099	"	"	Pyrite	15
7100	"	"	Calcite and pyrite	6
7101	"	"	Calcite	12
7102	"	"	Brown calcite crystals	15
7103	"	"	Stalactites	8
7104	"	"	Stalagmites	3
7105	"	"	Cyathophyllum	7
7106	"	Presented	Deposits from Mammoth Hot Springs	Indef.
7107	"	"	Limestone with barnacles attached	3
7108	"	"	Cinnabar	1
7109	"	"	Cinnabar crystals and some native quicksilver	1
7110	"	"	Vein rock with cinnabar	1
7111	"	"	Vein rock, barren (gangue)	1
7112	"	"	Foot wall rock (serpentine)	1

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
Duluth, Minn.	Drillings from Duluth deep well.	No. 47, Depth 1,457 feet.
" "		" 48, " 1,468 "
" "		" 49, " 1,477 "
" "	"	" 50, " 1,487 "
" "	"	" 51, " 1,495 "
" "	"	" 52, " 1,500 "
" "	"	" 53, " 1,507½ "
Independence, Iowa	Hamilton	C. W. Irish, Iowa City, Iowa.
Pella, Iowa	Sub. Carb.	" " "
Madison Co., Iowa	Upper Carb.	" " "
Widdler, Canada	Hamilton	" " "
Rockford, Iowa	Chemung	" " "
" "	"	" " "
" "	"	" " "
" "	"	" " "
" "	"	" " "
" "	"	" " "
Independence, Iowa	Hamilton	" " "
" "	"	" " "
" "	"	" " "
Solon, Iowa	Trenton	" " "
Fillmore Co., Minn	Sub. Carb.	" " "
Pella, Iowa	Upper Carb.	" " "
Madison Co., Iowa	"	" " "
" "	"	" " "
" "	"	" " "
Pella, Iowa	Sub. Carb.	" " "
Iowa City, Iowa	Hamilton	" " "
St. Peters, Chester Co., Pa		J. Eyerman, Easton, Pa.
" " "		" " "
" " "		" " " [French Creek mines
" " "		" " "
" " "		" " "
" " "		" " "
" " "		" " "
" " "		" " "
" " "		" " " [Uberroth mine.
Friedensville, Shegle Co., Pa		
Town 64-6, S. E. ¼ Sec. 18		J. G. Emery.
Beaver Mine, Ont., Can		J. W. Bist, 328 Oak st., Minneapolis.
Blaine Twp., Anoka Co		H. V. Rumohe.
Big Fork, Ont., Can		Stanley Newton, 12 miles bel. Big Falls, Big Fork
Fields Crossing, Ont	Utica slate	A. W. Vogdes (Georgian Bay.)
South America		P. D. McMillan.
Balto Co., Md		G. H. Williams.
" "		"
St. Augustine, Fla		Mrs N. H. Winchell. [Science Hall.
		N. H. Winchell. (packing round steam pipes)
Grand Rapids, Mich	Sub. Carb.	C. A Whittemore.
" "	"	" above No. 7086.
" "	"	" 2 feet deep.
" "	"	" 3 feet deep.
" "	"	" ½ mile N. E. of No. 7086.
" "	"	" showing penetration of iron oxide.
West of Grand Rapids, Mich	"	" above the limestone. [crystals.
Grand Rapids, Mich	"	" lining of cavity cells in place of
" "	Drift	" fossiliferous.
Brunswick, Maine		"
" "		"
Topsham, Maine		"
Grand Rapids, Mich		"
		"
		" Myrtle st. quarry.
Grand Rapids, Mich		From C. A. Whittemore.
" " "		" "
" " "		" " 25 yrs. growth, cellar.
" " "		" " " " "
" " "		" "
Yellowstone Park		J. B. Alexander.
Port Clinton, Puget Sound		"
New Almaden, Cal.		The Quicksilver Mining Company.
" "		" "
" "		" " "
" "		" " "
" "		" " "

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
7113	June, 1890	Presented	Hanging wall rock (alta)	1
7114	"	Geol. Survey	Hinckley sandstone	5
7115	July, 1890	"	Jaspilyte pebble	1
7116	"	"	Kidney iron ore	1
7117	"	"	Gray granite drillings	Indef.
7118	"	"	Pyrites	1
7119	"	"	Inyo marble (dolomite)	1
7120	Aug., 1890	Exchange	Silicified wood	1
7121	"	"	Pectolite (massive)	1
7122	"	"	Garnet in mica schist	1
7123	"	"	Syenite	1
7124	"	"	Granite	1
7125	"	"	Garnet in mica schist	1
7126	"	"	White marble	1
7127	"	"	Trachyte	1
7128	"	"	Limestone	1
7129	"	"	Granite	1
7130	"	"	Chalcedony	5
7131	"	"	"	1
7132	"	"	"	1
7133	"	"	Colemanite (borate of lime)	3
7134	"	"	Sulphur (massive)	1
7135	"	"	Roscœlite (on quartz)	1
7136	"	"	Dye stuff, used for painting canoes and coloring tapa	1
7137	"	"	Chrysolite	Indef.
7138	"	"	Asbestos	"
7139	"	"	Ulexite (borate of lime)	1
7140	"	"	Volcanic ash or "White Lava"	1
7141	"	"	Syenitic granite	1
7142	"	"	Volcanic ash (indurated)	2
7143	"	"	Selenite	2
7144	"	"	Calcite	1
7145	"	"	Obsidian	2
7146	"	"	Halite	1
7147	"	"	Actinolite	1
7148	"	"	Feldspar	1
7149	"	"	Selenium (rare)	1
7150	"	"	Fuchsite	1
7151	"	"	Gneiss	1
7152	"	"	Colton marble	1
7153	"	"	Linarite (rare)	3
7154	"	"	Porphyritic diorite	3
7155	"	"	Gneiss, wall rock of Stonewall mine	1
7156	"	"	Core of diamond drill	1
7157	"	"	Quartz	1
7158	"	"	"Slickensides"	1
7159	"	"	Jasper	4
7160	"	"	Porphyry	1
7161	"	"	Hanging and foot wall of Nevada City mine	1
7162	"	"	Rock specimen, the deepest working of Comstock lode	1
7163	"	"	Syenite	1
7164	"	"	Steatite (soapstone)	1
7165	"	"	Diorite (used for paving)	1
7166	"	"	Ione red sandstone	1
7167	"	"	Granite	1
7168	"	"	Gold quartz	1
7169	"	"	Quartz and pyrite	1
7170	"	"	San Jose yellow sandstone	1
7171	"	"	Aragonite	1
7172	"	"	Wollastonite	1
7173	"	"	Altered serpentine and bronzite	1
7174	"	"	Gold quartz (Soulsby Mine)	1
7175	"	"	Halotrichite	Indef.
7176	"	"	Talcose slate, hard	1
7177	"	"	Hornblende	1
7178	"	"	Sample of foot and hanging wall rock	1
7179	"	"	Rock samples	3
7180	"	"	"	1
7181	"	"	"	1
7182	"	"	"	2
7183	"	"	"	3
1784	"	"	Foot wall of Nevada City Mine	1
1785	"	"	Stalactite (Clough's cave)	3
1786	"	"	Quartz with galenite and pyrite	1

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
New Almaden, Cal		The Quicksilver Mining Company.
Hinckley, Minn		N. H. Winchell.
Arlington street, Minneapolis	Drift	N. H. Winchell.
" "	"	N. H. Winchell.
LeMars, Iowa		J. E. Todd, from near 1,400 feet down.
Near Porter, Minn		J. F. Fries.
California		California State Mining Bureau, No. 19
Sonoma county, Cal		" " " " " 21
Tehama county, Cal		" " " " " 22
Stickeen River, Alaska		" " " " " 23
Kern county, Cal		" " " " " 24
Raymond, Fresno county, Cal		" " " " " 25
Reed Ranch, Marine county, Cal		" " " " " 26
Placer county, Cal		" " " " " 27
Waterloo Mt., Cal		" " " " " 28
Kern county, Cal		" " " " " 29
Oro Grand, San Bernardino Co., Cal		" " " " " 30
Aurora, Nevada		" " " " " 31
Tuolumne county, Cal		" " " " " 32
Volcano, Amador county, Cal		" " " " " 33
Calico, San Bernardino, Co., Cal		" " " " " 34
Humboldt Co., Nev		Cal. St. Min'g Bu., (Rabbit Hole mine) " 35
California		" " " 36
Panipe Island, South Sea		" " " 37
Tuolumne Co., Cal		" " " 38
Shasta Co., Cal		" " " 39
Esmeralda Co., Nev		" " " 40
Volcano, Amador Co., Cal		" " " 41
Tuolumne Co., Cal		" " ('country r'ck' of Soulsby mn.) " 42
Mokelumne Hill, Calaveras Co., Cal		" " " 43
Monterey Co., Cal		" " " 44
San Bernardino Co., Cal		" " " 45
Glass Mt., Napa Co., Cal		" " " 46
San Bernardino Co., Cal		" " " 47
Sonoma Co., Cal		" " " 48
Mariposa Co., Cal		" " " 49
Honduras		" " " 50
Arch Bend, Orange Co., Cal		" " " 51
Humboldt Co., Cal		" " " 52
Colton, San Bernardino Co., Cal		" " " 53
Cerro Gordo, Inyo Co., Cal		" " " 54
Shasta Co., Cal		" " " 55
San Diego Co., Cal		" " " 56
Pica Cañon, Los Angeles Co., Cal		" " (oil well No. 9) " 57
Sheep Ranch, Tuolumne Co., Cal		" " " 58.
San Bernardino Co., Cal		" " " 59
California		" " " 60
Calico, San Bernardino Co., Cal		" " " 61
Nevada Co., Cal		" " " 62
Virginia City, Nev		" " " 63
Point St. Pedro, Cal		" " " 64
El Dorado Co., Cal		" " " 65
California		" " " 66
Ione, Amador Co, Cal		" " " 67
Loomis, Placer county, Cal		" " (Mtn. View mine) " 68
Fresno county, Cal		" " " 69
Los Angeles county, Cal		" " " 70
California		" " " 71
Suisun, Solano county, Cal		" " " 72
Del Norte county, Cal		" " " 73
Santa Clara county, Cal		" " " 74
Tuolumne county, Cal		" " " 75
Alameda county, Cal		" "
Soulsbyville, Toulumne county, Cal		" "
Tuolumne county, Cal		" "
Sonora, Toulumne county, Cal		" "
San Bernardino county, Cal		" " (Fenner)
Daggett, Cal		" "
Near Poverty Hill		" "
Colusa county, Cal		" "
Providence, San Bernardino Co., Cal		" "
Nevada county, Cal		" "
Tulare county, Cal		" "
Los Angeles county, Cal		" "

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens.
7187	Aug., 1890	Exchange	Tourmaline schist	1
7188	"	"	Slate	1
7189	"	"	Trachyte	1
7190	"	"	Basalt (porphyritic)	3
7191	"	"	Quartz	1
7192	"	"	"	3
7193	"	"	Picrolite and serpentine	1
7194	"	"	Geysers	3
7195	"	"	Mariposite, "Blue Jay"	1
7196	"	"	Talcose rock	1
7197	"	"	Chalcedony	4
7198	"	"	Dike rock	1
7199	"	"	Contact between slate and greenstone	1
7200	"	"	Hanging wall, Amador Gold mine	1
7201	"	"	Wall rock in Washington mine	1
7202	"	"	Dike along "Mother Lode"	2
7203	"	"	"Diorite"	1
7204	"	"	Lava	1
7205	"	"	Rock specimens	5
7206	"	"	Agate	1
7207	Sept., 1890	"	Borax crystals (artificial)	1
7208	"	"	Hanksite	1
7209	"	"	Ulexite (cotton balls)	1
7210	"	"	Borax crystals (tincal)	1
7211	"	"	Glauberite crystals	6
7212	"	"	Orthoclase crystals	4
7213	"	"	Borax crystals (tincal)	5
7214	"	"	Colemanite (borate of lime)	1
7215	"	"	Arsenopyrite (mispickel)	1
7216	"	"	Metallic antimony (native)	1
7217	"	"	Stibiconite	1
7218	"	"	Metacinnabarite	1
7219	"	"	Cinnabar	1
7220	"	"	"	1
7221	"	"	"	1
7222	"	"	" (in sandstone)	1
7223	"	"	Calymene mammillata Hall (and others)	1
7224	"	"	Murchisonia gracilis Hall (and others)	3
7225	"	"	Diplograptus peosta Hall	4
7226	"	"	Orthoceras sociale Hall	16
7227	"	"	Tentaculites sterlingensis Meek and Worthen	2
7228	"	"	Strophomena alternata Conrad	3
7229	"	"	Receptaculites	1
7230	"	"	Smithsonite	1
7232	"	"	Bythotrephis succulens Hall	1
7233	"	"	Sioux quartzyte	2
7234	"	"	Garnets in schist	3
7335	"	"	Hornblende schist	1
7236	"	"	Talc	1
7237	"	Presented	Garnets in mica schist	1
7238	"	Geol. Survey	"Winnipeg" limestone	1
7239	May, 1890	Purchased	Meteoric stones	Indef.
7240	April, 1890	"	Meteoric irons	2
7241	Aug., 1890	"	Meteoric stones (chondritic)	1
7242	Sept., 1890	Exchange	Pipe creek meteorite (chondrite)	1
7243	.....	Presented	Quartz crystals	1
7244	1891	"	Magnetic iron ore	1
7245	1891	.....	Staurolite	1
7250	Apr., 1891	Geol. Survey	Ischadites iowensis Owen	1
7251	"	"	Receptaculites iowensis Hall	1
7254	"	Exchange	Trigonocarpon triloculare Hildreth	14
7255	"	"	Trigonocarpon hexacostatus	1
7256	"	"	" "	1
7257	"	"	Rhabdocarpon	2
7259	"	"	Parts of crinoid stems	.....
7260	1891	"	Selenite	.....
7262	1891	"	Phosphate rock: representing *redondite*	1
7263	1891	"	Phosphate rock: representing *redondite*	1
7264	1891	"	Phosphate rock: representing *redondite*	5
7265	1891	"	Phosphate rock representing *renondite*	6

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
San Benito county, Cal.		Calif. State Mining Bureau.
Calaveras, Cal.		" " "
San Luis Obispo, Cal.		" " "
Fresno county, Cal.		" " "
Mt. St. Helena, Napa county, Cal		" " "
San Francisco, Cal.		" " "
El Dorado county, Cal.		" " "
Sonoma county, Cal.		" " "
California.		" " " (Mother Lode.)
"		" " "
"		" " "
"		" " "
"		" " "
South Jackson, Cal.		" " "
California.		" " " (Julian dists.)
Centerville, Cal.		" " "
Virginia, Nev.		" " " (C and C Shaft.)
Silver Peak, Nev.		" " "
Gila River, Ariz.		" " "
Central America.		" " "
San Bernardino county, Cal.		Henry G. Hanks, San Francisco. No. 1
" "		" " " " 2
Esmeralda county, Nev.		" " " " 3
San Bernardino county, Cal.		" " " " 4
" "		" " " " 5
Maiden, Mont.		" " " " 6
Esmeralda county, Nev.		" " " " 7
San Bernardino county, Cal.		" " " " 8
Tulare county, Cal.		" " " " 9
Kern county, Cal.		" " " " 10
Lander county, Nev.		" " " " 11
Lake county, Cal.		" " " " 12
" "		" " " " 13
Sonoma county, Cal.		" " " " 14
San Luis Obispo county, Cal.		" " " " 15
Napa county, Cal.		" " " " 16
Graf, Iowa.	Trenton	F. W. Plapp, Dubuque, Iowa.
" "	"	" " "
" "	Hudson River	" " "
" "	"	" " "
Dubuque, Iowa.	Trenton	" " "
" "	Gelena	" " "
" "		" " "
Grant county, Wis.	Trenton	" " "
Rowena, South Dak.		" " "
Hanover, N. H.		" " "
Olcott Falls, Vermont.		" " "
Norwich, "		" " "
Alaska.		A. L. Broughton.
Minneapolis, Minn.	Drift	Prof. N. H. Winchell.
Winnebago county, Iowa.		N. H. and H. V. Winchell. Fell May 2, 1890.
Kiowa county, Kansas.		N. H. Winchell—See Am. Geol., Vol. V., p. 309.
Washington county, Kansas.		Fell June 25, 1890. [Y. Acad. Sci., 1889.]
Bandera county, Texas.		Dr. H. Hensoldt—See Vol. VIII, Trans., N.
Tower, Minn.	Keewatin	Capt. R. J. Williams, Breitung iron mine.
Cerro de Mercado, Mexico		Rev. J. A. Wright.
Pike Rapids, Mississippi River.		
Wasioja, Dodge county Minn.	Galena	N. H. Winchell.
" " "	"	
Youngstown, Ohio.	Carbon	W. H, McGinnis.
" "	"	"
" "	"	"
" "	"	"
		"
Ohio.		" (Crystals in clay matrix).
Ellsworth township, Mahoning Co., O.		C. H. Hitchcock—The very best-40 p ct. P_2O_5.
Island of Redonda, Caribbean Sea.		For No.'s 7262-7271, see Bul. Geol. Soc. Amer. Vol. II, p. 6.
" "		C. H. Hitchcock.—The compact light colored part is supposed to be nearly pure *Redondite.*
" "		C. H. Hitchcock.—High grade:—Nearly 40 p ct. P_2O_5.
" "		C. H. Hitchcock.—About 35 p ct P_2O_5.

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
7266	1891	Exchange	Phosphate rock: representing *redondite*	5
7267	"	"	" " "	5
7268	"	"	" " "	1
7269	"	"	Phosphate earth. "	.....
7270	"	"	Volcanic tufa	1
7271	"	"	Lava	1
7272	"	"	Calcite	1
7273	"	"	"	1
7274	"	"	"	1
7275	"	"	Trigonocarpon	4
7276	"	"	"	1
7277	May, 1891	Presented	Granitic gneiss	1
7278	1890	"	Iron slag	1
7279	Dec., 1891	Geol. Survey	Philodops trentonensis var minor W. and S	3 slabs.
7280	July, 1891	"	Subulites elongatus Conrad	7
7281	"	"	Murchisonia tricarinata Hall	2
7282	"	"	Pleurotomaria subconica Hall	8
7284	"	"	Murchisonia helicteres Salter	6
7289	"	"	Raphistoma lenticularis Sowerby	5
7290	"	"	Raphistoma	2
7291	"	"	Maclurea	6
7292	"	"	Cyrtolites compressa Conrad	4
7293	"	"	Bucania (Tremanotus?) buelli Whitfield	2
7294	"	"	Bucania	3
7295	"	"	Bucania bidorsata Hall	1
7296	"	"	Bellerophon	3
7297	"	"	Bellerophon wisconsensis Whitfield	4
7298	"	"	Bellerophon bilobatus Sowerby	25
7303	"	"	Subulites elongatus Conrad	1
7304	"	"	Pleurotomaria subconica Hall	1
7308	"	"	Maclurea bigsbyi Hall	1
7309	"	"	Cyrtolites compressa Conrad	1
7310	"	"	Bellerophon wisconsenis Whitfield	2
7311	"	"	Bellerophon bilobatus Sowerby	6
7312	"	"	Maclurea	1
7313	"	"	Pleurotomaria subconica Hall	3
7314	"	"	Murchisonia tricarinata Hall	3
7316	"	"	Bellerophon wisconsensis Whitfield	1
7317	"	"	Bellerophon bilobatus Sowerby	1
7318	"	"	Bucania (Tremanatus?)	2
7319	"	"	" "	1
7321	"	"	Pleurotomaria subconica Hall	4
7328	"	"	Raphistoma lenticularis Sowerby	4
7330	"	"	Bellerophon bilobatus Sowerby	1
7333	"	"	Raphistoma lenticularis Sowerby	5
7337	Aug. 1891	"	Murchisonia gracilis Hall	19
7343	July 1891	"	Trochonema	1
7344	"	"	Murchisonia gracilis Hall	3
7345	Aug. 1891	"	Murchisonia major Hall	3
7346	"	"	Bellerophon	1
7347	"	"	Trochonema	4
7348	"	"	Raphistoma lenticularis Sowerby	2
7349	"	"	Maclurea	2
7351	"	"	Bellerophon bilobatus Sowerby	12
7352	"	"	Bellerophon wisconsensis Whitfield	1
7353	"	"	Raphistoma lenticularis Sowerby	1
7354	July 1891	"	Bellerophon bilobatus Sowerby	26
7356	"	"	Maclurea	4
7357	"	"	Trochonema	1
7358	"	"	Pleurotomaria subconica Hall	2
7546	"	"	Homotrypa seperata var.	1
7547	"	"	Philloporina reticulata Hall	1
7548	"	"	Rhinidictya fidelis Ulrich	2
7549	"	"	Rhinidictya trentonensis Ulrich	3
7550	"	"	Monotrypa	5
7551	"	"	Leptotrypa hexagonalis Ulrich	1
7552	"	"	Rhinidictya	1
7553	"	"	"	1
7554	"	"	Rhinidictya fidelis Ulrich	1
7555	"	"	Nicholsonella ponderosa	1
7557	"	"	Leptotrypa hexagonalis Ulrich	1

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
Island of Redonda, Caribbean Sea..	.....	C. H. Hitchcock.—About 27 p ct. P_2O_5.
" "	.....	" About 24 p ct. P_2O_5.
" "	.....	" Splendid grains or concretions.
" "	.....	" About 12 p ct P_2O_5.
" "	.....	" From tunnel in midst of workings.
" "	.....	" .....
New Galilee, Beaver county, Pa....	.....	H. W. Williams (Brown).
" "	.....	" (White).
" "	.....	" "
Ohio.....	Carbon.....	H. W. Williamson. The Mt. Hope type of the country (nuts in matrix.)
"	"	" (shell of the nut.) [mines.
.....	Taconic?..	Frank L. Nason, rock of the N. J. magnetite
Tribune fire, Minneapolis	.....	H. V. Winchell, resembles meteoric iron.
St. Paul, Minn.....	Trenton	C. Schuchert.
Janesville, Wis.....	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
Beloit, Wis.....	"	" fromC.&N.W.R.R.qry,3½m. n.of Beloit.
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
Rockton, Ill.....	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
Beloit, Wis.....	"	" fr. Samp's qry. in the "Up. Buff Beds
"	"	"
Neenah, Wis.....	Galena.....	"
Oshkosh, Wis.....	"	"
"	"	"
Graf, Iowa.....	Cincinnati....	"
Janesville, Wis.....	Trenton	"
"	"	"
Dubuque, Iowa.....	Galena..	"
"	"	"
"	"	"
"	"	"
McGregor, Iowa.....	Trenton	"
"	"	"
"	"	"
"	"	"
Mineral Point, Wis.....	"	"
"	"	"
"	"	"
"	"	"
McGregor, Iowa.....	"	"
"	"	"
Janesville, Wis.....	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
Near Beloit, Wis.....	"	"
"	"	"
"	"	"

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
7558	July, 1891	Geol. Survey...	Ptilodictya subrecta Ulrich	2
7559	"	"	Batostoma fertile ? Ulrich	1
7560	"	"	Rhinidictya trentonensis Ulrich	1
7561	"	"	Batostomella trentonensis Nicholson	1
7562	"	"	Ptilodictya falciformis var. acuminata James	6
7563	"	"	Rhinidictya	1
7564	"	"	Rhinidictya paupera Ulrich	1
7565	"	"	Dekayella	8
7566	"	"	Stellipora antheloidea Hall	1
7567	"	"	? Hemiphragma ottawaense Foord	2
7568	"	"	Homotrypa	111
7569	"	"	Prasopora insularis Ulrich	130
7570	"	"	Prasopora simulatrix Ulrich	33
7571	"	"	Prasopora simulatrix ? Ulrich	1
7573	"	"	Prasopora simulatrix Ulrich	71
7574	"	"	Monotrypa nodosa Ulrich (M. S.)	4
7575	"	"	Trematopora ositida Ulrich, et al	1
7576	"	"	" " "	1
7577	"	"	Dræospora fragilis Billings	2
7578	"	"	Batostomella simulatrix Ulrich	3
7579	"	"	Undetermined ramose forms	Many
7580	"	"	Crepipora hemispherica ? Ulrich	2
7581	"	"	Monotrypella quadrata var. multituberculata Whit.	1
7582	"	"	Heterotrypa	5
7583	"	"	"	1
7584	"	"	Heterotrypa singularis Ulrich	3
7585	"	"	Ceramoporella irregularis Whitfield	8
7586	Aug., 1891	"	Spatiopora	3
7587	"	"	"	4
7589	"	"	Batostomella variabile Ulrich	10
7590	"	"	Crepipora	6
7591	"	"	Prasopora contigua Ulrich	4
7592	"	"	Batostoma minnesotensis ?	2
7593	July, 1891	"	Rhinidictya fidelis Ulrich	1
7594	"	"	" " "	1
7595	"	"	Leptotrypa hexagonalis Ulrich	2
7596	Aug., 1891	"	Pachydictya acuta var. elegans Ulrich	1
7597	"	"	Stictoporella angularis var. intermedia Ulrich	1
7598	"	"	Rhinidictya septata Ulrich	5
7599	"	"	Stictoporella angularis var. intermedia Ulrich	4
7600	"	"	Homotrypa minnesotensis Ulrich	1
7601	"	"	Prasopora insularis Ulrich	141
7602	"	"	Monotrypa cumulata Ulrich	1
7603	"	"	Batostomella trentonensis Ulrich	1
7606	"	"	Batostoma	6
7607	"	"	Pachydictya acuta Hall, et al	1
7608	"	"	" "	1
7609	"	"	" "	1
7611	"	"	Prasopora insularis Ulrich	19
7612	"	"	Rhinidictya paupera Ulrich	1
7613	"	"	Batostoma humile Ulrich	19
7614	"	"	Basal expansion of undet. ramose bryozoans	5
7615	"	"	Callopora pulchera? Ulrich	3
7616	"	"	Pachydictya acuta Hall	5
7617	"	"	Stictoporella angularis Ulrich	2
7618	"	"	Hemiphragma irrasum Ulrich	2
7619	"	"	Pachydictya acuta Hall, et al	13
7620	"	"	Proboscina tumulosa Ulrich	1
7621	"	"	Rhinidictya mutabilis	2
7622	"	"	Prasopora conoidea Ulrich	17
7623	"	"	Pachydictya acuta Hall	1
7624	"	"	Crepipora? denticulata Ulrich	2
7625	"	"	Prasopora occultata Foord	5
7626	"	"	Monotrypa cumulata Ulrich	6
7627	"	"	Hemipragma irrasum Ulrich	1
7628	"	"	Prasopora insularis Ulrich	10
7629	"	"	Monotrypa cumulata Ulrich	1
7631	"	"	Monticulipora ramifera Ulrich	3
7632	"	"	Pachydictya acuta Hall	1
7633	"	"	Dekayia trentonensis Ulrich	2
7635	"	"	Monotrypa cumulata Ulrich	6
7636	"	"	Homotrypa similis Foord	3
7637	"	"	Prasopora insularis Ulrich	8
7638	"	"	Leptotrypa	1

ADDITIONS. – *Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
Near Beloit, Wis	Trenton	C. Schuchert.
Rockton, Ill	"	"
"	"	"
Neenah, Wis	Galena	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
Oshkosh, Wis	"	"
Iron Ridge, Wis	Cincinnati	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
"	"	"
Graf, Iowa	"	"
"	"	"
"	"	"
Dubuque, Iowa	Galena	"
McGregor, Iowa	Trenton	"
"	"	"
Mineral Point, Wis	"	"
"	"	"
"	"	"
Decorah, Iowa	Galena	"
"	Trenton	"
"	Galena	"
"	Trenton	"
"	"	"
"	Galena	"
"	"	"
"	"	"
Six m. s. of Cannon Falls, Minn	"	Scofield and Schuchert.
" " "	"	"
" " "	"	"
" " "	"	"
" " "	"	"
" " "	"	"
" " "	"	"
" " "	"	"
" " "	"	"
Preston, Minn	Trenton	"
Six m. s. Cannon Falls, Minn	Galena	"
Two m. s. e. "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
Chatfield, Minn	Trenton	W. H. Scofield.
Holden, Minn	Galena	"
"	"	"
"	"	"
Seven m. s. Cannon Falls, Minn	"	Scofield and Schuchert.
" " "	"	"
" "	"	"
Kenyon, Minn	"	W. H. Scofield.
"	"	"
Nine m. s. Cannon Falls, Minn	"	Scofield and Schuchert.
9 miles south Cannon Falls, Minn	"	" "
Warsaw, Minn	"	W. H. Scofield.
" "	"	"

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
7639	Aug., 1891.	Geol. Survey...	Pachydictya acuta Hall.	5
7640	"	"	Callopora multitabulata Ulrich	6
7641	"	"	Prasopora insularis Ulrich	1
7642	"	"	Monotrypa cumulata Ulrich	1
7643	"	"	Pachydictya acuta? Hall	2
7644	"	"	Prasopora insularis Ulrich	1
7645	"	"	Homotrypa similis Foord	1
7646	"	"	Pachydictya occidentalis? Ulrich	3
7647	"	"	Ceramoporella	1
7649	"	"	Callopora	16
7650	"	"	Stictoporella frondifera Ulrich	2
7652	"	"	Callopora multitabulata Ulrich	5
7653	"	"	Lichenaria typa W and S	1
7654	"	"	Trematopora primigenia Ulrich	1
7655	"	"	Homotrypa exilis Ulrich	1
7656	"	"	Crepipora? denticulata Ulrich	4
7657	"	"	Dekayella	12
7658	"	"	Prasopora	2
7659	"	"	Callopora multitabulata Ulrich	9
7660	"	"	Anolotichia impolita Ulrich	2
7661	"	"	Trematopora primigenia Ulrich	3
7662	"	"	Crepipora? denticulata Ulrich	1
7663	"	"	Rhinidictya mutabilis Ulrich	1
7664	"	"	Batostoma winchelli Ulrich	22
7665	"	"	Callopora multitabulata Ulrich	5
7666	"	"	Prasopora insularis Ulrich	14
7667	"	"	Homotrypa separata Ulrich	1
7668	"	"	Batost ma minnesotensis Ulrich	2
7669	"	"	Dekayella	1
7670	"	"	Homotrypa	8
7671	"	"	Lingula philomela Billings	1
7672	July, 1891.	"	Lingula riciniformis var. galenensis W. and S	3
7673	"	"	" " " " "	10
7674	Aug., 1891.	"	Lingula hurlburti N. H. Winchell	2
7675	"	"	Lingula deflecta W. and S	7
7676	"	"	Lingula deflecta Winchell and Schuchert?	1
7677	July, 1891.	"	Lingula iowensis Owen	11
7678	"	"	" "	5
7679	Aug., 1891.	"	" "	2
7680	"	"	" "	8
7681	"	"	Lingula canadensis Billings	1
7682	"	"	" "	1
7683	July, 1891.	"	Lingulasma galenensis W. and S	1
7684	"	"	" "	1
7685	"	"	" "	3
7686	Aug., 1891	"	" "	1
7687	July, 1891	"	Lingula trentonensis Conrad	3
7688	Aug., 1891	"	Schizotreta pelopea Billings	7
7689	July, 1891	"	" "	1
7690	"	"	" " "	1
7691	Oct., 1880	"	Trematis huronensis Billings	1
7692	July, 1891	"	Crania setigera Hall	4
7693	Aug., 1891	"	" " "	2
7694	July, 1891	"	" " "	3
7695	"	"	" " "	2
7696	"	"	" " "	1
7697	"	"	Crania trentonensis Hall	3
7698	"	"	Lysocrania ulrichi Hall	1
7699	"	"	" "	2
7700	Aug., 1891	"	" " "	2
7701	"	"	Lysocrania ulrichi ? Hall	1
7702	"	"	Rauffella filosa Ulrich	3
7703	"	"	" " "	17
7704	"	"	" " "	4
7705	"	"	Rauffella ?	1
7706	"	"	Probably the remains of some sponge	2
7707	"	"	Rauffella filosa Ulrich	1
7708	"	"	" " "	1
7709	"	" ...	Cylindrocœlia minnesotensis Ulrich	1
7711	July, 1891	"	Hindia parva Ulrich	19
7712	Sept., 1880	"	Astylospongia	2
7714	July, 1891	" ...	Receptaculites oweni Hall	6
7715	Aug., 1891	"	" " "	10
7716	"	"	" " "	1

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
Warsaw, Minn..	Galena	W. H. Scofield.
Mineola, Minn	"	"
" "	"	"
" "	"	"
" "	"	"
4 miles S. W. Cannon Falls, Minn	"	Scofield and Schuchert.
" " " "	"	"
" " " "	"	"
" " " "	"	"
Fountain, Minn	Trenton	"
" "	"	"
Preston, Minn	"	"
" "	"	"
" "	"	"
" "	"	"
Near Fountain, Minn	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
" "	"	"
Preston, Minn	"	"
Near Fountain, Minn	"	"
" "	Galena	"
" "	"	"
Chatfield, Minn	Trenton	W. H. Scofield.
" "	"	"
" "	"	"
" "	"	"
Granger, Minn	Cincinnati	Mr. R. H. Hasse of Granger.
Neenah, Wis	Galena	C. Schuchert.
Oshkosh, Wis	"	"
Mantorville, Minn	"	W. H. Scofield.
Near Fountain, Minn	"	C. Schuchert.
Spring Valley, Minn	Cincinnati	"
Dubuque, Iowa	Galena	"
Decorah, Iowa	"	"
Near Aspelund, Minn	"	Scofield and Schuchert,
Mantorville, Minn	"	"
" "	"	C. Schuchert.
Hader, Minn	"	W. H. Scofield.
Neenah, Wis	"	C. Schuchert.
Oshkosh, Wis	"	"
Decorah, Iowa	"	"
Bear creek, S. of Hamilton, Minn	"	"
Janesville, Wis	Trenton	C. Schuchert.
Mantorville, Minn	Galena	Scofield and Schuchert.
Dubuque. Iowa	"	C. Schuchert.
Neenah, Wis	"	"
Minneapolis, Minn	Trenton	C. L. Herrick.
St. Paul, Minn	"	C. Schuchert.
Near Preston, Minn	"	Scofield and Schuchert.
Decorah, Iowa	"	C. Schuchert.
Mineral Point, Wis	"	"
Beloit, Wis	"	C. Schuchert, C. & N. W. R. R. quarries.
Janesville, Wis	"	C. Schuchert.
St. Paul, Minn	"	"
6 miles south of Cannon Falls, Minn.	Galena	Scofield and Schuchert.
Near Fountain, Minn	Trenton	" " "
7 miles south of Cannon Falls, Minn.	Galena	" " "
Near Fountain, Minn	Trenton	" " "
Near Preston, Minn	"	Scofield and Schuchert.
Decorah, Iowa	"	C. Schuchert.
" "	"	"
2 miles S. E. of Cannon Falls, Minn.	Galena	Scofield and Schuchert.
6 miles south of Cannon Falls, Minn.	"	" " "
7 miles south of Cannon Falls, Minn.	"	" " "
6 miles south of Cannon Falls, Minn.	"	" " "
Oshkosh, Wis	"	C. Schuchert.
Spring Valley, Minn	Niagara	N. H. Winchell.
Dubuque, Iowa	Galena	C. Schuchert.
6 miles south of Cannon Falls, Minn.	"	W. H. Scofield and C. Schuchert.
Sec. 12, Holden, Goodhue Co., Minn.	"	" " "

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
7717	Aug. 1891	Geol, survey....	Receptaculites oweni Hall	2
7718	"	"	Receptaculites oweni ? Hall	2
7719	"	"	Receptaculites oweni Hall	2
7720	"	"	" " "	2
7721	"	"	" " "	7
7722	"	"	Receptaculites iowensis Owen	2
7723	"	"	Receptaculites fungosus Hall	1
7724	"	"	Receptaculites globularis Hall	3
7725	Sept., 1880.	"	Protarea vetusta Edwards & Haime	1
7726	Aug., 1891.	"	Columnaria alveolata Hall	1
7732	"	"	Cretaceous limonite	1
7733	"	Presented.....	Black oxide of manganese	Indef.
7734	July, 1891..	Geol. survey....	Columnaria alveolata Hall	3
7735	Sept., 1891.	"	Limestone concretion from slate (aininike).	1
7736	"	"	Chert	1
7737	July, 1891..	"	Streptelasma profundum Hall	13
7738	"	"	" "	20
7739	"	"	" "	2
7740	"	"	" "	156
7741	Aug., 1891.	"	" "	3
7742	"	"	" "	11
7743	"	"	" "	1
7744	July, 1891..	"	Streptelasma corniculum Hall?	12
7745	"	"	" "	6
7746	Aug., 1891..	"	" "	4
7747	"	"	" "	13
7748	"	"	" "	5
7749	"	"	" "	7
7750	"	"	" "	8
7751	"	"	" "	13
7752	"	"	Streptelasma	2
7753	"	"	Streptelasma rusticum Billings	12
7754	July, 1891..	"	" "	7
7755	Aug., 1891.	"	Diplograptus pristis (Hisinger) Hall	4
7756	July, 1891..	"	Diplograptus pristis? (Hisinger) Hall	2
7757	"	"	Diplograptus putillus Hall	1
7758	"	"	Diplograptus pristis (Hisinger) Hall	9
7759	Aug., 1881..	"	Climacograptus typicalis Hall	5
7760	"	"	Diplograptus putillus Hall	2
7761	"	"	Dictyonema	1
7762	July, 1891	"	Orthis (Plectorthis) whitfieldi Winchell	10
7763	Aug., 1891	"	" " " "	10
7764	"	"	" " " "	6
7765	"	"	Orthis (Plectorthis) plicatella Hall	2
7766	"	"	" " " "	2
7767	July, 1891	"	Orthis (Dinorthis) pectinella Emmons	1
7768	Aug., 1891	"	Orthis (Dinorthis) pectinella var. sweeneyi Winchell.	3
7769	July, 1891	"	" " " "	6
7770	Aug., 1891	"	Orthis (Dinorthis) meedsi var. germana W. and S.	3
7771	"	"	Orthis (Dinorthis) meedsi W. and S	2
7772	"	"	" " " "	9
7773	"	"	" " " "	10
7774	"	"	" " " "	10
7775	"	"	" " " "	7
7776	"	"	" " " "	4
7777	"	"	" " " "	4
7778	"	"	" " " "	6
7779	"	"	" " " "	6
7780	"	"	" " " "	18
7781	"	"	" " " "	5
7782	"	"	" " " "	5
7783	July, 1891	"	" " " "	4
7784	"	"	" " " "	7
7785	"	"	Orthis (D.) pectinella var. sweeneyi Winchell	8
7786	Aug., 1891	"	Orthis (D.) subquadrata Hall	Many
7787	Sept., 1881	Presented	" " "	3
7788	Aug., 1891	Geol. survey....	" " "	4
7789	"	"	Orthis (D.) proavita W. and S	7
7790	July, 1891	"	Orthis (D.) deflecta Conrad	16
7791	"	"	" " "	9
7792	"	"	" " "	6
7793	"	"	Orthis (Dinothis) deflecta Conrad	3
7794	"	"	" " "	5
7795	Aug., 1891	"	Orthis tricenaria Conrad	2

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality,	Formation.	Collector and remarks.
Minneola, Minn.	Galena	W. H. Scofield and C. Schuchert.
Stewartsville, Minn.	"	" " "
3 miles south of Cannon Falls, Minn.	"	" " "
Near Fountain, Minn	"	" " "
Decorah, Iowa	"	C. Schuchert.
"	"	"
"	"	"
Dubuque, Iowa	"	"
Spring Valley, Minn.	Cincinnati	N. H. Winchell.
Preston, Minn.	Trenton	C. Schuchert.
Winona county, Minn.		
Monticello, Minn.		By J. N. Stacy.
Rockton, Ill.	Trenton	C. Schuchert.
Beaver Mine, Ont., Can.	Aininike	H. V. Winchell.
" "	"	"
Rockton, Ill.	Trenton	C. Schuchert.
Beloit, Wis.	"	" (Samp's quarry.)
Janesville, Wis.	"	"
Mineral Point, Wis.	"	"
Fountain Minn.	"	Scofield and Schuchert.
Preston, Minn.	"	"
Cannon Falls, Minn.	"	"
Oshkosh, Wis.	Galena	C. Schuchart.
Decorah, Iowa.	Trenton	"
Nine miles S. ofCannon Falls, Minn.	Galena	Scofield and Schuchert.
Two m. S. E. of Cannon Falls, Minn.	"	"
Kenyon, Minn.	"	"
Twelve m. S. of Cannon Falls, Minn.	"	"
Three m. S. of Cannon Falls, Minn.	"	"
Seven m. S. of Cannon Falls, Minn.	"	"
Florence, Iowa	Cincinnati	"
"	"	"
Graf, Iowa	"	C. Schuchert.
Granger, Minn.	"	Scofield and Schuchert.
Graf, Iowa	"	C Schuchert.
"	"	
"	"	
Mantorville, Minn.	Galena	Scofield and Schuchert.
Granger, Minn.	Cincinnati	"
"	"	"
Graf, Iowa	"	C. Schuchert.
Spring Valley, Minn.	"	Scofield and Schuchert.
Near Granger ,Minn.	"	"
9 m. S. of Cannon Falls, Minn.	Galena,	"
12 m. S. of Cannon Falls, Minn.	"	"
Decorah, Iowa.	Trenton	C. Schuchert.
2 m. S. of Cannon Falls, Minn.	"	Scofield and Schuchert.
McGregor, Iowa	"	C. Schuchert.
9 m. S. of Cannon Falls, Minn.	Galena	Scofield and Schuchert.
McGregor, Iowa.	Trenton	C. Schuchert.
6 m. S. of Cannon Falls, Minn.	Galena	Scofield and Schuchert.
12 m. S. of Cannon Fall, Minn.	"	"
2 m. S. E. of Cannon Falls, Minn.	"	"
3 m. S. W. of Cannon Falls, Minn.	"	"
7 m. S. of Cannon Falls, Minn	"	"
Mineola, Minn.	"	"
Warsaw, Minn.	"	"
Kenyon, Minn.	"	"
Fountain, Minn.	"	"
Preston, Minn.	Trenton	"
Decorah, Iowa.	Galena	C. Schuchert.
Neenah, Wis.	"	"
Oshkosh, Wis.	"	"
Decorah, Iowa.	Trenton	"
Spring Valley, Minn.	Cincinnati	Scofield and Schuchert.
" "	"	John Klechler (part of No. 4094)
Graf, Iowa.	"	C. Schuchert.
Spring Valley, Minn	"	Scofield and Schuchert.
Janesville, Wis.	Trenton	C. Schuchert.
Beloit, Wis.	"	"
Mineral Point, Wis.	"	"
McGregor, Iowa.	"	"
Minneapolis, Minn.	"	H. V. Winchell.
2 m. S. of Cannon Falls, Minn.	"	Scofield and Schuchert.

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
7796	Aug., 1891	Geol. Survey	Orthis tricenaria Conrad	1
7797	"	"	" "	5
7798	July, 1891	"	" "	35
7799	"	"	" "	5
7800	"	"	" "	3
7801	"	"	" "	14
7802	"	"	" "	10
7803	"	"	" "	2
7804	Aug., 1891	"	" "	7
7805	"	"	" "	5
7806	July, 1891	"	Orthis bellarugosa Conrad	4
7807	"	"	" "	3
7808	"	"	" "	2
7809	"	"	" "	2
7810	"	"	" "	2
7811	Aug., 1891	"	" "	3
7812	"	"	" "	3
7813	July, 1891	"	Orthis insculpta, subquadrata, etc	1
7814	"	"	Orthis insculpta	3
7815	"	"	" "	2
7816	May, 1885	Donation	Platystrophia biforata Schlotheim	1
7817	Aug., 1891	Geol. Survey	" "	8
7818	"	"	" "	8
7819	"	"	" "	9
7820	"	"	" "	5
7821	"	"	" "	3
7822	"	"	" "	21
7823	"	"	" "	20
7824	July, 1891	"	" "	25
7825	"	"	" "	6
7826	"	"	Platystrophia biforata Schlotheim	5
7827	"	"	" "	5
7828	Aug., 1891	"	" "	2
7829	Nov., 1891	Exchange	Monticulipora mammillata	6
7834	"	"	Orthis lynx	26
7839	"	"	Orthoceras	3
7842	"	"	Murchisonia major	2
7846	"	"	Receptaculites oweni	1
7847	"	"	Halysites catenulatus	1
7848	"	"	" "	1
7849	"	"	Favosites favosus	1
7850	"	"	Zaphrentis	1
7852	"	"	Aulopora cornuta	1
7853	"	"	Strombodes pentagoneus	1
7854	"	"	Favosites forbesi	1
7855	"	"	Stromoptera concentrica	1
7856	"	"	Favosites dumosus	2
7857	"	"	Lithographic limestone	1
7858	"	"	" "	3
7859	"	"	Syringopora harveyi	1
7860	"	"	Spirifera marionensis	3
7361	"	"	Styldlites	2
7862	"	"	Zapdrentis	3
7863	"	"	Zaphrentis elliptica	3
7865	"	"	Productus flemingi	2
7866	"	"	Productus punctatus?	1
7667	"	"	Rhynchonella ringens	2
7568	"	"	Athyris incrassata	2
7869	"	"	Spirifera grimesi	3
7870	"	"	Terebratula rowleyi	1
7871	"	"	Euomphalus latus	2
7890	"	"	Amethystine quartz	1
7891	"	"	Calcareous tufa	1
7892	July, 1891	Geol. Survey	Orthis (Dalmanella) testudinaria	2
7893	"	"	" " "	5
7894	"	"	" " "	6
7795	Aug., 1891	"	" " "	16
7896	"	"	Orthis (Dalmanella) hamburgensis ? Walcott	5
7897	"	"	Orthis (Dalmanella) testudinaria	3
7898	"	"	" " "	15
7899	"	"	" " "	32
7900	"	"	" " "	12
7901	"	"	" " "	17
7902	April, 1879	"	" " "	30

ADDITIONS.—*Continued.*

GENERAL MUSEUM, 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
Near Fountain, Minn.	Trenton	Scofield and Schuchert.
Preston, Minn.	"	" "
Janesville, Wis.	"	C. Schuchert.
Beloit, Wis.	"	"
Mineral Point, Wis.	"	"
" "	"	"
Decorah, Iowa.	"	"
McGregor, Iowa.	"	"
12 m. S. of Cannon Falls, Minn.	Galena	Scofield and Schuchert.
6 m. S. of " "	"	" "
Rockton, Ill.	Trenton	C. Schuchert.
Neenah, Wis.	Galena.	"
Janesville, Wis	Trenton	"
McGregor, Iowa.	"	"
Decorah, Iowa.	"	"
Near Fountain, Minn.	Galena	Scofield and Schuchert.
Mineola, Minn	"	"
Iron Ridge, Wis.	Cincinnati	C. Schuchert.
" "	"	"
Graf, Iowa.	"	"
Cannon Falls, Minn.	Galena	Dr. Sandberg.
6 m. S. of Cannon Falls, Minn.	"	Scofield and Schuchert.
12 m. S. of " "	"	" "
3 m. S. of " "	"	" "
2 m. S. E. of " "	"	" "
Kenyon, Minn.	"	W. H. Scofield.
Near Fountain, Minn.	"	Scofield and Schuchert.
Decorah, Iowa.	"	C. Schuchert.
Oshkosh, Wis.	"	"
Neenah Wis.	"	"
Iron Ridge, Wis.	Cincinnati	"
Graf, Iowa	"	"
Preston, Minn.	Trenton	Scofield and Schuchert.
Louisville, Kentucky.	Hudson River	From Rev. Wm. H. Barris.
Shelby county, Kentucky	Silurian	"
" "	"	"
Pike county, Mo.	Trenton	"
Ralls county, Mo.	"	"
Jones county, Iowa.		"
" "	Silurian	"
" "	Niagara	"
" "	"	"
" "	Hamilton	"
" "	Niagara	"
" "	"	"
" "	"	"
Fort Erie, Canada.	Hamilton	"
Pike county, Mo.	Choteau	"
"	"	"
"	"	"
Marion county, Mo.	Burlington	"
"	"	"
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"	"	"
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"	"	"
"	"	"
"	"	"
Anderson county, S. C.		"
Marion county, Mo.		"
Rockton, Ill.	Trenton	C. Schuchert.
Mineral Point, Wis.	"	"
McGregor, Iowa	"	"
Decorah, Iowa.	"	Scofield and Schuchert.
Preston, Minn.	"	" "
Fountain, Minn.	Galena	" "
" "	"	" "
2 miles S. E Cannon Falls.	"	" "
4 miles south of Cannon Falls, Minn.	"	W. H. Scofield.
Mineola, Minn.	"	N. H. Winchell.
Kenyon, Minn.		

MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
7903	July, 1891	Geol. Survey	Orthis (Dalmanella) testudinaria	55
7904	"	"	" " "	3
7905	"	"	" " "	22
7906	Aug., 1891	"	" " "	14
7907	"	"	" " "	1 slab.
7908	"	"	" " "	4
7909	"	"	" " "	9
7940	"	Exchange	Jacupirangite, pyroxene facies	1
7941	"	"	Jacupirangite, nepheline facies	1
7942	"	"	Jacupirangite	1
7943	"	"	Jacupirangite, magnetite facies	1
7944	"	"	Magnetite bearing rock	1
7945	"	"	" " "	1
7946	"	"	" " "	1
7958	"	Geol. Survey	Crania setigera Hall	1
7959	July, 1891	"	Orthis (Dalmanella) subæquata Conrad	5
7960	"	"	" " " "	13
7961	"	"	" " " "	Indef.
7962	"	"	" " " "	7 slabs
7963	Aug., 1891	"	" " " "	18
7664	"	"	" " " "	16
7965	"	"	" " " "	9
7966	"	"	" " " "	4
7967	"	"	" " " "	12
7968	"	"	" " " "	10
7969	July, 1891	"	Orthis (D.) subæquata var. gibbosa Billings	1
7970	Aug., 1891	"	" " " "	Indef.
7971	"	"	" " " "	1
7972	"	"	" " " "	3
7973	July, 1891	"	Orthis (D.) subæquata var. perveta Conrad	5
7974	"	"	" " " "	1
7975	"	"	" " " "	3
7976	"	"	" " " "	3
7977	"	"	" " " "	7
7978	1876–1879	"	Orthis (D.) subæquata var. conradi Winchell	1
7979	"	"	" " " "	5
7980	July, 1891	"	" " " "	4
7981	"	"	" " " "	3
7982	"	"	" " " "	1
7983	Aug., 1891	"	Lingula riciniformis var. galenensis W. and S	1
7984	July, 1891	"	Stictoporella angularis var intermedia Ulrich	2
7985	Aug, 1891	"	Orthis testudinaria var meeki	Indef.
7986	July, 1891	"	Streptelasma profundum Hall	27
7987	"	"	Fenestella granulosa Whitfield	Slab.
7988	"	"	Fistulipora (??) solidissima Whitfield	14
7989	"	"	Batostomella	6
7690	"	"	Constellaria insincera Ulrich (MS.)	3
7991	"	"	Batostomella simulatrix Ulrich	4
7992	"	"	Trematopora annulifera Wnitfield	1
7993	"	"	Batostomella	13
7996	"	"	Homotrypa	6
7997	"	"	? Fistulipora lens Whitfield	3
7998	"	"	Monotrypella quadrata var. rectangularis Whitfield	16
7999	"	"	Batostoma	10
8000	"	"	"	8
8001	"	"	Atactoporella	3
8002	"	"	Callopora	2
8003	"	"	Callopora rugosa Whitfield	12
8004	"	"	Homotrypella	6
8005	"	"	Atactoporella	8
8008	"	"	Constellaria polystomella Nich	1
8009	"	"	Ceramoporella granulosa Ulrich	11
8010	"	"	Ceramoporella minima Ulrich (MS)	5
8011	"	"	Crepipora simulans Ulrich	1
8012	"	"	Anolotichia ponderosa Ulrich	1
8013	"	"	Stromotopora arachnoidea Hall	2
8014	"	"	Batostoma	8
8015	"	"	Batostomella gracilis Nicholson	1
8016	"	"	Batostomella simulatrix Ulrich	4
8017	"	"	Monotrypella multituberculata Whitf	2
8018	"	"	Monotrypella rectangularis Whitf	5
8019	"	"	Callopora crenulata Ulrich	1
8020	"	"	Callopora multitabulata Ulrich	17
8021	"	"	Homotrypa similis Foord	4

ADDITIONS.—*Continued.*

GENERAL MUSEUM IN 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
Granger, Minn	Galena	Scofield and Schuchert.
Dubuque, Iowa	"	C. Schuchert.
Oshkosh, Wis	"	"
Neenah, Wis	"	"
Decorah, Iowa	"	"
Graf, Iowa	Cincinnati	"
Iron Ridge, Wis	"	"
Jacupiranga, Brazil		O. A. Derby.
" "		"
" "		"
" "		" [ondary silica.
Ipanema, Brazil		" alteration to mica and then to sec-
" "		" alteration to secondary silica. [etc
" "		" alteration, with barite, tridymite,
		" alteration, with secondary silica.
Chatfield, Minn	Trenton	W. H. Scofield.
Mineral Point, Wis	"	C. Schuchert.
McGregor, Iowa	"	"
Decorah, Iowa	"	"
" "	"	"
Preston, Minn	"	Scofield and Schuchert.
Fountain, Minn	"	" "
Chatfield, Minn	"	W. H. Scofield.
2 m. S. E. of Cannon Falls, Minn	"	Scofield and Schuchert.
Minneapolis, Minn	"	C. L. Herrick.
St. Paul, Minn	"	C. Schuchert.
Mineral Point, Wis	"	"
Chatfield, Minn	"	Scofield and Schuchert.
Decorah, Iowa	"	C. Schuchert.
Minneapolis, Minn	"	C. L. Herrick.
Janesville, Wis	"	C. Schuchert.
Beloit, Wis	"	"
Mineral Point, Wis	"	"
Decorah, Iowa	"	"
Near Fountain, Minn	"	N. H. Winchell.
Minneapolis, Minn	"	C. L. Herrick (From No. 5088.)
" "	"	"
Janesville, Wis	"	C. Schuchert.
Beloit, Wis	"	"
Decorah, Iowa	"	"
Fountain, Minn	Galena	Scofield and Schuchert.
Preston, Minn	Trenton	" "
Spring Valley, Minn	Hudson River	" "
Decorah, Iowa	Trenton	C. Schuchert.
Iron Ridge, Wis	Hudson River	"
Near Iron Ridge, Wis	"	"
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Graf, Iowa	"	"
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6 m. S. Cannon Falls, Minn	Galena	Scofield and Schuchert.
" " "	"	" "
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MUSEUM

SPECIMENS REGISTERED IN THE

Serial No.	Obtained. When.	Obtained. Whence.	Name.	Number of specimens
8022	July, 1891	Geol. Survey	Dekayia trentonensis Ulrich	1
8023	"	"	Petigopora asperula Ulrich	1
8024	"	"	Prasopora contigua Ulrich	11
8025	"	"	Monotrypa cumulata Ulrich	1
8026	Aug., 1891	"	Basal portion of Batostoma species	1
8027	"	"	Pachydictya acuta Hall	1
8028	"	"	Phylloporina reticulata Hall	1
8029	"	"	Dekayia trentonensis Ulrich	2
8030	"	"	Homotrypa subramosa	10
8031	"	"	Ceramoporella	2
8032	"	"	Hemiphragma peculiare Ulrich	1
8033	"	"	Hemiphragma irrasum Ulrich	2
8034	"	"	Batostomella trentonensis Nicholson	13
8035	"	"	Monticulipora ramifera Ulrich	4
8037	"	"	Prasopora conoidea Ulrich	2
8038	"	"	Callopora crenulata Ulrich	1
8039	"	"	Calopora multitabulata Ulrich	27
8040	"	"	Batostomella trentonensis Nicholson	6
8041	"	"	Hemiphragma irrasum Ulrich	5
8042	"	"	Hemiphragma peculiare Ulrich	2
8043	"	"	Homotrypa similis Foord	1
8044	"	"	Constellaria incipiens Ulrich	1
8045	"	"	Stomatopora inflata Hall	1
8046	"	"	Prasopora insularis Ulrich	6
8047	"	"	Probiscina tumulosa Ulrich	1
8048	"	"	Monticulipora ramifera Ulrich	3
8049	"	"	Callopora multitabulata Ulrich	25
8050	"	"	Batostomella trentonensis Nicholson	12
8051	"	"	Hemiphragma irrasum Ulrich	4
8052	"	"	Hemiphragma peculiare Ulrich	5
8053	"	"	Ceramoporella	1
8055	"	"	Solenopora compacta Billings	1
8056	"	"	Batostoma	3
8057	"	"	Prasopora insularis Ulrich	2
8058	"	"	Homotrypa similis Foord	9
8059	July, 1891	"	Diploporella obliquata Ulrich (MS.)	1
8060	"	"	Leptotrypa acervulosa Ulrich	14
8061	"	"	Homotrypa subramosa Ulrich	4
8062	"	"	Monticulipora ramifera Ulrich	4
8063	"	"	Batastoma humile Ulrich	4
8064	"	"	Hemiphragma irrasum Ulrich	3
8065	"	"	Petigopora	1
8066	"	"	Stomatopora proutana Miller	1
8067	"	"	Callopora multitabulata Ulrich	11
8068	"	"	Callopora crenulata? Ulrich	2
8069	"	"	Nematopora ovalis Ulrich	1
8070	"	"	Homotrypa minnesotensis Ulrich	14
8071	"	"	Homotrypa	1
8072	"	"	Batostoma fertile? Ulrich	2
8073	"	"	Dekayella	1
8074	"	"	Nicholsonella	1
8075	"	"	Arthropora simplex Ulrich	1
8076	"	"	Rhinidictya nicholsoni Ulrich	1
8077	"	"	Batostoma	15
8078	"	"	Hemiphragma irrasum Ulrich	3
8079	"	"	Batostomella trentonensis Ulrich	6
8080	"	"	Homotrypella	5
8081	"	"	Batostomella nana Ulrich	1
8082	"	"	? Callopora crenulata Ulrich	3
8083	"	"	Callopora multitabulata Ulrich	6
8084	"	"	Batostomella	6
8086	"	"	Monticulipora	10
8087	Aug., 1891	"	Batostoma?	6
8088	"	"	Callopora angularis Ulrich	3
8089	"	"	Atactopora typicalis var. praecursor Ulrich	1
8090	"	"	Homotrypa minnesotensis Ulrich	2
8091	"	"	Homotrypa exilis Ulrich	1
8092	"	"	Batostoma winchelli Ulrich	5
8093	"	"	Batostoma minnesotensis?	1
8094	"	"	Atactoporella typicalis var. praecursor Ulrich	1
8095	"	"	Batostoma winchelli var. Ulrich	2
8096	"	"	Callopora multitabulata Ulrich	7
9097	"	"	Callopora angularis Ulrich	1
8098	"	"	Dekayella	6
8099	"	"	Homotrypa subramosa Ulrich	2
8100	"	"	Bythopora herricki Ulrich	2

ADDITIONS—*Continued.*

GENERAL MUSEUM, 1889, 1890 AND 1891.

Locality.	Formation.	Collector and remarks.
6 m. S. of Cannon Falls, Minn.	Galena	Scofield and Schuchert.
" " " "	"	" "
" " " "	"	" "
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" " " "	"	" "
Preston, Minn.	Trenton	" "
6 m. S. of Cannon Falls, Minn.	"	" "
" " " "	Galena	" "
7 m. S. of Cannon Falls, Minn.	"	" "
" " " "	"	" "
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2 m. S. of Cannon Falls, Minn.	"	" "
" " " "	"	" "
" " " "	Trenton	" "
" " " "	Galena	" "
" " " "	"	" "
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" " " "	"	" "
" " " "	"	" "
Kenyon, Minn.	"	W. H. Scofield.
Holden, Minn.	"	"
" "	"	"
Decorah, Iowa	"	C. Schuchort.
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" "	Galena	"
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Neenah, Wis.	"	"
" "	"	"
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" "	"	"
Chatfield, Minn.	Trenton	W. H. Scofield.
" "	"	"
" "	"	"
Near Fountain, Minn.	"	Scofield and Schuchert.
" " "	"	" "
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VI.

ADDITIONS TO THE LIBRARY SINCE THE REPORT OF 1889.

A

Albany. New York State Museum of Natural History. Annual reports, 36 and 38.

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VII.

CATALOGUE OF THE METEORITES IN THE UNIVERSITY COLLECTION, WITH REFERENCES TO LITERATURE DESCRIBING THEM.

A number is given to each fall represented in the collection. Where there are several specimens from the same fall small italicized letters are used. A complete bibliography of the following meteorites has not been attempted, but under each fall we have tried to give the reference to the first description, and to other articles containing exhaustive descriptions, or new facts not mentioned in the first description. The catalogue is arranged chronologically as to the dates of fall or discovery.

No. 1. **Medvedewa, Krasnojarsk, Siberia.** [**The Pallas Iron.**] Found in 1749. Museum number, 4119.

G. Rose; Pogg. Ann., 1825, iv, p. 186.

N. von Kokscharow; Bull. l'Acad. Imp. Soc. St.-Pétersbourg, 1870, xx, No. 3.—Mémoires l'Acad. Imp. Soc. St.-Pétersbourg, xv, No. 6.—Jahrb. Mineralogie, 1870, p. 778.

A. Langier; Mem. Mus. Hist. Nat., 1817, iii, pp. 341-352.

E. H. von Baumhauer; Archives Néerlandaises, 1871, vi.

G. von Helmersen; Zeitsch. Deutsch. Geol. Gesell., xxv, p. 347. A Goebel; Bull. Ac. Imp. Sc., St.-Pétersbourg, 1874, xx, p. 100.

Iron. Irregular ragged specimen of a coarse metallic sponge, enclosing olivine in more or less rounded cavities. Most of the olivine has fallen out. Weight, 144 grams.

[*By exchange with Yale College.*]

No. 2. **Istlahuaca, Toluca, Mexico.** Found in 1784. Museum number, 4694.

Gazeta de Mexico, 1784-'85, vol. i, pp. 146, 200.

W. J. Taylor, Proceed. Acad. Nat. Sci. Phila., 1856, vol. viii, pp. 128-130.—Am. Jour. Sci., 1856, [2], xxii, pp. 374-376.

Iron. Irregular rusted piece. Two sides polished, one of them showing well marked Widmannstättian figures. Weight, 105.6 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 3. **Zacatecas, Mexico.** Found in 1792. Museum number, 4696.

C. Bergmann; Neues Jahrb. Min., 1856, p. 297.

H. Mueller; Quart. Jour. Chem. Soc., 1859, xi, pp. 236–240.

a. Iron. Irregular fragment. One side polished, the others rusted. Weight, 1.45 grams.

b. Smaller rusted fragments similar to *a.* Weight, 2.18 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 4. **Albacher Muehle, Bitburg, Rhenish Prussia.** Found in 1802. Museum number, 4416.

J. F. John; Jour. Chemie u. Physik, 1826, xlvi, p. 386.

Iron. Small fragment, much rusted and similar in appearance to the Ovifak iron. Weight, 4.55 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 5. **Durango, Mexico.** Found in 1804(?). Museum number, 4419.

Iron. Fragment which has been hammered and one end broken off. Weight, 10 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 6. **Weston, Fairfield Co., Connecticut.** Fell at 6:30 a. m., Dec. 14, 1807. Museum number, 4122.

Profs. Silliman and Kingsley; Am. Jour. Sci., 1869 [2], xlvii, pp. 1–8.

(This account is reproduced from the Memoirs of the Connecticut Academy of Arts and Sciences)

Stone. Gray ground-mass holding chondri and grains of iron scattered through it. Fragment with a small portion of the crust attached. Weight, 5 grams.

[*By exchange with Yale College.*]

No. 7. **Stannern, Iglau, Moravia.** Fell at 6 a. m., May 22, 1808. Museum number, 4408.

J. Moser; Ann. Physik, 1808, xxix, pp. 309–327.

C. Rammelsberg; Ann. Physik, 1851, lxxxiii, pp. 591–597.

G. Tschermak; Min. Mittheil., 1872, heft ii, p. 83.

a. Stone. Light gray fragment. One face has a black vitreous crust. Weight, 0.95 grams.

b. Smaller fragment of the same. One side shows crust. Weight, 0.4 gram.

c. Smaller fragments. Weight, 0.13 gram.

[*By exchange with Prof. C. U. Shepard.*]

No. 8. **Babb's Mill, Green Co., Tennessee.** Found in 1818. Museum number, 3351.

G. Troost; Am. Jour. Sci., 1845, [1], xlix, pp. 342–344.
C. U. Shepard; Am. Jour. Sci., 1847, [2], iv, pp. 76–77.
W. S. Clark; Metallic meteorites, 1852, pp. 65–66.

Iron. Thin slab; one side has been polished and etched but shows no distinct figures. Two of the edges show crust. Weight, 21 grams. "Its color is rather whiter than that of pure iron; and it is very malleable, equal, if not superior, in this respect to the softest wrought iron." (Am. Jour. Sci., [1], xlix, p. 343.)

[*By exchange with Prof. J. L. Smith.*]

No. 9. **Juvenas, Ardeche, France.** Fell at 3:30 p. m., June 15, 1821. Museum number, 3339.

L. N. Vauquelin; Ann. Chemie u. Physik, 1821, xviii, pp. 421–423.
A. Langier; Ann. Chemie u. Physik, 1821, xix, pp. 264–273.
C. Rammelsberg; Ann. Physik. Chemie, 1838, lxxviii, pp. 585–500.

a. Stone. Fine grained, gray, crumbling, showing almost no iron. Weight, 0.98 grams.

b. Two smaller fragments of the same, showing part of a black vitreous crust. Weight, 0.42 grams.

c. Four smaller fragments. No crust. Weight, 0.42 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 10. **Coahuila, Mexico.** Museum numbers, 3349 and 3361. Found in 1827 (?). Museum numbers, 3349 (*b*), 3361 (*a*).

J. L. Smith; Amer. Jour. Sci., 1855, [2], xix, pp. 160–161; 1869, [2], xlvii, pp. 383–385; 1876, [3], xii, pp. 109–110; 1878, [3], xvi, pp. 270–272.

a. Iron. Rectangular block, with five faces polished, the sixth face showing a dull brown rusted surface. Weight, 3060 grams.

b. Daubréelite from the above meteorite. Weight, 0.0562 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 11. **Drake Creek, near Nashville, Tennessee.** Fell at 4 p. m., May 9, 1827. Museum number, 3353.

H. Seybert; Am. Jour. Sci., 1830, [1], xvii, pp. 326–328.
E. H. Baumhauer; Ann. Physik. Chemie, 1845, lxvi, pp. 498–503.

a. Stone. Gray, fine-grained groundmass, with many small grains of iron. One face has a dull brown crust. Weight, 13.5 grams.

b. A smaller fragment of the same. Weight, 2 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 12. **Vouille, Poitiers, Vienne, France.** Fell July 18, 1831. Museum number, 4697.

Stone. Gray, sprinkled with bright iron grains. No crust. Weight, 0.4 gram.

[*By exchange with Prof. C. U. Shepard.*]

No. 13. **Coahuila, Mexico.** [**Butcher Irons.**] Found in 1837. Museum number, 3358.

J. L. Smith; Am. Jour. Sci., 1855, [2], xix, pp. 160–161; 1867, [2], xliii, pp. 384–385; 1869, [2], xlvii, pp. 383–385.

Iron. Cut slab, not polished; one side shows a grain of daubréelite surrounded by troilite. Weight, 67.35 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 14. **Cold Bokkeveld, Cape of Good Hope, Africa.** Fell at 9 a. m., Oct. 13, 1838, Museum number, 3341.

M. Faraday; Philosoph. Trans., 1839, pp. 83–87.

E. P. Harris; Sitz. Wien Akad., 1859, xxxv, pp. 5–12.

Stone. Black, with white specks, but apparently no iron. Weight, 1.45 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 15. **Pine Bluff, Little Piney, Missouri.** Fell at 3:30 p. m., Feb. 13, 1839. Museum number, 4,410.

C. U. Shepard; Am. Jour. Sci., 1840, [1], xxxix, pp 254–255.

Stone. Light gray, with darker grains and small specks of iron scattered through it. Fragment, without crust. Weight, 1.4 grams.

[*By exchange with Prof. C. U. Shepard*]

No. 16. **Putnam County, Georgia.** Found in 1839. Museum number, 4693.

J. E. Willet; Am. Jour. Sci., 1854,[2],xvii, pp. 331-332.

Iron. Small irregular fragment, much rusted. Weight, 34 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 17. **Coney Fork, Carthage, Smith County, Tennessee.** Found in 1840. Museum number, 3348.

E. Boricky; Neues Jahrb. Min., 1866, pp. 808-810.

Iron. Specimen with three cut faces at right angles, to each other. These faces are polished and two of them show Widmannstättian figures. Weight, 193.5 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 18. **Magura, Szlanicza, Arva, Hungary.** Found in 1840. Museum number, 4123.

A. Loewe; Neues Jahrb. Min., 1849, p. 199.

C. Bergmann; Ann. Physik. Chemie, 1857, pp. 256-260.

A. W. Wright; Am. Jour. Sci., 1875, [3], ix, pp. 294-302.

Iron. Irregular specimen with one face polished, another showing the crust. Largely made up of bright nickeliferous iron. Weight, 23 grams.

[*By exchange with Yale College.*]

No. 19. **Pusinsko Selo, Milena, Croatia.** Fell at 3 p. m., April 26, 1842. Museum number, 4411.

Stone. Light gray fragment with no crust. Shows grains of iron. Weight, 2.51 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 20. **Bishopville, South Carolina.** Fell March 25, 1843. Museum number, 4699.

C. U. Shepard; Am. Jour. Sci., 1846, [2], ii, pp. 379-381; 1848, [2], vi, pp. 411-414.

W. S. von Walterhausen; Ann. Chem. Pharm., 1851, lxxix, pp. 369–374.

J. L. Smith; Am. Jour. Sci., 1855, [2], xix, pp. 162–163; 1864, [2], xxxviii, pp. 225–226.

G. Rose; Abh. Berlin. Akad., 1863, pp. 117–122.

C. Rammelsberg; Abh. Berlin. Akad., 1870, pp. 121–123.

M. E. Wadsworth; Am. Jour. Sci., 1883, [3], xxvi, pp. 32–36, 248.—Mem. Mus. Comp. Zool., 1884, xi, pt. 1, pp. 199–201.

G. Tschermak; Die Mikros. Besch. der Meteoriten, 1883, i, pp. 9, 10.—Sitz. Wien. Akad., 1883, lxxxviii, [1], pp. 363–365.

Stone. White and gray. A number of small fragments and some powder; also a few fragments of the crust.

In 1846, Shepard described three new minerals from this meteorite, —chladnite, idiolite and apatoid. The last two are usually considered as easily decomposable compounds of sulphur with other elements of the stone. The silicate, chladnite, has aroused much discussion, and several mineralogists have investigated the meteorite because of this mineral. The general opinion seems to be

that chladnite is similar to enstatite. But Wadsworth says; "Chladnite ought no longer to be regarded as enstatite of the purest kind, as stated in most mineralogies, but rather as a mineral aggregate of which enstatite, feldspar and augite are the principal constituents.

Weight 2.49 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 21. **Sevier County, Tennessee.** Found in 1845. Museum number, 3346.

Iron. Irregular rusted fragment of nickeliferous iron. This meteorite is supposed to be identical with the one which was described in 1840 from Crosby's Creek, Cocke Co., Tennessee. Other specimens contain nodules of graphite. Weight 46.5 grams.

[*By exchange with J. L. Smith.*]

No. 22. **Hartford, Linn Co., Iowa.** Fell at 2:45 p. m., Feb. 25, 1847. Museum number, 3761.

C. U. Shepard; Am. Jour. Sci., 1847, [2], iv, pp. 288–289; 1848, [2], vi, pp. 403–405.

C. Rammelsberg; Monatsber. Ak. Wiss. Berlin, 1870, lxx, pp. 457–459.

Stone. With light gray groundmass showing chondritic structure, and with numerous grains of iron, some of them quite large. One face polished. Two of the edges show a dull black earthy crust.

Shepard remarks; "The most remarkable feature of the Iowa stone, however, consists in the homogeneousness of its earthy composition. It appears to contain but a single mineral species of this description, and this one which, though perhaps the most common in other meteoric stones, has until now escaped a separate recognition. I have therefore ventured to bestow upon it a distinct name, that of *howardite.*" Rammelsberg later found that howardite was mainly a mixture of olivine and bronzite.

Weight 21 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 23. **Murfreesboro, Rutherford Co., Tennessee.** Found in 1847. Museum number, 3355.

G. Troost; Am. Jour. Sci., 1848, [2]. v. pp. 351–352.

Iron. Slab with one face polished and etched. Shows typical Widmannstättian figures. Weight 66.5 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 24. **Monroe, Cabarras Co., North Carolina.** Fell at 3 p. m., Oct. 31, 1849. Museum number, 4698.

J. H. Gibbon; Am. Jour. Sci., 1850, [2], ix, pp. 143–146.
C. U. Shepard; Proc. Am. Assoc. Adv. Sci., 1850, iii, pp. 149–152.

Stone. Small fragment without any crust. Dark gray with light grains, and thickly sprinkled with iron. Weight 3.1 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 25. **Union County, Georgia.** Found in 1853. Museum number, 4414.

Iron. Small fragments, much rusted. Weight, 0.63 gram.

[*By exchange with Prof. C. U. Shepard.*]

No. 26. **Sarepta, Saratov, Russia.** Found in 1854. Museum number, 4413.

J. Auerbach; Sitz. Wien Akad., 1864, xlix, [2], p. 497.

Iron. Cuttings. Weight, 2.5 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 27. **Cranbourne, near Melbourne, Victoria, S. Australia.** Found in 1854. Museum number, 3341.

W. Haidinger; Sitz. Akad. Wiss., xliv, April 18, June 6, and Oct. 17, 1861; xlv, Jan. 9, 1862.
Walter Flight; Phil. Trans., 1882.—Chapter in the history of meteorites, 1887, pp. 174-181.

a. Iron. Rough fragment, almost silver-gray in color. Weight, 3.9 grams.

b. Another similar fragment. Weight, 3.5 grams.

c. Fifteen smaller pieces. Weight, 4.08 grams.

"This meteorite contains many nodules of troilite lying here and there amongst the plates and crystals of nickel-iron, always in rounded masses, only very occasionally an ill-defined cleavage plane being met with. They vary in size from half an inch to more than two inches in length, are usually covered with a thin layer of graphite, sometimes with some daubrëelite surrounding them; and one nodule, consisting of graphite, was found to inclose troilite, which had aggregated inside the graphite in a curious way, so that the section of the nodule suggested the outline of a holly-leaf. * * * * Graphite occurs occasionally, but rarely, as nodules; sometimes as nodules inclosing troilite, like the one already referred to; sometimes in large sheet-like masses, in one case about four inches in length and two inches wide. (*Walter Flight.*)

[*By exchange with Prof. J. L. Smith.*]

No. 28. **Pernallee, Madura District, Madras, India.** Fell at noon, Feb. 28, 1857. Museum number, 4124.

E. Pfeiffer; Sitz. Wien Akad., 1863, xlvii, [2], pp. 460-463.
S. Meunier; Compt. rend., 1871, lxxiii, p. 346.

Stone. Dark gray, with large white, dark-gray and brown grains. Dull black crust and polished face, showing specks of iron distributed through the mass.

"Its structure has been described as pisolitic: Meunier, on the contrary, likens it to a coarsely granular grit. The grains composing it are often angular, sometimes more or less rounded, and in each instance have the characters of fragments which have been detached from larger masses: the rock, in short, is a breccia. During a careful examination of its four specimens preserved in the Paris collection, Meunier noted the presence of twelve distinct species of grains. * * * * * The presence, says the author, in the 'polygenic conglomerate' of Parnallee of fragments belonging to seven types at least of distinct meteoric rocks, demonstrates the co-existence of these types in the star-mass whence this Indian meteorite came." (Walter Flight.) Weight, 8 grams.

[*By exchange with Yale College.*]

No. 29. **Trenton, Washington County, Wisconsin.** Found in 1858. Museum number, 3360.

J. L. Smith; Am. Jour. Sci., 1869, [2], xlvii, pp. 271-272.

Fr. Brenndecke; Ann. Rep. Smithsonian Inst. for 1869, 1871, pp. 417-419.

J. A. Lapham; Am. Jour. Sci., 1872, [3], iii, p. 69.

Iron. Slab with one of the edges showing crust. One face has been polished and etched and now shows very well marked Widmannstättian figures; it also shows what Prof. Smith called "Laphamite markings." These he figured, and described as follows:

"A polished surface when etched gives well marked Widmannstättian figures. There is something, however, peculiar about the markings on this iron, which is doubtless common to other irons, but which has heretofore escaped my observation, and I cannot discover, in a hasty investigation, that it has been noticed by others. My attention was called to this peculiarity by Mr. Lapham, on a slice of the meteorite sent him etched; should these markings be entitled to a separate notice, I propose calling them *Laphamite markings.* The little drawing accompanying this, which is on a somewhat exaggerated scale, will show what they are. The Widmannstättian figures are *a*, bright metallic, with convex ends and sides; *b c*, of a darker color, are the other markings, usually smaller and with the sides and ends concave. The material of which these dark figures are composed, seems to have enveloped the lighter colored portion, which serves to make the dark lines so beautifully conspicuous. A good pocket glass will show that the darker figures are striated, with lines at nearly right angles to the bounding surfaces. When the figure is nearly square, the lines extend from each of the four sides, but when much enlongated, as at *c*,

they are parallel with the longer sides. Often these lines do not reach the middle of the figure, where only a confused crystallization can be detected. In the interior of the enlongated figures, the lines are quite irregular, often running together, and showing a striking resemblance to woody fibre. The nature of these markings may be readily understood. They indicate the axes of minute columnar crystals, which tend to assume a position at right angles to the surface of cooling." The specimens in the museum shows markings that answer well to the above description and to the figure mentioned.

Weight, 180 Grams.

[*By exchange with Prof. J. L. Smith.*]

No. 30. **Staunton, Augusta County, Virginia.** Found in 1858. Museum number 4120.

J. W. Mallet; Am. Jour. Sci., 1871, [3], ii, pp. 10-15; 1878, [3], xv, pp. 337-338.—Brit. Assoc. Report (Brighton), 1872, p. 77.—Proc. Royal Soc., xx, p. 365.—Pogg. Ann., cxlvii, p. 134.

Iron. Slab, with one face etched, showing well marked Widmannstättian figures. Edges with crust. Mallet made four analyses of different pieces of this meteorite and each time found a very small percentage of tin. Weight 90 grams.

[*By exchange with Yale College.*]

No. 31. **Coopertown, Robertson County, Tennessee.** Known in 1860. Museum number 3356.

J. L. Smith; Am. Jour. Sci., 1861, [2], xxxi, p 266.

Iron. Slab with both faces polished; one showing very large Widmannstättian figures distinctly, the other in distinctly. Weight 94 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 32. **Orgueil, Tarn-et-Garonne, France.** Fell at 8 p. m., May 14, 1864. Museum number 3340.

S. Cloez; Comptes Rendus, 1864, lix, pp. 37-40.

F. Pisini; Comptes Rendus, 1864, lix, pp. 132-135.

Stone. No iron. Dead black with white specks and dull black crust. Weight, 1.683 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 33. **Bonanza, Coahuila, Mexico.** Found in 1865. Museum number, 3758.

C. U. Shepard; Am. Jour Sci., 1867, [2], xliii, pp. 384-385.

Iron. Irregular fragment, three of whose faces are polished. Two of these have been partially etched and show Widmannstättian figures rather indistinctly. Weight, 39.8 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 34. **Knyahinya Unghvar, Hungary.** Fell at 5 p. m., June 9, 1866. Museum numbers, 3350(*a*) and 3760(*b*).

A. Kenngott; Sitzber. Ak. Wiss. Wien, 1869, lix, p. 873. —Phil. Mag., 1869, xxxvii, p. 424.

J. V. Schiaparelli; Entwurf einer astronomischen Theorie der Sternschnuppen, 1871, Stettin: Nahmer., p. 267.

E. H. von Baumhauer; Archives Néerlandaises, 1872, vii, p. 146.

W. von Haidinger; Sitzber. Ak. Wiss. Wien, liv. 200 and 513.

G. Rose; Monatsber. Ak. Wiss. Berlin, lxvii, p. 203.

a. Stone. One face polished showing light and dark colored chondri and specks of iron. Three of the faces are covered with a dark crust. A fifth shows a broken surface with the iron rusted.

"It is computed that over a limited area more than a thousand stones, weighing in all from 8 to 10 cwt., must have fallen. The largest found is now preserved in the Vienna collection; it weighs 293.3 kilog. (5 cwt. 3 qrs. 3 lbs.), and measures 2 ft. 4 in. long and 18 in. broad, and penetrated the ground to a depth of 11 feet. * * * * * To the naked eye the section appears to be finely granular and of a gray tint, and even with a very moderate power is seen to present spherular structure, recalling, if relative size be left out of consideration, that of the globular diorite of Corsica. The opaque ingredients are nickel-iron, troilite and a black substance; in addition to these are two crystalline mineral species, the one colorless and transparent and somewhat fissured, the other gray and translucent and presenting an appearance of lamellar structure; both appear in angular and rounded granules, and both are bi-refractive; they are differently affected by hydrochloric acid, and from other differences in their crystalline characters it may be inferred that the gray silicate is an enstatite, the colorless silicate is olivine.*

Weight, 14 grams.

[*By exchange with Prof. J. L. Smith.*]

b. Stone. Bluish gray, with grains of iron sprinkled through it, in some places in groups. Weight, 5.82 grams.

[*By exchange with Prof. C. U. Shepard.*]

*Walter Flight; a Chapter in the History of Meteorites, p. 145.

No. 35. **Bear Creek, Denver Co., Colorado.** Found in 1866. Museum number, 4691.

C. U. Shepard; Am. Jour. Sci., 1866, [2], xlii, pp. 250–251.

J. Henry; Am. Jour. Sci., 1866, [2], xlii, pp. 286–287.

J. L. Smith; Am. Jour. Sci., 1867, [2], xliii, pp. 66-67.

C. T. Jackson; Am. Jour. Sci., 1867, [2], xliii, pp. 280-281.

Iron. Irregular fragment with one face cut. Very coarsely crystalline. Called the Aeritopos meteorite by Prof. Shepard. Weight, 41.5 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 36. **Auburn, Macon Co., Alabama.** Found in 1867. Museum number, 4417.

C. U. Shepard; Am. Jour. Sci., 1869, [2], xlvii., pp. 230-233.

J. L. Smith; Am. Jour. Sci., 1870, [2], xlix, p. 331.

Iron. Irregular fragment, much rusted, and one side partially polished. The meteorite seems to be made up of a mass of granular concretions. After polishing a face of this meteorite Prof. Shepard says:

"The face, on being subject to the action of dilute nitric acid, gave me a series of markings altogether new. They are extremely fine and delicate in their dimensions, and require a strong light with the aid of a microscope to be seen with distinctness. The first character that displays itself is somewhat that of a mesh or network, and arises from the polygonal boundaries of the granular concretions. The areas within these lines or edges (which are exceedingly thin) have a glittering luster when held at a fixed angle to the light, though this angle often varies for different concretions, as in the case of a polished surface of coarse grained calcite or fluor. The second character that arrests attention in examination, is the finely striated surface of each concretion,—one set of lines being perfectly straight and equi-distant, as in calcite and labradorite, while a second set, but less distinct, cross these at right angles. The final peculiarity of the markings consists in this,—that these fine striæ are wholly made up of dots or beads, which are arranged in almost absolute contact, and are therefore to be regarded as consisting wholly of sections of rhabdite needles, while on the other hand, the mesh-like markings, first noticed, are composed of plates of schreibersite."

Weight, 24.92 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 37. **Pultusk, Sielce Nowy, Poland.** Fell at 7 p. m., Jan. 30, 1868. Museum numbers, 3352 (*c*), 3759 (*a*) and 4121(*b*).

G. Werther; Schrift. Konigsberg Gessel., 1868, ix, pp. 35-40.

G. vom Rath; Neues Jahrb. Min., 1869, pp. 80-82.

C. Rammelsberg; Mon. Berlin Akad., 1870, pp. 448-452.

a. Stone. One face polished, showing numerous glistening iron grains. The rest of the specimen is covered by a dull, brown crust. Weight, 100 grams.

[*By exchange with Prof. C. U. Shepard.*]

b. Part of a smaller individual with one side polished, the others showing crust. Weight, 11 grams.

[*By exchange with Yale College.*]

c. Part of a still smaller individual; one side polished and the others mostly covered with crust. Weight, 7.5 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 38. **Ovifak, Island of Disko, Greenland.** Found in 1870. Museum numbers, 3345 (*a* and *b*) and 4412 (*c*).

A. E. Nordenskjöld; K. Vet-Akad. Förh., 1870, p. 873; (see translation in Geological Magazine, 1872, [1], ix, p. 518.)

J. Lorenzen; Zeit. Deut. Geol. Gesell., 1883, xxxv, pp. 695-703.

G. A. Daubrée; Compt. rend., 1877, lxxxiv, p. 66; lxxxvii, p. 911.

J. L. Smith, Ann. Chemie. Phys., 1879, [5], xvi, pp. 452-505.

a. Native iron, formerly supposed to be of meteoric origin. Taken from basaltic rocks. Irregular, much rusted, piece appearing somewhat granular. Weight, 430 grams.

[*By exchange with Prof. J. L. Smith.*]

b. A small slab of the same, polished on both sides. Weight, 45 grams.

[*By exchange with Prof. J. L. Smith.*]

c. Fragment of the same, much rusted. Weight, 14.5 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 39. **Searsmont, Waldo Co., Maine.** Fell at 8:15 a. m., May 21, 1871. Museum number, 4409.

C. U. Shepard; Am. Jour. Sci., 1871, [3], ii, p. 133.

J. L. Smith; Am. Jour. Sci., 1871, [3], ii, pp. 200-201.

a. Stone. Gray and crumbling. One side shows a black spongy crust which is much thicker than the crust usually seen on meteorites. Weight, 0.83 gram

b. Smaller fragment, also showing crust on one side. Weight, 0.5 gram.

[*By exchange with Prof. C. U. Shepard.*]

No. 40. **Waconda, Mitchell Co., Kansas.** Found in 1874. Museum number, 3342, (*a*) and 3762 (*b*).

C. U. Shepard; Am. Jour. Sci., 1876, [3], xi, pp. 473-474.

J. L. Smith; Am. Jour. Sci., 1877, [3], xiii, pp. 211-213.

a. Stone. Light gray, friable, clay-like mass containing very little iron. One side with a dull black crust. Weight, 72 gram.

[*By exchange with Prof. J. L. Smith.*]

b. Stone. Light gray fragment without crust. One face polished, showing considerable iron in two places. Weight, 72 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 41. **Mejillones, near the Desert of Atacama, South America.** Found in 1874. Museum number, 4695.

Iron. Small pieces of cut slab.

[*By exchange with Prof. C. U. Shepard.*]

No. 42. **Butler, Bates County, Missouri.** Found in 1874. Musenm number, 3357.

G. C. Broadhead; Am. Jour. Sci., 1875, [3], x, p. 401.

J. L. Smith; Am. Jour. Sci., 1877, [3], xiii, p. 213.

A. Brezina; Sitz. Akad. Wiss., 1880, lxxxii, Oct. Heft.

Iron. Thin slab with one face polished and etched, showing large and well marked Widmannstättian figures. The specimen contains a small nodule of triolite.

"It was noticed that the greater part of the iron had an even dull appearance, but in this lustreless iron gray part lay numerous—in part individual, in part grouped together—lamellæ, of which four differently directed systems appear on the sections. The lamellæ together form a skeleton—an octahedral skeleton. The groundmass, though lustreless and structureless, shows a peculiar play of light; its hardness is remarkably low, a little below 4, being distinctly scratchd by fluor."*

Weight, 104 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 43. **Iowa County, Iowa.** Fell at 10:30 p. m., Feb. 12, 1875. Museum number, 3359.

A. W. Wright; Am. Jour. Sci., 1875, [3], ix, pp. 459–460; 1875, [3], x, pp. 44–49.

*Walter Flight; A Chapter in the History of Meteorites, p, 187.

N. R Leonard; Am. Jour. Sci., 1875,[3], x, pp. 357–363,
J. L. Smith; Am. Jour. Sci., 1875,[3], x, pp. 362–363.
C. W. Irish; An Account of the Detonating Meteor of Feb. 12, 1875, Daily Press Job Printing Office, Iowa City.
G. A. Daubrée; L'Institut, 1875, (Nos. 105–122), p. 38.
C. W. Gümbel; Sitzungsber. Wiss. München, 1845, v. p. 313.

Stone. A complete individual, in the form of a parallelogram, 3 inches by 2½ and 1 inch where thickest. Nearly completely covered with a dull black crust, some of the fractures showing crust partially formed. One end cut, showing compact, rather dark gray stony substance with many iron grains sprinkled through it. Similar in appearance to the Pultusk and to the more recent Winnebago meteorites.

Weight, 306.66 grams,

[*By exchange with Prof. J. L. Smith.*]

No. 44. **Santa Catarina, Rio San Francisco do Sul, Brazil.** Known in 1875. Museum numbers 4415(*a*) and 4692(*b*).

Guignet and Almeida; Comptes Rendus, 1876, lxxxiii, pp. 917-919.

a. Iron. A small fragment with one side polished. Weight, 18.35 grams.

b. A smaller fragment of the same. Weight 7.071 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 45. **Warrenton, Warren County, Missouri.** Fell Jan. 3, 1877. Museum number, 3347.

J. L. Smith; Am. Jour. Sci., 1877,[3], xiii, p. 243; 1877, [3], xiv, pp. 222–224.

a. Stone. Bluish-gray, soft, clay-like mass, with very little iron. A spongy blue-black crust on one side.

Weight, 13 grams.

b. Similar fragment, showing a small area of crust.

Weight, 9.5 grams.

c. A smaller fragment. No crust. Weight, 5 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 46. **Cynthiana, Harrison County, Kentucky.** Fell at 4 p. m. Jan. 23, 1877. Museum number, 3343.

J. L. Smith; Am. Jour. Sci., 1877,[3], xiii, p. 243; 1877, [3], xiv, pp. 224–227.

a. Stone. Dull gray, with white grains and some iron particles. One side with a dull black crust partially full of pittings. Another side polished. Weight, 31.5 grams.

b. Smaller fragment of the same, showing crust on one side. Weight, 8 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 47. **Sarbanovac, Soko-Banjia Alexinatz, Servia.** Fell at 2 p. m., Oct. 13, 1877. Museum number, 4407.

E. Döll; Verhandl. d. K. K. Geol. Gesell., 1877, No. 16, p. 283.

S. M. Losanitch; Berichte d. Deut. Chem. Gessel., 1878, xi, p. 96.

Stone. Light gray fragment, with dark gray grains and some iron particles. No crust. Weight, 1.75 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 48. **Casey County, Georgia.** Found in 1877. Museum number, 3354.

A. Brezina; Stizber. Akad. Wiss., 1880, lxxxii, Oct. part.

Iron. Thin slab with one side polished and etched, but showing no Widmanstättian figures. Weight 36.5 grams.

[*By exchange with Prof. J. L. Smith.*]

No. 49. **Estherville, Emmet County, Iowa.** [**"The Perry Meteor."**] Fell at 5 p. m., May 10, 1879. Museum numbers, 3058 (*a* to *e*), 4125 (*f*) and 4128 (*g*).

S.F. Peckham; Am. Jour. Sci., 1879 [3], xviii, pp. 77-78.

C. U. Shepard; Am. Jour. Sci., 1879 [3], xviii, pp. 186-188.

J. L. Smith; Am. Jour Sci., 1880, [3], xix, pp. 459-463, 495. (Prof. Smith's account was also published in the Eighth Annual Report of the Geol. and Nat. Hist. Survey of Minn., pp. 176-180.)

S. Meunier; Comptes Rendus, 1882, xciv, pp. 1659-1661.

M. E. Wadsworth; Mem. Mus. Comp. Zool., 1884, vol. xi, pt. I, pp. 97-101.

a. This is the second largest of the pieces that have been found. It was discovered two miles west of the largest piece, which weighed 437 pounds, and originally weighed 170 pounds.

"The masses are rough and knotted like large mulberry calculi, with rounded protuberances projecting from the surface on every side; the black coating is not uniform, being most marked between the projections. These projections have sometimes a bright metallic surface, showing them to consist of nodules of iron; and they also contain lumps of an olive-green mineral, having a distinct and easy cleavage. The greater portion of the stony material is of a gray color, with this green mineral irregularly distributed through it. * * * * * * The masses are quite heavy and vary much in specific gravity in their different parts; but the average can not be less than 4.5. When broken one is immediately struck with the large nodules of metal among the gray and the green stony substances, some of which will weigh 100 grams or more. In this respect the meteorite is unique, it differing entirely from the mixed meteorites of Pallas, Atacama, etc., or the known meteoric stones rich in iron; for in none of these has the iron this nodular character. * * * * * The constitution of this meteorite, so far as I have been able to make it out, is therefore as follows: Bronzite, abundant; olivine, abundant; nickeliferous iron, abundant; troilite in moderate quantity; chromite, in minute quantity; silicate, not yet well determined."* This specimen is a large irregular mass, much rusted, and one end has been sawed off leaving a polished surface.

Weight, 60,210 grams (132¾ pounds.)

[*Purchased for the Museum by Prof. E. J. Thompson*]

b. Rough irregular pieces. Two sides are cut; another shows crust. Weight, 215 grams.

[*Purchased by for the Museum Prof. E. J. Thompson.*]

c. Irregular piece, one side cut. Weight, 41 grams.

[*Purchased for the Museum by Prof. E. J. Thompson.*]

d. Irregular ragged piece, one side cut. Weight, 19.5 grams.

[*Purchased for the Museum by Prof. E. J. Thompson.*]

e. Rough ragged fragment. Weight 19.2 grams.

[*Purchased for the Museum by Prof. E. J. Thompson.*]

f. Small irregular piece of one of the iron nodules. One side polished and etched, showing Widmannstättian figures. Weight, 8 grams.

[*Presented by Prof. C. W. Hall:*]

g. Small fragments of peckhamite from the above meteorite. Weight 0.672 gram.

[*Purchased probably from Prof. J. L. Smith.*]

No. 50. **Lexington Co., South Carolina**. Found in May, 1880. Museum number, 4418.

*Am. Jour. Sci., 1880, [3], xix. This silicate is probably peckhamite.

C. U. Shepard; Am. Jour. Sci., 1881, [3], xxi, pp. 117–119.

Iron. Irregular fragment with three faces polished. One of them is etched, but shows Widmannstättian figures only indistinctly. Weight, 17.5 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 51. **Ivanpah, San Bernadino Co., California.** Found in 1880. Museum numbers, 4420 (*b*) and 4421 (*a*).

C. U. Shepard; Am. Jour. Sci., 1880, [3], xix, pp. 381–382.

a. Iron. Cuttings. Weight, 2.3 grams.

b. Small irregular fragment of iron. Weight, 1.98 grams.

[*By exchange with Prof. C. U. Shepard.*]

No. 52. **Brenham, Kiowa Co., Kansas.** Found in 1885. Museum number, 7240.

N. H. Winchell and J. A. Dodge; Amer. Geologist, 1890, v, pp. 309–312; 1890, vi, pp. 370–377.

G. F. Kunz; Science, 1890, xv, p. 359.—Trans. N. Y. Acad. Sci., 1890, ix, pp. 186–194.

a. Iron. A coarse, metallic sponge containing olivine, chromite and troilite.

"Metallic iron comprises somewhat less than one-half the meteorite, and it serves as a matrix in which are embraced amygdaloidal or roundish masses from the size of a pea to that of a musket ball, and larger, of the black and yellowish minerals which comprise nearly the whole of the rest of the mass." This mass originally weighed 211 pounds. "It was approximately globular, with a broad shallow depression that encircled it about half way. Its exterior is oxidized by long exposure, some of the mineral grains having been profoundly affected by the penetration of iron oxide." About 85 pounds have been cut off from one side of the mass, leaving a plane surface which has been figured in the American Geologist, vol. vi, plate vii.

Weight, 55,790 grams (123 pounds).

b. Slab cut from the above mass, about one inch thick and 42 inches in circumference. Weight, 9410 grams.

Shown in plate vii, vol. vi, Dec., 1890, of the American Geologist.

c. Irregular mass with two sides polished; one has been etched and shows Widmannstättian figures; this surface also is figured in the American Geologist, vol. vi, p. 272. Weight, 2648 grams.

k. Wedge-shaped piece. $3\frac{1}{2}$ inches long, $1\frac{1}{2}$ wide and $2\frac{1}{4}$ thick at the large end. All the faces cut except one,

which is the largest and is covered by crust. Weight, 630 grams.

l. Irregular piece, with three sides cut, one partially cut, and the other with crust. Contains a large proportion of the black minerals. Weight, 630 grams.

m. Irregularly rectangular piece. Four faces cut; another shows crust. About 2½ inches by 2 by 1½. Weight, 570 grams.

p. Irregular ragged piece of metallic sponge. Most of the olivine has fallen out, but there is considerable of the black minerals present. Weight, 100 grams.

q. Ragged fragment, having some iron and considerable of black minerals. Weight, 28 grams.

r. Ragged fragment. There is considerable olivine and a small amount of the black minerals present. Weight, 17.7 grams.

s. Rusted, ragged fragment with considerable olivine. Weight, 12.7 grams.

t. Irregular fragment with a small amount of the black minerals and no olivine. Weight, 12 grams.

u. Ragged fragment; a small amount of the black minerals, but no olivine present. Weight, 11.8 grams.

v. Irregular fragment with considerable of the black minerals but no olivine. Weight, 11.3 grams.

w. Ragged sponge of iron containing nothing else. Weight, 9.6 grams.

x. Irregular rusted spongy fragment, having a little olivine. Weight, 9.1 grams.

y. Ragged fragment of iron containing nothing else. Weight, 8.9 grams.

z. Ragged fragment with considerable of the black minerals and very little olivine. Weight, 8.7 grams.

aa. Ragged, rusted fragment. Weight, 7.4 grams.

ab. Coarse cuttings, mostly iron. Weight about 4000 grams

ac. Finer cuttings. Weight, 1100 grams.

ad. Finest cuttings. Weight about 5500 grams.

No. 53. **Bandera Co., Texas. [Pipe Creek Meteorite.]** Found in 1887. Museum number, 7242.

A. R. Ledoux; Trans, N. Y. Acad. Sci., 1889, viii, pp. 186-187.

Stone. Slab, one fourth inch thick and five inches in circumference; both faces and two edges have been pol-

ished. Dark brown apparently porous groundmass holding black grains and irregular shining iron particles. Weight, 24.6 grams.

[*By exchange with Dr. H. Hensoldt.*]

No. 54. **Winnebago County, Iowa.** Fell at 5.15 p. m., May 2, 1890. Museum number, 7239.

G. F. Kunz; Trans. N. Y. Acad. Sci., 1890, ix, pp. 201–203.

J. Torrey and E. H. Barbour; Amer. Geologist, 1891, viii, pp. 67–72.

a. Stone. Large individual measuring about 13 inches in greatest diameter, and about 9 inches in the other directions. Covered by crust, except where it has been somewhat broken along the edges, and an area 7 by 3 inches on one side, from which a piece of the stone, not more than an inch thick, has been broken off. This is the 66-pound stone figured in the American Geologist, vol. viii, p. 68.

"This meteor is a typical chondrite, apparently of the type of the Parnallite group of Meunier, which fell February 28th,1857,at Parnellee, India. The stone is porous, and when placed in water to ascertain its specific gravity, there is a considerable ebullition of air. The specific gravity on a fifteen-gram piece, was found to be 3.638. The crust is rather thin, opaque black, not shining, and, under the microscope is very scorious, resembling the Knyahinya (Hungary) and the West Liberty (Iowa) meteoric stones. A broken surface shows the interior color to be gray spotted with brown, black and white, the latter showing the existence of small specks of meteoric iron from one to two millimetres across. Troilite is also present in small rounded masses of about the same size. On one broken surface was a very thin scum of a black substance, evidently graphite, soft enough to mark white paper; a feldspar (anorthite) was likewise observed, and enstatite was also present."*

"The dead black scoriaceous crust when broken, reveals a light gray stone interspersed with innumerable dark particles of iron and globules of troilite, quite like the Iowa County stones in appearance. Thin seams and cracks occur occasionally filled with a substance that has somewhat the appearance of graphite, and small spheroidal masses of olivine are abundant."†

Weight, 29.820 grams (65.75 pounds.)

[*Purchased on the spot by H. V. Winchell, of the party on whose farm it fell.*]

b. Individual completely covered by crust. Weight, 961.5 grams.

*Trans. N. Y. Acad. Sci., ix, p. 201.

† Amer. Geologist, viii, p. 67.

c. Fragment broken from the large individual (*a*). Shows a few minute dark veins or seams. About half the surface covered by crust. Weight, 450 grams.

d. Individual completely covered by crust, except a small area on one side. Weight, 75.8 grams.

e. Complete individual. Crust broken on edges in two or three places, and on one side it is thinner and rather glassy in appearance. Weight, 62.7 grams.

f. Individual completely covered by crust. Weight, 49.3 grams.

g. Irregular fragment. Two sides (or about half its surface) covered by crust. Weight, 48.6 grams.

h. Irregular individual completely covered by crust except where it has been broken off in a few places. Weight, 46.1 grams.

i. Roughly rectangular individual, about 1¾ inches by 1 by ¾; mostly covered by crust, but on one side the crust is imperfectly formed, as if a piece was here broken off a short time before striking the ground. One broken and partially polished. Weight, 45.3 grams.

j. Fragment more than half covered with crust. Weight, 40.5 grams.

k. Thin fragment about 2 inches long and 1¼ wide. Over half covered by crust. This is probably a piece from the large individual (*a*). Weight, 32.7 grams.

l. Complete individual. Weight, 31.8 grams.

o. Irregular piece covered by crust, except at one side, which is rusted. Another side has a comparatively thin crust. Weight, 29.1 grams.

r. Individual. Small area of crust gone from one edge. Weight 20.4 grams.

s. Complete individual. One end has a rough surface and thinner crust. Weight, 19.6 grams.

t. Small fragment from the large individual (*a*). Shows small area of crust. Weight, 18 grams.

u. Individual. Crust broken some on edges and thinner on one side, which has a rough surface. Weight 16.6 grams.

v. Complete individual. Weight 16.2 grams.

x. Individual. Crust spongy on one side. Weight 14.9 grams.

y. Fragment about half covered by crust. Weight 14.6 grams.

ab. Complete individual in the form of an irregular three-sided fragment, the base of which has a very spongy crust. Small pieces of the crust broken off in two or three places. Weight 12.3 grams.

ac. Fragment about half covered by crust; the part without crust is apparently somewhat rusted. Weight 11.7 grams.

ad. Apparently an individual with one end broken off. Weight 11.6 grams.

ae. Individual, crust gone from part of one side. Weight 10.5 grams.

af. Individual. One side is rough and has thinner crust. Crust cracked off somewhat on the edges. Weight 10.1 grams.

ag. Piece all covered with crust, excepting one end. Crust very thick. Weight, 8.8 grams.

ah. Individual. Two-thirds the surface is rough and has thinner crust. Weight, 8.6 grams.

ai. Irregular individual. Crust imperfectly formed on one side. Weight, 8.3 grams.

aj. Complete individual. Weight, 8.3 grams.

ak. Complete individual. Weight, 7.5 grams.

am. Complete indvidual. On one side the crust appears thin and very porous. Weight. 7.3 grams.

an. Irregular individual, with one side rough where the crust is thin. Weight, 7.1 grams.

ao. Complete individual. Weight, 7 grams.

aq. Fragment, one-third covered by crust. Weight, 6.7 grams.

ar. Piece about two-thirds covered by crust. Weight, 6.4 grams.

at. Individual with about one-third of the crust gone. Weight, 6 grams.

au. Individual with crust thin on one side. Crust broken off in a few places. Weight, 5.6 grams.

av. Irregular fragment nearly one-half covered by crust. Weight, 5.5 grams.

aw. Individual with small area of crust gone. Weight, 5.4 grams.

ay. Complete individual. Weight, 5.2 grams.

az. Individual with crust broken off in two places. One side rough and with thinner crust. Weight, 5.03 grams.

ba. Complete individual. Weight, 4.91 grams.

bb. Complete individual. Weight, 4.9 grams.
bd. Complete individual. Weight, 4.3 grams.
be. Complete individual. Weight, 4.3 grams.
bg. Complete individual. Weight, 4 grams.
bi. Complete individual. Small area of crust broken off. Weight, 3.6 grams.
bj. Piece covered by crust, except on one side. Weight, 3.4 grams.
bk. Complete individual. Weight, 3.3 grams.
bm. Individual with small area of crust broken off one end. Weight, 2.9 grams.
bn. Complete individual. Weight, 2.8 grams.
bo. Complete individual. Crust in places quite porous or spongy. Weight, 2.7 grams.
bp. Individual with crust broken off in several places. Weight, 2.7 grams.
bq. Fragment about one-third covered by crust. Weight, 2.4 grams.
br. Piece two-thirds covered by crust. Weight 2.2 grams.
bs. Complete individual. Weight, 2.2 grams.
bt. Irregular fragment about one-half covered by crust. Weight, 2.1 grams.
bu. Complete individual. Weight, 2.1 grams.
bv. Complete individual. Crust thinner on surface; rough on one side. Weight 2 grams.
bw. Complete individual. Weight 1.9 grams.
bx. Complete individual. Weight, 1.84 grams.
by. Individual with some of the crust gone from one edge. Weight, 1.78 grams.
bz. Complete individual. Weight, 1.72 grams.
ca. Complete individual. Weight, 1.66 grams.
cb. Individual with crust broken off in places from the edges. Weight, 1.56 grams.
cc. Complete individual. Weight, 1.54 grams.
cd. Small irregular fragment showing no crust. Weight, 1.53 grams.
ce. Piece two-thirds covered by crust. Weight, 1.51 grams.
cf. Complete individual. Weight, 1.45 grams.
cg. Complete individual. Weight, 1.3 grams.
ch. Complete individual with rough surface. Weight, 119 grams.
ci. Complete individual. Weight, 1.09 grams.
cj. Complete individual. Weight, 1.03 grams.

ck. Complete individual. Weight, 0.98 gram.

cl. Complete individual with quite porous or spongy crust. Weight, 0.96 gram.

cm. Individual. Crust quite thick, and a small area of it broken off one end. Weight, 0.87 gram.

cn. Fragment one-third covered by crust. Weight, 0.85 gram.

co. Complete individual. Weight, 0.75 gram.

cp. Complete individual. Weight, 0.55 gram.

cq. Irregular fragment without any crust. Weight, 0.37 gram. *them.*]

[*Purchased on the spot by N. H. Winchell from parties who found*

No. 55. **Washington County, Kansas.** Fell June 25, 1890. Museum number, 7241.

Stone. Dark ground mass with some white grains and glistening metallic particles. Very heavy and rich in iron. Weight, 562 grams.

[*Purchased through H. V. Winchell.*]

No. 56. **Diablo Canon, Arizona.** Found March, 1891. Museum number, 7947.

Iron. Entire individual. Lenticular mass. Weight 12¾ ounces. Some pieces contained diamonds.

[*By exchange with A. E. Foote.*]

No. 57. **Diablo Canon, Arizona.** Found March, 1891.

Siliceous iron associated with the last. Weight, 7¾ ounces. Museum number, 7948.

A. E. Foote; Am. Jour. Sci., vol. xlii, p. 413, 1891.

About 1700 pounds have been found. The diamonds were discovered in cutting, by Prof. G. A. Kœig.

No. 58. **Fayette County, Texas. (La Grange Meteorite.)** Found in 1878 by farmers, but brought to light by Mr. H. Hensoldt in 1888. Museum number, 7949.

Chondritic stone, slab, length 22 in., width 11 in., ⅞ in. thick, weight, 16 pounds. [*By exchange with Henry A. Ward.*]

Howell; Science, Feb. 3, 1888, p. 55. J. E. Whitfield and G. P. Merrill; Am. Jour, Sci., 1888 [3] vol. xxxvi, p. 113.

Total weight about 146 kilos. * * *

"To the unaided eye the chondritic structure is not distinctly marked, a broken surface showing a fine grained and evidently crystalline-granular rock, very compact, of a greenish-gray color and thickly studded with small metallic points with a brassy lustre. A polished surface shows the stone to be composed of small chondri rarely over 2 mm. in diameter, thickly and firmly compacted in a fine granular groundmass. Throughout the entire mass are thickly distributed innumerable small irregular flecks of a steel-gray, brassy and bronze-yellow color, presumably native iron and pyrrhotite."

VIII.

NOTES ON THE PETROGRAPHY AND GEOLOGY OF THE AKELEY LAKE REGION, IN NORTHEASTERN MINNESOTA.

BY W. S. BAYLEY,

U. S. Assistant Geologist, Lake Superior Division.

Upon the request of the writer, a number of specimens of the rocks collected by members of the Minnesota Geological Survey from the region adjacent to Chub (Akeley) lake, in Sec. 29, T. 65 N., R. 4 W., Minn., were kindly furnished him for microscopic study by Prof. N. H. Winchell, State Geologist of Minnesota. At the time the request was made there was no intention of publishing the results of this study, but when the microscopical features of the different rocks were compared with each other, and with their structural relationships, it was discovered that an entirely new light was thrown on the latter, and that these must be given a different interpretation from that given them in the 16th and 17th Minnesota reports. Consequently, it has been thought wise by Prof. Winchell to make public what is now known concerning the rocks in this vicinity, in order that the geology outlined in the reports may be appreciated with a little more clearness than has heretofore been possible.

Since some of the conclusions reached by the Minnesota geologists, after study of the hand-specimens of these rocks, are here shown to be erroneous, in consequence of a mistaken supposition with reference to their nature, it would seem proper to emphasize once more the danger of generalizing concerning the relations of pre-Cambrian rocks before having subjected them to a thorough microscopical investigation.

I desire to thank Prof. Winchell for his courtesy in providing the material asked for, and for his kindness in affording this means for the publication of my article.

(1) Occurrence and Description of Specimens Mentioned in the 16th Report.

1327. (16th Ann. Report, p. 80). South and a little east of the NW corner Sec. 24, T. 65 N., R. 4 W.

At this place is a low northward facing Animikie bluff in which the strata dip southeastwardly about 12°. It is made up of ore on top and of alternating gray grit and sandstone, with some ore and chert, below (1327).*

Under the microscope 1327 is seen to be a well defined quartzyte, composed of rounded quartz-grains, contiguous to some of which may be detected enlargements. The inclusions are fine dust-like particles and liquid enclosures. Between the quartz-grains was once an abundant cement, but this has been changed to a crystallized aggregate of fine needles of hornblende and fibres of chlorite, that often unite to form radiating spherulites, in the centers of some of which are little irregular masses of magnetite. These spherulites are scattered here and there along the lines separating adjacent quartz-grains. Occasionally they are confined entirely to these interstitial spaces, but more frequently their fibres penetrate the quartz-grains on both sides, while sometimes a spherulite may be entirely surrounded by quartz (Fig. 1). Were it not quite certain that the rock is

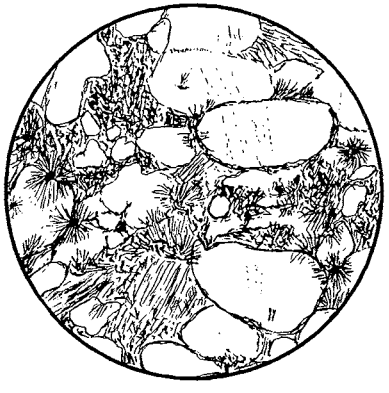

FIG. 1.
Fragmental quartzyte, with cementing material changed to chlorite and fibrous hornblende. No. 1327,x27.

fragmental, from the relations existing between the hornblende needles and the quartz, we would be led to regard the latter as

*The descriptions of occurrences are abstracted from the Minnesota reports, where they appear at greater lengths.

younger than the former. As the case stands, we must conclude that the spherulites have formed since the rock was laid down.

1329. (16th Ann. Report, pp. 81-82.) About 250 paces west of NE corner Sec. 22, T. 65 N., R. 4 W.

This specimen is a sample of a great dyke that cuts the gneiss underlying the rocks above mentioned. 1329 does not correctly represent the dyke, but it is the only sample that has been furnished. It is a very coarse-grained olivine-diabase, with long lath-shaped crystals of a plagioclase near andesine, large grains of light-colored olivine, and interstitial, allotriomorphic dark pink, slightly pleochroic augite, with much irregular magnetite in and around the augite. This last named mineral is quite fresh, except in small areas immediately next to feldspars, where it is slightly chloritized. The rock resembles very strongly the substance of the great dykes everywhere cutting the Animikie in th e lake Superior region.

1334 and 1335. (16th Ann. Report, p. 83.) SW ¼ Sec. 21, T. 65 N., R. 4 W.

The greenstone represented by 1329 extends southward to near the south line of Sec. 21, where it is evident that the greenstone has given way to the Animikie carrying magnetite. The most southern identifiable portion of the greenstone is represented by 1334. Beyond this there is a transition to a rock represented by 1335, which is heavily bedded. It dips south at 45° and apparently underlies the iron beds (1336). The rock has not the characteristics of an eruptive, but it appears to have those of a basic sedimentary bed which has been metamorphosed. Such a rock has not before been seen in Minnesota. 1334 and 1335 occur in two bluffs on the opposite sides of a narrow E. and W. lake.

1336. (16th Ann. Report, p. 82.) NE ¼, NE ¼ Sec. 29, T. 65 N., R. 4 W.

"This ore is well characterized olivinitic, magnetic, granular, the yellowish waxy grains of olivine being mingled rather uniformly with the grains of magnetite."

1334, which, if the beds all dip south, is the lowermost member of this interbedded series, is mainly an aggregate of very small grains of an almost colorless augite, surrounding here and there a larger grain of the same mineral. The smaller grains are very irregular in shape, while the larger ones are long and narrow, as if vertical sections of crystals flattened parallel to their basal planes. There is a rude parallel ar-

rangement of the grains so that the rock possesses a kind of stratified structure. In addition to the augite there are in bands in the section small grains of a greenish-brown hornblende. These are intermingled with the grains of the augite mosaic, and like these are rudely arranged in parallel directions. A few grains of magnetite scattered through the mosaic and an occasional grain of quartz complete the list of the rock's constituents. There is no evidence of any kind that the rock was ever clastic. It appears rather to be a modified eruptive. The augite mosaic has certainly resulted from the fracturing of large grains of pyroxene and the movement of the fractured parts from their original positions. In one portion of the slide this process may actually be seen in operation. A large grain of augite is granulitized around its edges, while its interior is crossed by many irregular lines of fracture, which divide the grain into hundredsof smaller ones. The slightest movement would suffice to transform this broken grain into an augite mosaic exactly like that elsewhere in the section. 1335, into which 1334 is supposed to grade, is not very different in its structure from 1334. It is an aggregate of tiny rounded grains of almost colorless augite, and grains and tiny lath-shaped crystals of plagioclase forming a mosaic in which lie much altered large grains of augite, changed on their edges to greenish-brown hornblende and peppered throughout with dust-like grains of magnetite. A few grains of the hornblende are also discovered in other parts of the slide, but they occur in such relations to the other minerals as to leave no doubt that they are derived from large grains of augite (Fig. 2). The composition, as well as

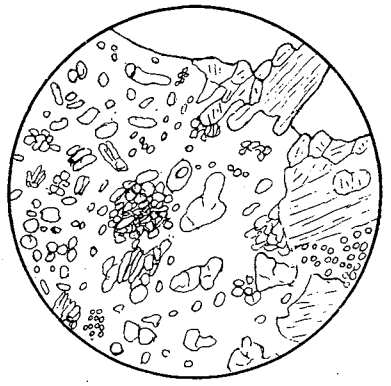

FIG. 2.

Granulitic gabbro, with large grains of green hornblende and small rounded ones of augite in a groundmass of plagioclase that appears in ordinary light to be a homogenous mass. No. 1335,x87.

the structure of the rock, places it among the granulitic gabbros so well described by Judd,* and ascribed by him to the movement of a gabbro rock mass, while in the pasty condition just prior to complete solidification. 1336, the iron ore above 1335, is mainly an aggregate of olivine and augite, and irregular grains of magnetite. The latter mineral is in large pieces scattered between the other two, especially between the grains of olivine, and in small rounded grains included in the latter. The large pieces are apparently secondary, while the small round grains are probably original. The olivine is older than the pyroxene. It is in round grains of a yellowish green color included in large pieces of augite, and it also forms a groundmass of interlocking grains in which the plates of pyroxene lie. These latter are large and are very irregular in outline. They include olivine and stretch far out into the interstices between the grains of the groundmass. The color is bright green. There is no noticeable pleochroism and the extinction is about 35° (Fig. 3).

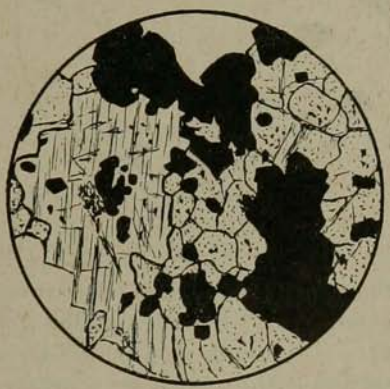

FIG. 3.
"Ore" in gabbro, consisting of olivine (stippled) hornblende (vertically striated) and magnetite (solid black). No. 1336, x27.

This rock like the others (1334 and 1335) is undoubtedly a modified eruptive. It certainly is not fragmental, nor is there any proof that it is a changed fragmental. No metamorphic rocks of this kind have ever been described, nor is it plain how such might be formed, except by complete fusion and recrystallization, in which case the result would not be distinguishable from an original eruptive. Fig. 3. shows the structure of the ore.

* Quart. Jour. Geol. Soc., 1886, p. 49.

1340 and 1341. (16th Ann. Report, p. 85.) The quartzyte with which the ore is associated is well developed a little to the west of 1336. Here it dips 48° to the south, the quartzyte and magnetic quartz-schist being from 140 to 150 feet thick, and the associated olivinitic ore beds perhaps 50 feet. Interbedded with one of the quartzyte layers (1340) is a bed of gabbro (1341), which varies rapidly in its structure from the coarse grain of the ordinary gabbro to the fine grain of the rock called "muscovado" in the 15th, 16th, 17th and 18th Annual Reports.

1340. The so-called quartzyte, is not a fragmental rock, but is one composed of interlocking quartz-grains, including magnetite. (Fig. 4.) The latter, which is the older of the two

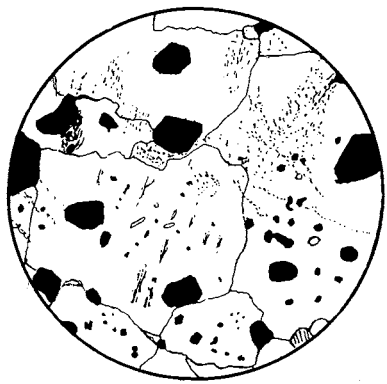

FIG. 4.
Crystallized quartzyte, associated with "ore" and granulitic gabbro. No. 1340, x27.

components is often in well marked octahedrons enclosed in the quartz, but more frequently it is in rounded grains, either surrounded by a quartz individual, or situated between several of them. In the latter case the grains are slightly altered on their edges to a brownish earthy product, probably limonite, or to a green decomposition product, either chlorite or hornblende. The quartz interlocks by sutures that are perhaps not quite as irregular on the whole as the sutures of granitic quartz, but they are too irregular to be regarded as due to any cause but the crystallization of the quartz *in situ*. A comparison of fig. 4 with fig. 1 will show plainly the difference in structure between this crystallized quartzyte and the fragmental quartzitic sandstone of the Animikie.

1341. The gabbro interbedded with the crystallized quartzyte is in an intermediate phase between the coarse grained normal olivine gabbros and the granulitic varieties, in which the

pyroxene occures in small rounded grains. The olivine is in the ordinary form. The plagioclase is in irregular grains, with a tendency to the lath-shaped forms of diabasic feldspar. Its gabbroitic character is evinced in the abundance of dust-like particles scattered through it, and especially by their thick accumulation toward the centers of all grains. The pyroxene is a light-colored augite, thickly crowded with magnetite grains, small masses of limonite and tiny plates of brown biotite. Some of the augite is in ophitic plates between the feldspars, but most of it is in little rounded grains. The magnetite, nearly all of which is secondary, is thickly strewn through the section in long irregular grains in and between the other constituents, especially the augite and olivine, and in tiny rounded grains in the augite and the plagioclase.

(16th Ann. Report, pp. 86-87.) The great quartzyte of which No. 1340 is a sample, "is near the top* of the Animikie, and, since it is a new feature in the northeast part of Minnesota, it deserves a name. It apparently occupies the same horizon as the quartzyte at the head of Wauswaugoning bay. Because of the association with it of iron beds it has been called "Pewabic quartzyte."

1343 and 1346. Near the center of the NE ¼ of the SW ¼ of Sec. 25, T. 65 N., R. 5 W., the Pewabic quartzyte is again met with (1343,) dipping 55° S., and further north occurs greenstone (1345) quite like that in sections 21 and 29, T. 65 N., R. 4 W., (viz., 1334 and 1335) but approaching a little more closely to the rock called "muscovado" in other reports.

1347. (16th Ann. Report, p. 88.) The best sample of "muscovado" comes from the shore of Muscovado lake, in Sec. 36, T. 65 N., R. 5 W.

1343, which is said to be a sample of the Pewabic quartzyte, is an olivinitic rock which is probably but a very basic phase of gabbro, just as the olivine bombs of basalts are nothing† but very large accumulations of olivine and other basic minerals in the surface equivalents of the gabbros. It is composed almost exclusively of olivine and quartz. The latter is probably the younger component as it occurs in subangular grains, often entirely surrounded by olivine, to whose contours it appears to adapt itself. It includes tiny grains of magnetite, rounded

*In Bulletin No. 6 of the Minnesota Geological Survey (p. 125) this quartzyte is put at the bottom of the Animikie, and it is no longer regarded as the equivalent of the Wauswaugoning quartzyte.

†Bauer: Neues Jahrb. für. Min., etc., 1891. II, p. 200.

ones of olivine, and some small acicular, almost colorless crystals that are thought to be pyroxene. The olivine constitutes over ninety per cent. of the entire rock. It is in closely crowded, mutually interfering, pale yellowish-green grains, containing a few magnetite inclusions and some that appear to be of glass. Occasionally an olivine grain may be included within a quartz grain, but usually the olivine forms a compact granular groundmass in the occasional interstices of which the quartz has recrystallized. Another mineral occurring in the rock in very small quantity is a bright green pyroxene that is very slightly pleochroic. The fine series of striations apparent on it indicate a diallage. This mineral is found only in very small pieces between the olivines, or between this mineral and quartz. It is probably more common in the latter position than in the former. It is undoubtedly younger than the olivine and older than the quartz. The constitution and structure of the rock point directly to the gabbros as its nearest relatives.

1345 is a granulitic gabbro, composed of rounded grains of augite and plagioclase, the latter of which often include the former, and large plates of brown hornblende. The hornblende is very strongly pleochroic and is present in small flakes scattered between the augite grains, and in large ones in areas where the augite is most thickly accumulated. From the fact that many of the grains of augite in the section are partially changed to green and brown hornblende, it is inferred that all of this mineral is secondary. Its contours are very irregular and the peripheral portions of the larger plates are granulated exactly as is the augite.

1347, like 1334 and 1335, is a granulitic gabbro, but unlike the latter two rocks it contains an abundance of hypersthene and but very little olivine. All the components are beautifully fresh. The plagioclase is in very irregular pellucid grains, enclosing magnetite and hypersthene, besides a few glass inclusions. The hypersthene forms more or less rounded grains lying between the plagioclase grains, and sometimes included in them. It is pleochroic in deep pink and light green tints, and it includes a few magnetite grains. In many portions of the section the grains are isolated, but in other portions they unite to form accumulations, between the grains of which large masses of magnetite lie. The olivine, when present, is in large irregular grains, very much decomposed with the production of much magnetite.

The relation of this rock to a gabbro is too clear to need emphasizing. The components are those of the gabbros, while the structure corresponds exactly to that of the granulitized varieties.

DISCUSSION.

Of the rocks above described, 1327 is a fragmental quartzyte, 1329 a diabase, 1334, 1335, 1345 and 1347 are granulitic gabbros, 1341 is an intermediate phase between the normal gabbros and the granulitic varieties, 1336 a very basic aggregate of gabbro components, 1343 a similar basic aggregate with the addition of quartz, and 1340 a crystallized quartzyte.

In the 16th Annual Report of the Minnesota Geological Survey, 1327 is called a chert, 1336 an Animikie bed (presumably quartzyte) carrying ore, 1340 a quartzyte (presumably fragmental), 1343 quartzyte (Pewabic quartzyte), and 1345 and 1347 "muscovado."

The most evident results of the microscopic study of the rocks are with respect to their nature. 1327 is not a chert, but like all the other non-eruptive Animikie beds described, it is a sedimentary clastic rock.

The "muscovados" that have so frequently been mentioned in the reports as very peculiar basic rocks whose true nature is unknown, have been learned to be granulitic phases (sometimes quartzitic) of the very common gabbros so prevalent in northeastern Minnesota.

The "Pewabic quartzyte" (1343) and its associated ores (1336) are about as far removed from being quartzytes as possible. Instead of being acid fragmental rocks, most of them are basic crystalline ones, and from their very nature they may safely be considered as phases of gabbro.*

From the single section of 1340 it is not possible to learn much. However, the rock is not a fragmental quartzyte like the quartzyte of the Animikie beds, and consequently cannot be regarded as the equivalent of fragmental quartzytes existing at other places in the lake Superior basin. If we may be permitted to interpret the result of the study of section 1340 by means of the knowledge gained during the investigation of a suite of specimens collected from the Akeley lake region by the United States Geological Survey, we must conclude that

* In this paragraph it is not intended to deny the possibility of any of the so-called Pewabic quartzytes being true fragmentals. It is merely asserted that much of this rock in the Akeley lake region is a phase of gabbro, and that none of it in this neighborhood is fragmental.

this rock, though a completely crystallized quartzyte, is nothing more nor less than an extreme phase of the gabbro. In other words, it is a completely altered gabbro rather than an independent rock species, and hence it must be classed with the gabbro overlying the Animikie and not with the Animikie fragmentals.

From the above statements it is quite clear that some of the conclusions reached by the Minnesota geologists with respect to the relations of the Akeley lake ores to the Animike beds must be modified. From the mere fact that the former dip south at high angles (30°–55°), while all of the Animike beds are only moderately inclined (12°–25°), it might be argued that the two series are different. A stronger argument, however, is discovered when we learn that none of the beds belonging to the former series are fragmental, while all of those of the Animike are either clastic or but slightly altered diabases. Moreover the Akeley lake ores are underlain by modified gabbro, while the ores themselves are probably phases of the same rock, which extends from this place southward for many miles as a typical olivine-gabbro. We must then class the ores, and even much of the rock called "Pewabic quartzyte" with the gabbros. Even though some of the rock called "Pewabic quartzyte" may be a true quartzyte in the Animikie, it is evident that it is not of as great importance for correlation purposes as has been supposed.

Some of the conclusions published in the 16th report (pp. 84, 85) of the Minnesota Survey, must thus be modified before they can be accepted as correct. Without entering further into the discussion of the various conclusions in detail, it will prove sufficient for the present purpose to state them briefly in their modified forms. The changes, which the writer thinks are necessitated by the knowledge of the true nature of the rocks concerned, may be learned by comparison of the original conclusions* as published in the Minnesota report, with those here given.

1. The ore beds of the Akeley lake series belong with the overlying gabbro, and not with the Animikie.

2. The iron-bearing rock is a phase of the gabbro into which it passes above.

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* The numbering of the conclusions corresponds with that used in the Minnesota report.

3. The bedded rocks of the iron belt are granulitic gabbros, and consequently are eruptives, and not changed sedimentaries.

4 and 5 may stand unchanged, if by quartzyte is not understood a fragmental rock.

6. The rocks interbedded with the ores are special phases of gabbro.

7, 8 and 9 remain unchanged so far as the conclusions are concerned.

10. Since the so-called Pewabic quartzyte of the Akeley lake region is in most cases a gabbro, it cannot be correlated with quartzytes in the Animikie in other regions. In the Akeley lake region it is certainly near the bottom of the gabbro.

(II) Occurrence and Description of Specimens Mentioned in the 17th Report.

451 (H) and 452 (H). (17th Ann. Report, p. 107.) NW¼ Sec. 28, T. 65 N., R. 4 W.

Southeast of 1334 and 1335, and east of 1336, 1340 and 1341, and nearly on their strike, are beds of Animikie (?) slate and ore, dipping at 60°–75°, and lying upon a biotitic gabbro, which has slightly metamorphosed their lowest quartzitic and ore layers. Nos. 451 and 452 show the changes and gradation of the Animikie beds as they become crystalline and pass through metamorphosed strata into the greenstone.

453 (H). (17th Ann. Report, p. 108,) is another specimen of the Animikie from a drill hole a little to the south of 451 and 452.

451 (H), like the rocks to the west of it, is a gabbro, and not a fragmental rock in any sense of the word. Its structure, like that of 1341, is intermediate between that of the true gabbros and that of the granulitic varieties. It contains large plates of almost colorless augite and of strongly pleochroic hypersthene, surrounded by an aggregate of rounded grains of the same minerals, flakes of brown biotite and irregular grains of colorless plagioclase. In the immediate neighborhood of the larger pyroxenes the small grains of this mineral are orientated to correspond with the orientation of the larger ones, from which they are separated by the plagioclase. The biotite is in large flakes with strong pleochroism in bright yellow and

dark bronzy tints, that lie within the large grains of pyroxene and between the smaller grains, and in very small ill-defined masses within the larger grains of both the augite and the hypersthene. It is also found included in the plagioclase, and occurring between the feldspar grains. Of the plagioclase nothing need be said save that it is the youngest of the original components, the biotite being regarded as secondary. The arrangement of the various constituents in a rudely parallel manner produces an apparent stratification, which no doubt was the phenomenon that led to the supposition that the rock is part of the sedimentary Animikie. The microscope shows clearly that this is not the case. The rock is surely eruptive, and is a phase of the great gabbro flow.

No. 452(H), which was thought to represent a more metamorphosed phase of 451, is a crystallized quartzyte, like 1340, which lies to the west of it. That it should be classed as an extremely acid phase of the gabbro is indicated by the existence in it of large masses of augite and secondary green hornblende. When these minerals are in contact with the quartz grains the latter are bounded by a fringe of very fine needles that are probably hornblende.

No. 453 H, also supposed to be an Animikie fragmental by the Minnesota geologists, is very similar to 1336 and 1343 in structure. In composition, however, it differs from these in that the pyroxene is mainly hypersthene. This is present in very large plates, including small rounded grains of a light green augite and bright green masses of hornblende, besides numerous grains of magnetite, that are so abundant as to make the rock nearly as much of an ore of iron as 1336. From the nature of the rock it is quite plain that it is a phase of gabbro.

454 (H.) (17th Ann. Report, p. 109.) "In the NW ¼ Sec. 35, T. 65 N., R. 5 W., is a knoll of Animikie quartzyte. * * * It dips south about 75° and strikes east and west. Across the valley which lies to the south side of it, is found gabbro."

This rock, like 452 (H,) is a crystallized quartzyte, composed of interlocking grains of quartz, including large numbers of magnetite grains. In addition to the included magnetite there is an abundance of this mineral between the quartz grains. A few flakes of hornblende or chlorite occur between the quartzes and long slender needles of some opaque mineral extend from the edges of the included magnetites far out into the surrounding substance. The most important fact in connection with these three rocks is that the one (451 H) farthest removed from

the underlying (metamorphosing?) greenstone is least like a sedimentary rock. Consequently those nearest the greenstone (452) can not have been formed from it by the metamorphosing action of the latter—using "metamorphosing" in the sense in which it is used in the Minnesota report.

455 (H), 456 (H), and 458 (H.) (17th Ann. Report, p. 109-110.) NW ¼ Sec. 35, T. 65 N., R. 5 W. The knoll in which 454 (H) is found extends westward as a ridge, with a precipitous bluff about 40 feet high, facing north. The upper half or two-thirds of the bluff is Animikie quartzyte and ore, dipping 70° S., and the lower portion is Keewatin(?) greenstone like that north of Akeley lake (the granulitic gabbro, W. S. B.) The contact between the two is fine. The Animikie is but very slightly modified by the igneous rock beneath it. But at other places to the east the Animikie is greatly metamorphosed, so that the line of contact is not discernible. The greenstone near the contact is a little finer grained and less massive than it is two feet below; but no other change is apparent in it. 456 (H), 456A (H), 456B (H), 456C (H), are specimens of this greenstone, taken in order receding from the line of contact. 456D (H) is greenstone from a point 150 paces further west, and 455A (H) is the Animikie above it.

In describing the petrographic features of the rocks it will be best to begin with 456C (H) and pass from this, the most nearly normal phase of the underlying greenstone, to the more special phases occurring nearer the contact and ending with 455A (H), the supposed Animikie above it.

456C (H) consists of coarse grains of gabbroitic plagioclase filled with dust inclusions and tiny crystals of apatite, and large plates and small grains of pyroxene, besides magnetite and biotite. The pyroxene is augite and hypersthene, the former of which not only occurs in the broad plates and large irregular grains characteristic of gabbro, but also in small rounded grains surrounding these, and stretching as aggregates far out between the plagioclases. The hypersthene is found only in the rounded grains. The large grains of augite are much altered, the most prominent alteration products being tiny flakes of a strongly pleochroic reddish-brown biotite, some green hornblende and irregular masses of magnetite. Besides the biotite included within the pyroxene, there are large flakes of the same mineral between the augite and the plagioclase, and others between adjacent feldspar grains. Since the larger flakes are exactly like the smaller ones in every respect but

size, and since the latter are undoubtedly secondary, it is inferred that the larger ones are also secondary, and that their great abundance in the neighborhood of the plagioclase is due to a reaction between this mineral and the augite.

There are other interesting features connected with this slide, but enough has been said to indicate that the rock from which it was made is a true gabbro, in which the beginning of a granulitization of the pyroxene may be detected.

456B (H) differs from 456C (H), mainly in that the plagioclase is more frequently in lath-shaped individuals, and the pyroxene is more completely granulated. Magnetite and biotite are less abundant than in 456C (H), and hypersthene may be more abundant. The rock approaches more nearly the granulitic gabbros than the normal phases of this rock.

456A (H) is a very fine-grained granulitic rock, containing a very large quantity of biotite and magnetite. Occasionally the feldspars have long, narrow cross sections, but in this respect only does the rock resemble diabase. Most of the plagioclase as well as all of the pyroxene is in rounded grains. The magnetite is in irregular grains and in little crystals, and the biotite is in small flakes that are about as broad as they are long. The features are those of a fine-grained eruptive with gabbro characteristics.

456 (H), which, according to the descriptions in the 17th Report, is a specimen taken from the immediate contact of the gabbro with the overlying beds, is a granulitic gabbro, in which is a vein of very coarse pyroxene. The granulitic portion of the rock is not very different from 456B (H). It is an aggregate of small grains of pyroxene, and of pellucid plagioclase, together with small plates of brown biotite, all including many smaller grains of magnetite, and all arranged in a somewhat parallel manner, that is not the result of pressure. Through this passes a vein of irregularly interlocking, coarse grains of pyroxene, both augite and diallage, and greenish-brown hornblende, scattered through which are a few plates of biotite and grains of plagioclase and magnetite. Along the edges of the vein the amounts of green hornblende, of biotite, and of magnetite increase, and the structure gradually becomes granulitic.

These four specimens are thus seen to belong with the gabbro. The granulitic variety can be traced back into a rock that shows but traces of granulitization, so that there can be but little doubt that the former are, as has been repeatedly

stated, but special phases of the latter. The greenstones underlying the supposed Animikie rocks in this place are then not Keewatin, but they are identical in every respect with the overlying rock, which is certainly not Keewatin.

455A (H). The section of this rock, which is a sample of the supposed Animikie above the greenstone, consists of two very distinct portions. The major part is composed of thickly crowded plates of hypersthene, filled with magnetite and including an occasional grain of quartz. The minor portion is like the crystallized quartzytes 452 (H) and 454 (H), though the quartz grains are perhaps a little more rounded than in these two cases. They include magnetite and rounded grains of hypersthene and numerous large liquid cavities, and are often separated from each other by thin seams of limonite. Between the two areas mentioned is a sort of transition zone in which the quartz-grains and hypersthene are intermingled in about equal proportions with the latter between the grains of the former.

The quartzitic portion of this rock is either a vein in it, or it is but a very acid phase of the granulitic gabbro. In the hand specimen the quartzitic band is but a fraction of an inch in width. In either case the rock loses its importance as a means for determining the age of the gabbro. It is certainly not part of a clastic bed, but it is a portion of the gabbro.

458 (H). (17th Ann. Report, p. 110.) North of the bluff from which 456 (H), etc., were taken, is a still higher ridge in which the rock appears to be slightly different from that in the southern ridge. This rock, under the microscope, is found to be a very fine-grained granulitic aggregate of colorless augite and plagioclase, with a little mica and magnetite and large decomposed areas of what were perhaps originally idiomorphic grains of augite. At present these larger areas consist largely of magnetite dust and green hornblende.

DISCUSSION.

It will not be necessary to discuss the bearing of the nature of the rocks described in the 17th Report upon the geology of the Akeley lake region at as great length as was done in the case of those mentioned in the 16th Report. It will be sufficient to call attention to the fact that the investigation of the former rocks substantiates the conclusions deduced from the study of those whose locations are given in the latter report.

All the beds that were supposed to be Animikie are discovered to be quite unlike any beds that are known to belong to this formation. They all dip at higher angles than do the Animikie rocks, and at the same angle as do some beds that are undoubtedly a part of the great gabbro flow. Moreover, most of the supposed Animikie layers are not fragmental. They are granulitic gabbros that may be traced step by step into a true gabbro, which has all the characteristics of the great gabbro of Minnesota, and which is entirely different from the thin beds of so-called gabbro that are interleaved with the Animikie. The quartzytes among these layers are not fragmental quartzytes, and hence can not be correlated with true fragmental quartzytes as far removed from them as those of Pokegama falls or the falls of Prairie river.* The writer would place them and their contained ores with the gabbro group† of Prof. Winchell. Even should the quartz layers interstratified with the granulitic gabbros be regarded as recrystallized fragmental beds, they would not have the same important significance as would be the case were they truly interstratified fragmentals, for they would owe their present condition to the action upon them of a later eruptive—the gabbro —and thus they could not be used to determine the age of this latter.

SUMMARY.

The three important results reached largely by the microscopic study of the rocks from the neighborhood of Akeley lake, are these:

1. Most of the rocks designated as Pewabic quartzyte in the neighborhood of Akeley lake are not quartzytes, but they are granulitic phases of gabbro. The remainder are crystallized aggregates of quartz. None of them are sedimentary rocks, and consequently none can serve to determine the age of the ore associated with them, or of the gabbro in which they occur.

2. On the other hand, the granulitic gabbros may be traced into true granitic gabbros, and into quartzose phases of granulitic varieties. Hence, the granulitic beds and their associated ores, are of the same age as the gabbro, whose structural relations to the younger and older formations must be appealed to in order to settle the question of age.

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* Cf. The Iron Ores of Minnesota: Bull. 6, Minn. Geol. Survey, p. 119.

† Iron Ores of Minnesota, p. 123.

3. Since so much of the "Pewabic quartzyte" is not quartzyte in any sense of the word, and since different beds that have been given this name are not all certainly of the same age*, it is evident that great care must be taken in the use of the "Pewabic quartzyte" for correlation purposes. Several different rocks have been included under this one title, hence, the "Pewabic quartzyte," as defined, cannot be relied upon as marking a definite horizon in the succession of the geological formations in northeastern Minnesota.†

APPENDIX.

Since the above was written, the attention of the writer has been called to the fact that the first and second of the above conclusions are practically identical with those reached by the Lake Superior Division of the United States Geological Survey several years ago. In 1883 and 1884 Mr. W. M. Chauvenet examined in the field the Akeley lake district and that to the westward. Thin sections of his material were examined by Prof. C. R. Van Hise early in 1885. With his field notes as a basis, and the microscopical results of Prof. Van Hise, he submitted a report to Prof. Irving from which the following abstracts are condensed:

Near Little Saganaga lake "An outcrop of heavy magnetitic iron ore rises in a smooth shoulder between walls of a distinctly bedded rock having the appearance of a quartzyte, but which proves under the microscope to be an olivine gabbro with quartz replacement. * * * The silicified gabbro shows distinct banding, stained with iron oxide along the contact of the layers. * * * The bed of magnetic ore occurs, therefore, in the gabbro formation."

The Akeley lake section is fully described. "Along the ridge on the north shore of Akeley lake a number of trenches were opened, which exposed a magnetic ore here occurring in the gabbro. The occurrence is quite similar to that described at Little Saganaga."

*Some are Animikie as determined by Prof. Winchell, while others are of the same age as the gabbro, which is regarded by the Minnesota geologists as Animikie, only because of the supposed interstratification with it of the granulitic gabbros, which were thought to be Animikie quartzyte.

†It is possible that by including under the Pewabic quartzyte only such rocks as are undoubtedly fragmental, as the quartzyte east of Gunflint lake and those along the south side of the Mesabi Range, a constant horizon may be established, which will be of great service in determining the ages of overlying and underlying beds. These rocks, however, cannot be correlated with the granulitic gabbros of the Akeley lake region nor their ores with the ores in the latter. It is this point upon which emphasis is especially placed in the above article.

Then follow details of the alternations of ordinary gabbro and what appears to be bedded quartzyte, after which it is said:

"The quartzytes of the above layers all appear to be merely the result of a substitution of quartz and magnetite for the minerals of a gabbro, in some cases for an olivine gabbro. * * * The silicified gabbro on Akeley lake, with seams of magnetite, have been traced southwest through Sections 25, 35, 34, T. 65 N., R. 5 W., to Mitchigamme lake."

Finally the following conclusion is drawn: "It is evident, from a study of the rocks at Akeley lake that the iron ore here lies wholly in the gabbro formation, much silicified and altered, and not in the Animikie."

Mr. W. N. Merriam, in 1886, made farther observations on the silicified gabbro belt at lake Gobbemichigomog and vicinity. The sections obtained from the material collected by Mr. Merriam were examined by Prof. Van Hise with the same results as those reached in the case of the Akeley lake rocks.

It thus appears that the Akeley lake silicified gabbro has a considerable east and west extent along the north contact of the gabbro, and that the results which have been reached from a study of the specimens collected by the Minnesota Survey are in accordance with those made by others in an independent study of which the writer was wholly ignorant until his paper was entirely written.

Colby University, Jan. 11, 1892.

NOTE.—The second foot note on the bottom of p. 209, expressing the main point of difference between the conclusions of Prof. Bailey and the reports of the Minnesota survey, is the only one to which here it is appropriate to call attention to. The minor variations in lithologic distinctions, when not due to insufficiency of the supply of material in Prof. Bailey's hands, can all be accounted for and are of but little purport in considering the general succession and structural relations of the formations. It is probable that when Prof. Bailey has seen the structural facts in the field he will modify his conclusions respecting the continuity of the Pewabic quartzyte from the Akeley lake region toward the southwest, and even to Pokegama falls.

There is, as the Minnesota reports have fully explained, a wonderful variety of lithology in the lower part of the Animikie by the agency of cotemporary eruptive action. The "non-fragmental" silica is a chemical precipitate in the early Animikie ocean. At distant points it is pure silica, in rolled grains. At points near the eruptive centers, as at Akeley lake, it has not only not acquired the rounded "fragmental conditions" but it has been crystrllized *in situ* by the heated eruptives, and has been mingled with tufaceous, eruptive fragmental elements. When this mixture is recrystallized it has a remote resemblance to an eruptive rock. But it is of oceanic structure, outwardly and internally, and cannot be affiliated correctly with the true eruptive gabbro.

Of course the intent of Prof. Bailey's paper is to establish the idea of Prof. Irving that the gabbro flood is later than the Animikie rather than near the bottom of it where the Minnesota geologists have placed it, but its purport confirms the Minnesota geologists in their conclusions. N. H. W.

NEW LOWER SILURIAN LAMELLIBRANCHIATA, CHIEFLY FROM MINNESOTA ROCKS.

BY E. O. ULRICH.

In the following pages I endeavor to give full descriptions and, it is hoped, sufficient illustrations of the principal and generally the more striking of the new Minnesota forms of this class that have been brought to my notice since 1885. Much of the material now described I owe to the disinterested kindness of Prof. C. W. Hall, of the State University, and to the unfailing friendship of my co-laborer, Mr. W. H. Scofield, of Cannon Falls. The last sent me every shell and cast of the interior contained in his extensive private cabinet. Many were in a good state of preservation, several belonged to species that I had not before seen (among them the remarkable shell from which I was enabled to work out the characters of the new genus *Plethocardia*), and all proved of material aid to me in determining the essential characters, variations, and limits of the species studied. The value of such aid may be better appreciated when I state that the Minnesota Trenton Lamellibranchiata are no exception to a rule that seems to prevail nearly every where in these rocks, namely, that in most cases the individuals of the species are anything but abundant. Yet, a few forms have been found in considerable numbers, and my observation would indicate that the majority of these shells are more or less gregarious in their habits, so that the number of known specimens of a species may at any time be greatly augmented.

In the Minnesota Lower Silurian rocks, excluding the beds beneath the top of the St. Peter's sandstone, the Lamellibranchiata are confined very largely to six horizons. The first of these is in the upper part of the Trenton limestone in which the fossil itself is almost invariably dissolved away so as to leave good moulds of both the exterior and interior in the matrix. This method of preservation is most favorable, since with the aid of gutta percha the judicious collector may study the most important of the original characters of the shells with comparative ease. Individuals of *Cypricardites rotundus* Hall, are abund-

ant, while another form of the genus near *C. ventricosus* Hall, and *Modiolopsis plana*, of the same author, are not uncommon. The types of *Cypricardites sardesoni* and *C. obtusifrons*, of this paper, are from the same bed, as are several other forms not yet specifically determined.

The second horizon is in the middle third or "Rhinidictya beds" of the Trenton shales. It has afforded *Modiolopsis similis*, *Orthodesma minnesotense*, *Technophorus extenuatus*, *Tellinomya nitida*, *Cypricardites cingulatus*, *C. glabellus*, *C. obtusifrons?*, *Whitella compressa*, and *W. concentrica*, all described by the author. Several other species are represented in my collections by specimens too illy preserved to admit of a satisfactory determination of their affinities.

The third horizon is in a bed that I place near the top of the upper third of the Trenton shales. It is exposed at a locality about six miles south of Cannon Falls, Minn., where it is overlaid by the Galena shales. It is the most interesting horizon for these fossils known to me in the state. Perhaps it is a local deposit, at any rate, none of the Lamellibranchiata described by me from this locality are as yet known in the same position from other points. An incomplete list of the species is as follows: *Tellinomya compressa*, *T. levata* (Hall), *T. planodorsata*, *T. pulchella* (Hall), *Lyrodesma poststriatum* (Emmons), *Modiolopsis concava*, *M. faba?* (Emmons), *Matheria rugosa*, *Cypricardites tenellus*, *C. haynianus?* (Safford), *Whitella scofieldi*, and *Plethocardia umbonata*. All of these species are preserved with the shell, from which the matrix can be cleaned with unusual ease.

In the fourth horizon, a bed of light colored shales underlying the Galena limestone, known to the survey as the Galena shales, all the shells of this class are preserved as casts of the interior. These are sometimes highly satisfactory, yet too often the opposite is true. Many of the specimens from this horizon therefore remain unclassified, and until better material becomes available it will not be possible to give a full list of the species. At least two, and very likely three species of *Cypricardites*, one of them probably *C. haynianus* (Safford), can be made out, besides *Tellinomya levata* (Hall), *T. planodorsata*, *Modiolopsis subelliptica*, *Whitella truncata*, and *Plethocardia suberecta*. There is also an elongate *Tellinomya* near *T. nasuta* Hall, a *Modiolopsis* near *mytiloides* Hall, and enough of other distinguishable forms to bring the total number to fifteen or more.

The fifth horizon is a layer a few feet thick at the base of the Galena limestone that I have named the "Platystrophia beds"

in an unpublished section of the Lower Silurian rocks of Minnesota. From this bed I have seen *Cypricardites tenellus, C. nanus?, Tellinomya astartiformis* (Salter), *T. intermedia, Cleidophorus consuetus,* and several undetermined forms.

The sixth horizon occurs in the Hudson river group at Spring Valley and other points in the southern part of the state. This formation is very thin in Minnesota, and the part represented is equivalent to the upper beds of the group as developed in Ohio and Indiana. Fossils are exceedingly plentiful in some of the layers, but consist chiefly of Brachiopoda. As a rule the Lamellibranchiata have suffered through compression, but a good proportion are in an excellent state of preservation. Among them I have recognized *Ambonychia casei* Meek and Worthen, *Whitella obliqua, Lyrodesma major* (described originally by me as *Cleidophorus major*), *Tellinomya recurva,* and *T. similis,* all species occurring also in Ohio. The *Cuneamya sulcodorsata* is, so far as is now known, restricted to this locality. Among the undetermined forms there is a *Modiolopsis* near *pholadiformis* (Hall), another near *M. concentrica* (Hall and Whitfield), one or two species of *Orthodesma,* and a *Tellinomya* near *iphigenia* of Billings.

Respecting the classification of Silurian Lamellibranchiata, it may be well to state that with the progress of our studies we have now arrived at a point where we can appreciate the heterogeneous character of the numerous forms grouped under the generic names *Modiolopsis,* and *Cypricardites,* and in a less degree *Pterinea, Ambonychia, Tellinomya, Cleidophorus,* and *Orthodesma.* I realize fully the inadequacy of the present grouping of the species, yet follow in the same tracks because I fail to see any remedy giving both rapid and permanent relief. Now and then a sharply distinguishable, because essentially Silurian, generic type may be encountered, but many others are indicated which it would be unwise to separate before being closely compared with the wealth of Devonian and Carboniferous forms now known. But that involved more time and labor than I found myself able to devote to the subject, and rather than increase the difficulties of revision, which must be undertaken sooner or later, I have, perhaps unwisely, allowed many species that were determined over ten years ago to be new to science, to lie unpublished in my cabinet. After fully considering the matter, it now appears to me that an incomplete knowledge of our fossil Lamellibranchiata is better than none at all, since the necessity for work in the branch will become all the more evident to students. It was therefore largely in the hope of entic-

ing other energies to the field that I began a series of publications on the subject in the American Geologist. The first of these appeared in the May number, the second in the September, and the third in the December number of that journal, during 1890. It was my intention to continue the papers through the two volumes for 1891, but illness prevented. Among the contemplated papers, one or more which I hope to publish during the present year, is one on species of *Tellinomya* and *Lyrodesma*, a second on *Cleidophorus*, *Cycloconcha*, and *Matheria*, a third on *Orthodesma* and related genera, a fourth on *Cuneamya*, and a fifth on *Ambonychia* and *Pterinea*. When these are published, and the results added to the present paper and the previous publications by Hall, Miller, Meek, and others, the Lower Silurian Lamellibranchiata will have arrived at a promising stage for good classificatory or monographical treatment. Whether or not I shall extend my work on them beyond that stage depends upon circumstances and the success of my endeavors to induce some one of our young paleontologists to take up the group as his specialty.

Two disputed points of nomenclature came up during the preparation of the present paper. The first pertains to the claims for recognition of *Ctenodonta*, Salter, as opposed to *Tellinomya*, of Hall. The latter name has priority, but Hall's original description is so faulty that no blame can attach to Salter for failing to recognize the genus. *Ctenodonta*, on the other hand, was established in a manner so satisfactory that no marked improvement on his diagnosis has since been attempted. Salter's name was adopted by Billings and Safford in this country, and it is now quite generally used in Europe. Hall's name however is used by most American authors. My own views on the points at issue are undecided, and I wish it to be understood that the adoption of *Tellinomya* in the following pages is not to be considered as final, but rather as provisional and in deference to the views of friends and the claims of the venerable author of the name.

The second point, relating to *Cypricardites* of Conrad and *Cyrtodonta* of Billings, brings up questions equally difficult to decide. I shall not here enter upon a discussion of the claims so ably upheld by Hall on the one side, and Billings on the other, and my adoption of *Cypricardites* is to be considered as no more final than in the case of *Tellinomya versus Ctenodonta*.

The thirty two cuts which illustrate the species described in this paper have been reproduced from my own drawings. In

every case the figures have been drawn with great care, and may be relied upon as representing the characters of the species so far as they are known to me.

In describing the rostral portion of the shells it will be noticed that I have, contrary to common usage, often drawn a slight distinction between the terms *beaks* and *umbones*. To meet the want of some term to indicate that portion of the beak which is visible in a side view, I call it the *umbone*, while the application of the term *beak* was restricted to the incurved extremity that in most cases is visible only in a dorsal or anterior view.

TELLINOMYA NITIDA, n. sp.

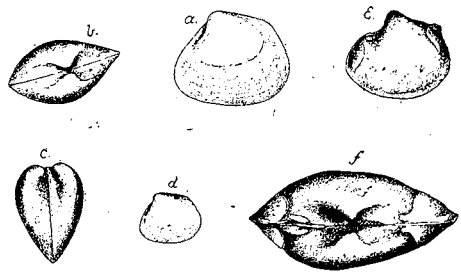


FIG. 1. *Tellinomya nitida*. n. sp. *a*, *b* and *c*, left side, cardinal, and posterior views x2, of a small specimen retaining the shell; *d*, natural size view of same; *e*, left side of a large and very perfect cast of the interior, nat. size; *f*, cardinal view of same, x2 to show the muscular scars.

Shell small, thin, moderately ventricose, subtriangular, the antero-cardinal region somewhat alated; umbones full, beaks closely incurved. Posterior extremity oblique, rather abruptly truncated, flattened, nearly straight, pinched and projecting slightly beyond the convex part of the shell in the upper half, and narrowly rounded below. Ventral margin gently convex, usually curving rather sharply upward at the ends. Anterior end wide, rounded and most prominent in the lower half, straightened above, the junction with the hinge-line subangular. Surface, excepting a few indistinct lines of growth, smooth.

Casts of the interior have strongly projecting beaks. The internal characters of the shell, so far as they can be made out from these casts, are as follows: Hinge line very slightly arcuate, with eight or nine strong teeth behind the beaks, and an undetermined number of smaller ones in front. Anterior

and posterior muscular impressions subequal, distinct, the posterior ones drawn out along the hinge margins. Above the anterior pair there is another much smaller elongated pair, lying close to the hinge. These features are all shown in fig. *f* of the above cut.

This species evidently belongs to the group of species of which *T. levata* Hall is a type, but its posterior end is shorter and more abruptly truncated, agreeing in that respect more closely with *T. abrupta* (*Ctenodonta abrupta* Billings). The latter however is a more ventricose and longer shell, and not as wide anteriorly.

Formation and locality:—Good specimens of this species with the shell are exceedingly rare, but casts of the interior are common in the middle third of the Trenton shales, of Minneapolis, Fountain and other localities in the state of Minnesota.

TELLINOMYA COMPRESSA, n. sp.

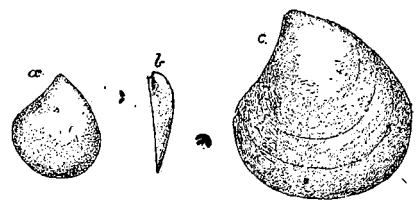


FIG. 2. *Tellinomya compressa*, n. sp. *a*, right valve of this species; *b*, posterior view of same; *c*, same, x2, showing the extremely fine concentric lines of the surface. These are preserved at the posterior end of the shell only.

Shell small, erect, the height greater than the length, subtriangular, compressed, thin; beaks small, almost acuminate, moderately incurved; umbones rather flat, the convex part of the shell terminating somewhat abruptly along the anterior and posterior cardinal margins. In the outline, these two margins, meeting at the beaks, form an angle of about 85 degrees, with the anterior gently convex and the posterior correspondingly concave. Aside from this difference in the curvature of the upper parts the ends are subequal, and round uniformly into the strongly convex ventral edge. Surface with faint lines of growth, and exceedingly fine, crowded, concentric striæ, six to eight in one mm.

Hinge line bent at a right angle, with about twenty teeth, the central ones very small, those on each side larger and bent. Muscular impressions not observed.

This species forms one extreme and *T. pectunculoides* Hall, the other, of a group of at least ten species of which *T. astartiformis* Salter, may be taken as the type. They are all much shorter than the species of the typical section of the genus.

Compared with related species *T. alta* Hall, is more erect, more ventricose, with the ventral margin less convex, and a thicker shell. *T. astartiformis* is near but differs in being more ventricose, more coarsely striated, and in having more obtuse beaks. Salter's species, excepting that it is more ventricose than either, is in all other respects very nearly intermediate between *T. compressa* and *T. intermedia.*

Formation and locality:—In the upper third of the Trenton shales, six miles south of Cannon Falls, Minnesota. It is here associated with *T. levata*? Hall, *T. pulchella* Hall, *Lyrodesma postritriatum* Emmons, *Modiolopsis concava*, n. sp. and a fossil very much like *Salterella billingsi* Safford.

TELLINOMYA PLANODORSATA, n. sp.

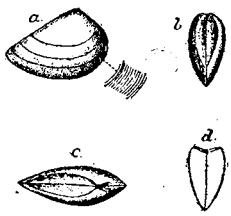


FIG. 3. *Tellinomya planodorsata*, n. sp., *a*, *b*, and *c*, left side, posterior, and dorsal views of the nearly perfect type specimen of this species, nat. size; *d*. sectional view of same, with the posterior dorsal side at the top of the figure.

Shell small, depressed convex, subtriangular or trapezoidal, the width and length respectively as ten is to fourteen; beaks small, incurved, scarcely projecting above the hinge, and situated about one third of the entire length from the anterior extremity. Posterior end long, subtriangular in outline, with the extremity subacute, and the dorsal side almost straight (faintly convex) from the beaks backward; ventral margin broadly rounded, anterior edge more strongly convex. Postero-cardinal side thick, with a large, sharply defined, and slightly concave lunette, reaching from the beaks to near the posterior extremity of the shell. Surface gently convex, scarcely sloping toward the lunette, marked with exceedingly fine striæ and a few stronger lines of growth.

Interior unknown, unless a cast of the interior from the overlying Galena shales belongs to this species. This cast which was formed by a shell of scarcely three fifths the length of the type specimen, agrees in most respects, only the beaks project considerably above the hinge line, causing the posterior cardinal line to be concave instead of straight or slightly convex. Still, we must remember that it is the inner or lower

side of the hinge plate that is represented in the internal cast, and as this is always thicker in these shells than the shell substance at the head of the beaks, it is to be expected that the latter would be more prominent in the casts than in the shell itself. The cast in question is considerably like those of *T. levata* Hall, differing mainly in being a little longer, less ventricose, with the back flatter, and in having the muscular scars much less distinct. Indeed, the latter are so faint that their shapes cannot be made out with certainty—a condition, again, to be expected in a species that evidently depended chiefly upon the large size and strength of the external ligament to keep its valves in position.

Taking the shell itself, I know of no species with which it might be confounded.

Formation and locality:– Same as the preceding.

TELLINOMYA INTERMEDIA, n. sp.

FIG. 4. *Tellinomya intermedia*, n. sp. *a*, and *b*, right and posterior views of an average example of this species, nat. size; *c*, cast of the interior of a left valve, nat. size, showing muscular scars, impressions of hinge teeth, and obtusely ridged character of the antero-cardinal region.

Shell thin, of medium size, moderately ventricose, rather erect, the height a little greater than the length. Outline subtriangular, at the beaks, which are obtusely acuminate and incurved, forming very nearly a right angle; anterior cardinal margin very gently convex, posterior cardinal edge correspondingly concave, ventral margin together with the curve into the ends forming a semicircle. Ends sub-equal, the posterior sometimes a little the longest (see fig. 4 *c*.). Umbones full, the remainder of the surface sloping uniformly to the free margins. An obscure sulcus may be detected near the anterior margin, and along the dorsal part of this end the surface descends abruptly to the hinge plane. Surface with strong, closely arranged, thread-like, concentric lines, about twelve in 5 mm. At intervals of about two or three mm. generally a fold stronger than the rest.

Casts of the interior exhibit a faint ridge and sulcus in the anterior end, two sharply defined muscular scars and pallial line in each valve, and above the posterior pair a much smaller

pair of scars situated close to the hinge. Hinge plate rather narrow, the teeth numerous, over thirty, as usual very small centrally, growing larger gradually toward the ends of the hinge.

This species is associated with and closely related to *T. astartiformis*, described by Salter from the Black River and Trenton limestones of Canada, but is a less ventricose shell, with coarser striæ, and more rounded ends and ventral margin. *T. compressa*, occupying a lower horizon, is more compressed, higher, has sharper beaks, and much finer striæ. Both *T. subrotunda* and *T.* (?) *hamburgensis* Walcott (Mon. U. S. Geol. Sur., vol. 8, p. 76) have a more rounded outline.

A very similar but smaller and clearly distinct species, differing chiefly in the crenulation of the hinge, occurs in the Utica horizon of the Cincinnati group, at Covington, Kentucky.

Formation and locality:—Not uncommon at the Platystrophia horizon at the base of the Galena limestones, near Fountain, Minnesota.

TELLINOMYA SUBROTUNDA, n. sp.

FIG. 5. *Tellinomya subrotunda*, n. sp. Two views, external and internal, of a well preserved right valve, nat. size.

Shell of medium size, comparatively thick, compressed, nearly circular in outline, with the beaks small, prominent, rather acuminate, curving inward and posteriorly. Posterior dorsal line straight except just beneath the beaks where it is concave. Anterior dorsal margin gently convex, rounding gradually into the general outline. Umbones small, the surface almost uniformly depressed-convex. At intervals of from two to three mm., the surface presents strong, lamellose lines of growth, and between these much finer concentric lines, about six in two mm.

Interior with subequal, ovate, moderately impressed, anterior and posterior muscular scars. Hinge plate strong, bent

at a little more than a right angle, with numerous (about thirty-five) small teeth, as usual strongest near the extremities of the hinge.

This species is more rounded and less ventricose than *T. intermedia*, is more rounded and evenly convex than *T. compressa*, and has more prominent beaks and more abruptly bent hinge than *T. pectunculoides* Hall. A species intermediate in character between the last and the present form, and the nearest relative of *T. subrotunda* known to me, occurs in the upper beds of the Cincinnati group at several localities in Ohio.

Formation and locality:—Base of the Trenton limestones, Mercer county, Kentucky. It is possible that certain illy preserved casts of the interior, from the upper part of the Trenton shales, near Cannon Falls, Minnesota, may belong to this species.

TELLINOMYA SIMILIS, n. sp.

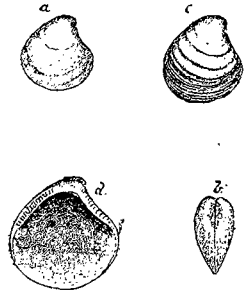


FIG. 6. *Tellinomya similis*, n. sp. *a* and *b*, left and posterior views of a rather small shell; *c*, left side of another specimen; *d*, interior of a large right valve. All the figures are of the natural size.

Shell small to medium size, moderately ventricose, subtriangular, the length and height respectively as five is to six. Umbones full, rounded, the rostral portion strongly recurved, with the beaks small, and projecting slightly above the hinge. Antero-dorsal edge convex, thick, flattened, but not sharply defined. Postero-dorsal edge rather strongly concave, impressed so as to form an illy defined, imperfect lunette. Anterior side almost uniformly convex, curving neatly into the well rounded ventral margin. Posterior side rather narrowly rounded and slightly produced in the lower half. Surface almost uniformly convex, highest a little above the center, generally with a few well-marked varices of growth, and with finer concentric lines in the lower part. Hinge plate of moderate strength, with numerous small teeth (thirty-five to forty-two), in the largest example seen with about twenty-seven anterior and fifteen posterior to the beak. Posterior teeth the largest, bent. Muscular scars faintly impressed.

The shape of this species is exceedingly like that of *T. astartiformis* Salter, of the Black River and Trenton limestones, but it is not so ventricose. If the hinge of that species is correctly represented in Salter's figures, the form under consideration must be regarded as specifically distinct, since it has smaller, less bent and more numerous teeth. According to Salter the teeth of *T. astartiformis* are largest on the anterior side, while in *T. similis* the opposite is the case.

It is also very much like its associate, *T. recurva*, but is distinguished by being a little higher, more uniformly rounded on the anterior side, and without the anterior sulcus. More important differences are the greater tumidity of the umbones, less prominent beaks, scarcely defined posterior lunette, and less strong hinge plate. Casts of the interior are separated chiefly by the greater thickness of the rostral portion. They are also nearly always of smaller size than those of *T. recurva*.

Formation and locality:—Upper beds of the Hudson River group, Spring Valley, Minnesota, and Blanchester, Ohio.

TELLINOMYA RECURVA, n. sp.

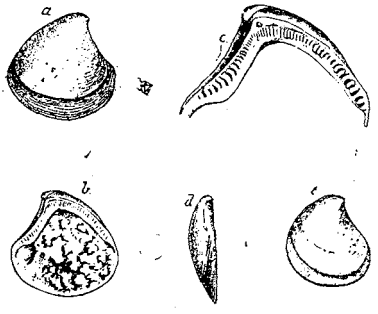


Fig. 7, *Tellinomya recurva*, n. sp. *a* and *b*, external and internal views of a left valve, nat. size; *c*, hinge of same, x2; *d*, posterior view of same; *e*, another left valve, nat. size, of somewhat different shape. Specimens from Spring Valley, Minn.

Shell small or of medium size, not thick, rather compressed, subtriangular, the length and height almost equal. Rostral portion strongly recurved, umbones small, depressed, beaks very prominent, posterior to the center of the shell. Dorsal slopes flattened, sharply defined, with the ridges projecting beyond or overhanging the edge of the hinge plate. This is true especially of the posterior side, where they form an elongated lunette. Anterior dorsal margin more strongly convex than in any other species known; posterior dorsal margin correspondingly concave. Outline, with the anterior side rather sharply rounded in the lower half, the ventral margin sloping

backward and most prominent a little behind the center, then curving upward to meet the concave posterior side at a point very nearly opposite the middle of the height of the shell. Posterior end rather narrowly rounded, most prominent just beneath the center. Surface with several strong growth lines, and between them fine concentric striæ, about ten in three mm. An obscure sulcus extends from the beak along the anterior margin to the antero-ventral region. Hinge plate very strong, bent at a right angle, the posterior half straight, with at least twenty small teeth, decreasing in size gradually toward the beak; anterior half gently convex, with about thirty teeth. Considering the unusual strength of the hinge plate, the teeth are very small. Anterior and posterior muscular scars large, moderately impressed.

Compared with other species the nearest appear to be *T. astartiformis* Salter, and *T. compressa*, and *T. similis* of the present paper. From the first it is distinguished by being less ventricose, in the flattening of the dorsal edges, and in the greater number and smaller size of the hinge-teeth. The second is more compressed, and has more erect beaks, finer surface striæ, and fewer hinge teeth. The third is without the anterior sulcus, has no sharply defined posterior lunette, is higher, generally of smaller size, and has the umbones more tumid, with the point of greatest convexity above the center.

Formation and locality:—Upper beds of the Hudson River group, Spring Valley, Minnesota. It is here associated with *T. similis*, *T.* near *iphigenia* Billings, *Lyrodesma major* Ulrich, and an abundance of Brachiopoda. Casts of the interior, apparently referable to this species, occur in equivalent beds at Oxford, Waynesville, and other localities in Ohio.

TECHNOPHOROUS (?) EXTENUATUS, n. sp.

Fig. 8, *Technophorus (?) extenuatus*, n. sp. Left side of the only example, a nearly perfect cast of the interior, seen. nat. size.

Shell small, compressed, elongate, alated and drawn out posteriorly. Beaks small, erect, moderately prominent, situated about one-fourth of the entire length from the anterior extremity. Just in front of the beaks the casts of the interior exhibit a deep though not very long impression. Anterior end broad, rounded, most prominent in the upper third; ventral margin broadly convex and slightly produced a little in front of the middle; behind this point the outline is nearly straight (slightly concave) sloping up toward the narrow (? pointed)

posterior extremity. Cardinal line nearly as long as the entire shell, gently concave behind the beaks. A thin, sharply defined ridge, slightly curved, extends across each valve from the beak to the lower side of the posterior end. Surface gently convex in the anterior half, marked with obscure concentric lines of growth.

Length about 21 mm., greatest height 10 mm., greatest convexity about 3.5 mm.

This is a peculiar shell, and it is with considerable doubt that I refer it to the recently proposed genus *Technophorus*, Miller (North Amer. Geol. and Pal., p. 514, 1890). I do so because in another undoubted species of the genus in my possession the posterior extremity of the hinge is drawn out in a manner similar to what we see in the present shell. The prolongation however is much less extensive in the undescribed species. Both the latter and Miller's type of the genus (*loc. cit.*) have two posterior ridges crossing each valve, and in both again the hinge line is straight.

The Cincinnati species which I called *Nuculites yoldiaformis* (Jour. Cin. Soc. Nat. Hist., vol. 2, p. 24, 1879), is probably a related form. As it is clearly not a true *Nuculites* and seemingly without any near relations to any established genus, it might be well to erect a new genus for their reception.

Formation and locality:—Rare in the middle third of the Trenton shales at Minneapolis, Minnesota. I am indebted to the liberality of Prof. C. W. Hall, of the State University of Minnesota for the only specimen seen.

CLEIDOPHORUS CONSUETUS, n. sp.

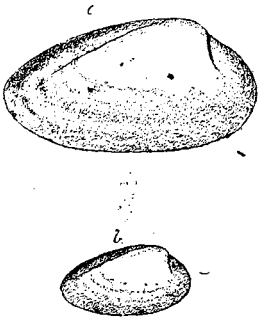


Fig. 9, *Cleidophorus consuetus*, n. sp. *a*, cast of a right valve of this species, x2; *b*, same of the natural size.

Shell above the medium size for the genus, transverse, moderately elongate, ovate, rather strongly convex, the length equaling nearly twice the height. Beaks small, incurved, flat-

tened. Dorsal line convex, sloping downward behind the beaks to the narrowly rounded posterior extremity. Anterior end neatly rounded, wider than the posterior. Ventral margin gently convex in the middle, more strongly and almost equally curved at the ends. An obscure umbonal ridge traceable from the beaks three fourths of the distance to the posterior basal edge. Above it an impressed narrow line, beyond which the surface descends rapidly to the dorsal margin. Casts of the interior with a narrow, slightly curved, clavicular impression just in front of beaks, extending but little more than one third of the distance to the antero-basal margin. Surface of casts with a few obscure growth lines or folds. Point of greatest convexity a little above and behind the center of the shell. In a dorsal view the central half of the outline is very slightly flattened.

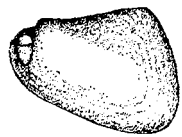
Length 17.2 mm., height 9.0 mm., thickness of both valves 5.3 mm.

This shell appears to be related to *C. cuneatus* and *C. elongatus*, described by Hall from the Silurian rocks of Nova Scotia (Can. Nat. and Geol., vol. 5, pp. 148 and 150, 1860). It is however specifically distinct, the shape being different and the posterior sinus situated higher up and very much less defined. *C. planulatus* (Conrad) and *C. ellipticus* Ulrich, also have somewhat different outlines, and have the cardinal slopes less abrupt, the whole surface in those species being more uniformly and less convex.

Formation and locality:—Rare in the Platystrophia horizon at the base of the Galena limestones. It is associated with *Tellinomya intermedia Ulrich*.

MODIOLOPSIS PLANA, Hall.

Modiolopsis planus HALL, 1861. Report Superintendent Geol. Sur. Wis., p. 30. Geol. Wis. vol. I, pp. 38 and 438, fig. 6.



The above cut represents an internal cast of the left valve of a shell that occurs rather rarely in the upper beds of the Trenton limestones at Minneapolis and other localities in the state. There can be no question of the identity of this Minnesota form with the Wisconsin types of the *Modiolopsis plana* Hall. The latter seem to have been smaller, being said to be about

three-fourths of an inch in length, but in all essential respects, our specimens agree sufficiently well with Hall's description and figure.

Among the most important features of the species is the elongate form and duplex character of the strongly impressed anterior muscular scar, the alate character of the postero-cardinal region, the length and straightness of the hinge line, and the wide truncated posterior end. The hinge also seems to have been unusually strong. In most of these respects the species approaches *M. truncata* Hall, of the Cincinnati group, more or less nearly.

These two species, together with several others, stand apart from the typical section of the genus, and should perhaps be separated under another generic name. But the whole genus *Modiolopsis* needs revision, and when this is done it will, I am satisfied, be found necessary to institute several subdivisions.

MODIOLOPSIS SIMILIS, n. sp.

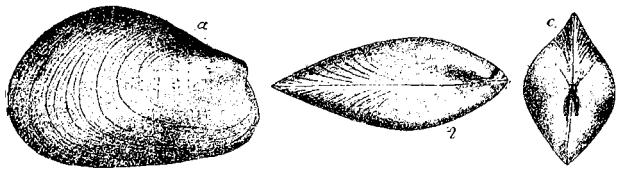


Fig. 11, *Modiolopsis similis*, n. sp. *a*, *b*, and *c*, right side, dorsal, and anterior views of a well preserved cast of the interior. nat. size.

Shell of medium size, elongate, ovate, widest in the posterior half, contracting to between one half and three fifths of the greatest width at the beaks. Hinge line nearly straight and about half as long as the shell posterior to the beaks. Anterior end small, neatly rounded; ventral margin nearly straight in the middle, curving up at the ends; posterior end broadly rounded, slightly produced in the lower half, sometimes forming an obtusely angular junction with the hinge line. Beaks nearly terminal, rather small, compressed, incurved, projecting moderately above the hinge. Surface moderately convex, most prominent along the posterior umbonal ridge, which is stronger than usual in species of this genus. Cardinal slope concave. A broad and comparatively well defined, mesial depression extends obliquely across the shell from the beak and, expanding, causes the straightening of the ventral margin.

Shell very thin, so that the muscular scars are scarcely visible in the casts. Surface with numerous fine concentric lines, and some stronger varices of growth.

Of all the described species of this genus known to me *M. concentrica* Hall and Whitfield, from the upper beds of the Cincinnati group, seems to be nearest. Excepting that the Minnesota shell is wider posteriorly, the two species agree very nearly in their outlines. In other respects however they are quite different, *M. concentrica* having a thicker shell, with the anterior muscular scar much more distinct, the beaks projecting less, the posterior umbonal ridge and median depression both lesser features, and the surface markings coarser. The outline of an undescribed species, from the base of the Trenton limestone of central Kentucky, agrees even better in its general contour with *M. similis*. But it too seems to be distinct, since in it the umbonal ridge and the mesial sinus are even less distinguishable than in *M. concentrica*.

Because of the exceeding thinness of its shell I would place *M. similis* into the same section of the genus that includes *M. cincinnatiensis* Hall and Whitfield, *M. pulchella* Ulrich, and *M. subtruncata* Ulrich. These are all widely removed from *M. modiolaris* Conrad, the type of the genus, and in some respects are nearer *Orthodesma*, Hall and Whitfield.

Formation and locality:—Rare in the middle third of the Trenton shales, at Minneapolis, Minnesota, where the illustrated specimen was found by Prof. C. W. Hall, of the State University, who kindly gave it to me for description.

MODIOLOPSIS SUBELLIPTICA, n. sp.

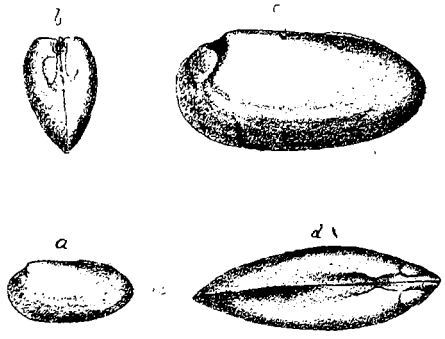


Fig. 12, *Modiolopsis subelliptica*, n. sp. *a*, left side of a cast of the interior, nat. size; *b*, *c*, and *d*, anterior, lateral, and dorsal views of same, x2.

Shell small, elongate-elliptical in outline, the length fully twice as great as the breadth, a little the widest anteriorly, with the dorsal and ventral margins subparallel and both gently

convex, the anterior end semicircular, the posterior more narrowly rounded and slightly produced in the middle. Beaks small, incurved, projecting but little above the hinge, situated about one-fifth of the entire length from the anterior extremity. Umbonal ridge slight, running close to the dorsal margin, causing the central part of the dorsal side of the shell to be somewhat flattened. Sides of valves moderately convex, with point of greatest convexity a little in front of and above the middle.

Casts of the interior show a sharply defined, ovate, anterior muscular scar, which must have been bounded on the inner side by a strong internal ridge, extending downward and curving forward from the hinge, at a point just in front of the beaks, to the lower end of the muscle. The posterior scar and pallial line are not distinguishable in the material at hand. The lower and anterior parts of casts exhibit a few, obscure, broad lines of growth.

This is one of a small group of species that remind one greatly of *Cleidophorus*, Hall, to which genus they might be referred were it not for the distinct impression of the anterior muscular scar. The shape and size of the present species is considerably like that of *Cleidophorus consuetus*, described in this paper, but, aside from other differences, the one relating to the presence of a muscular scar will distinguish them at once. I know of no described species of *Modiolopsis* sufficiently resembling this to necessitate comparisons.

Formation and locality:—Galena shales, near Cannon Falls, Minnesota.

MODIOLOPSIS CONCAVA, n. sp.

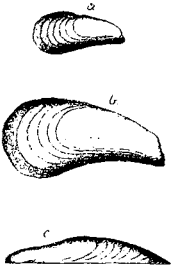


Fig. 13. *Modiolopsis concava*, n. sp. *a*, right valve of the natural size; *b*, and *c*, side and dorsal views of same, x2.

Shell very small, elongate, the greatest width less that half the length, curved, the posterior end much the widest, broadly rounded, the anterior end exceedingly short and narrow, con-

tracted beneath the beaks, which are small, compressed, and project but little above the hinge. Height of posterior third about two and one-half times as great as at the beaks. Dorsal side gently arcuate; anterior two-thirds of ventral margin strongly concave, a fact due in a great measure to the width of the sulcus and the rapid slope of the surface included in it. Umbonal ridge slight, cardinal slope rather strongly convex. In a dorsal view the anterior half of the shell appears compressed, yet the point of greatest thickness is very near the middle of the length.

Surface marked simply with concentric lines of growth. Internal characters not observed.

This peculiar species is another of the number that I am referring to *Modiolopsis* provisionally. I place it here, first, because it seems to be related to some forms of the *M. faba* section of the genus, and, second, because I know of no other established genus that would offer a more fitting placement.

Formation and locality:—Upper third of the Trenton shales, about six miles south of Cannon Falls, Minnesota.

ORTHODESMA MINNESOTENSE, n. sp.

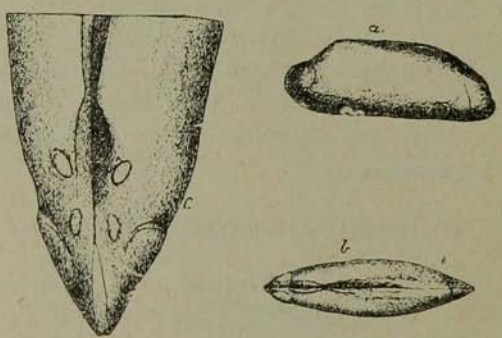


Fig. 14. *Orthodesma minnesotense*, n. sp. *a* and *b*, left side and dorsal views of a cast of the interior; *c*, dorsal view of anterior third enlarged to show the muscular scars. x4.

Shell small, elongate, subrhomboidal, with the dorsal and ventral margins nearly straight and parallel; the length two and one half times the width. Beaks small, incurved, compressed, projecting moderately above the hinge, and situated about one fourth of the entire length from the anterior extremity; posterior umbonal ridge subangular, cardinal slope abrupt, in casts of the interior with a linear impression close to and on each side of the hinge line. Anterior end small, contracted a little in front of the beaks, almost uniformly rounded; posterior

end oblique, sloping upward and forward from the produced and narrowly rounded lower part.

Interior with the anterior pair of muscular scars rather distinctly marked and large; above and between them and the beaks, two other very small pairs of scars are to be seen on the specimen figured above, but the posterior muscles left no appreciable impressions. Surface of casts with a few obscure folds of growth.

This species is related to *O. curvatum* Hall and Whitfield, though more nearly approaching *O. contractum* Hall, in the general outline. It differs from both in having the posterior end narrower, and in wanting the strong wrinkles which occur on the posterior cardinal slopes of those shells.

Formation and locality:—Middle third of the Trenton shales, St. Anthony Park, St Paul, Minnesota.

ORTHODESMA SAFFORDI, n. sp.

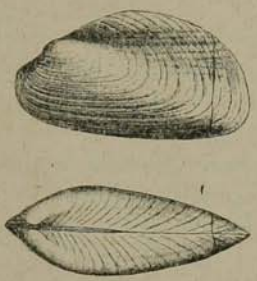


Fig. 15, *Orthodesma saffordi*, n. sp. Two views, side and dorsal, of a rather small specimen of this species, nat. size. The largest specimen seen is at least one-third larger.

Shell of medium size, elongate, trapezoidal, widest posteriorly, the length somewhat less than twice the greatest width; hinge line straight, with a narrow, concave ligamental area, extending about one-half of the entire length from the anterior extremity; ventral margin nearly straight or slightly convex, forming an angle of about 38 degrees with the hinge line. Anterior end narrow, about half as wide as the posterior part of the shell, its length equalling about one-fifth of the entire length, the outline erect above, subangular where it joins the extremity of the hinge, rounding below into the basal line. Posterior end wide, sharply curved and produced below, more gently curved and sloping forward in the middle and upper thirds, meeting the extremity of the hinge line without forming any perceptible angle. Beaks small, incurved, somewhat flattened on the umbones, projecting slightly above the hinge; umbonal ridge

strong, subangular, traceable generally to the postero-basal margin; cardinal slope at first concave, gradually flattening posteriorly; with a distinct, linear sulcus running midway between the umbonal ridge and the dorsal margin, and both above and beneath this, several other, but more obscure, radiating lines may be detected; ventral slope flattened.

Surface of the shell marked strongly with rather irregular and unequal concentric lines of growth. The radiating lines on the cardinal slope have been mentioned.

One of the specimens preserves a considerable part of the hinge. It is, so far as can be seen, perfectly straight both in front and behind the beaks, and without teeth or thickenings. The ligamental area, however, is rather wide and concave. Muscular impressions unknown.

This species is wider posteriorly than any other *Orthodesma* known to me. In the general outline, excepting that the beaks are too far from the anterior extremity, and the hinge too straight, it is more like *Modiolopsis*. But it has the same kind of hinge as *Orthodesma rectum* Hall and Whitfield, the type of the genus.* The depressed line in the cardinal slope is another feature that is frequently met with, especially in the casts of species of *Orthodesma*.

It gives me much pleasure to name this fine species for Prof. Jas. M. Safford, of Nashville, Tennessee, as a slight token of my appreciation of his valuable and long continued labors in American geology.

Formation and locality:—In the lowest member, Safford's "Central limestone," of the Trenton formation, at Murfreesboro, Tennessee. The beds holding this fossil are equivalent to either the Chazy or the lower part of the Birdseye.

*Hall and Whitfield say, in their generic description (Pal. Ohio, vol. ii, p. 93), that the hinge line is "contracted or bent beneath or anterior to them", *i. e.* the beaks, and this supposed feature they relied upon chiefly in distinguishing their genus from *Orthonota*, Conrad. But this supposed bending or contraction of the hinge line does not exist in *O. rectum* nor in *O. curvatum* or in any other species of *Orthodesma* known to me. The evidence bearing upon the disputed point afforded by my collections is, at any rate in the two species mentioned, unequivocal.

CYPRICARDITES SARDESONI, n. sp.

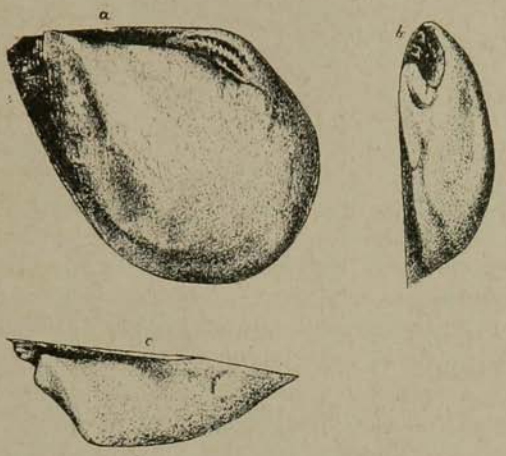


Fig. 16. *Cypricardites sardesoni*. n. sp. *a*, *b* and *c*, lateral, anterior, and dorsal views of a cast of the interior of a right valve, nat. size.

Shell of the medium size, known only from casts of the interior, and the impression of the hinge and free margins on the limestone matrix. The outline was subrhomboidal, with the cardinal and anterior margins nearly straight, and the two lines forming an angle of about 62 degrees; anterior extremity subacute or sharply rounded; hinge line equaling nearly three-fourths of the entire length; postero-ventral margin broadly rounded, almost semicircular; above this the posterior outline is somewhat straightened and slopes forward rapidly, meeting with the cardinal line to form an angle of about 135 degrees; the immediate junction however is not perceptibly angular.

In the casts the beaks project strongly, are nearly terminal, pointed, slightly incurved, greatly compressed, and somewhat twisted. A strong sulcus extends from the beaks to the antero-basal part of the cast; this sulcus occupies the larger part of the anterior slope, and from its inner side the umbonal ridge, constituting the highest portion of the surface, rises abruptly. For the reasons mentioned the anterior slope appears flattened and in part concave, while the posterior is almost uniformly convex to the margin. Cardinal slope abrupt, especially near the hinge.

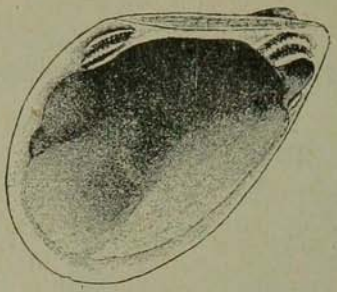


Fig. 17. Interior of left valve of *Cypricardites sardesoni*, n. sp., as shown in gutta-percha impressions.

Gutta-percha impressions, as shown in fig. 17, bring out the internal characters in a very satisfactory manner. They show a wide and faintly striated ligamental area, two lateral and two cardinal teeth, both pairs strong and distinctly crenulated on the sides. The cardinal pair are considerably curved, and the lower one forms the upper boundary of the very sharply impressed anterior muscular scar. On the whole the hinge impresses one as being unusually strong. The posterior muscular scar is large, ovate, double or prolonged below, and but faintly impressed.

I know of no associated species, nor of any now referred to this genus, that is at all likely to be confounded with *C. sardesoni*.

The specific name is given in honor of the discoverer, Mr. F. W. Sardeson, of Minneapolis, Minnesota, an enthusiastic collector and a promising student of paleontology.

CYPRICARDITES OBTUSIFRONS, n. sp.

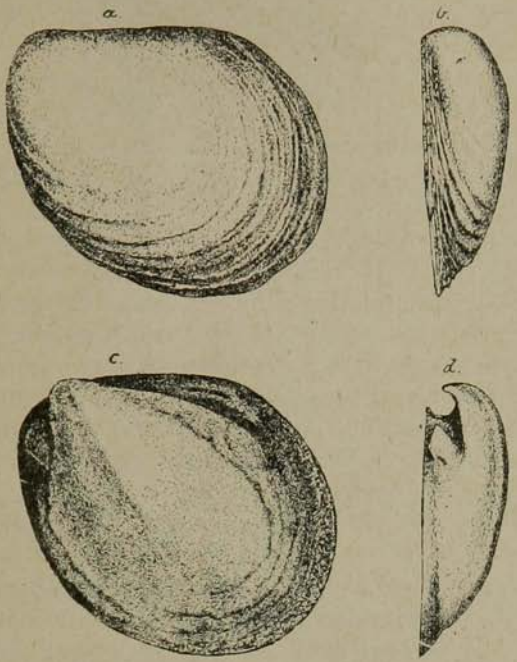


Fig. 18. *Cypricardites obtusifrons*, n. sp. *a*, and *b*, lateral and anterior views of a gutta percha impression of the exterior of a left valve; *c*, and *d*, similar views, of the cast of the interior of same shell; all nat. size.

Shell of medium size, scarcely ventricose, oblique, subovate, widest and broadly rounded posteriorly, with the beaks subterminal, small, projecting very slightly; umbonal region full, but scarcely distinguishable in the general convexity of the surface; anterior end obtuse, forming nearly a right angle with a straight hinge line, the junction between the two rounded; posterior and basal margins semicircular. Surface with the greatest convexity in the antero-dorsal third, the cardinal and anterior slopes more gently convex; surface markings consisting of rather irregular, fine and coarse, sublamellose lines of growth.

Casts of the interior with the beaks large, compressed, strongly, incurved; a moderate umbonal ridge and sulcus crosses the casts from the beaks in a direction nearly parallel with the anterior margin, becoming obsolete before reaching a point near the middle of the basal line. Anterior muscular scar deeply impressed, rather large, partly overhung by the projecting beak. Posterior scar illy defined.

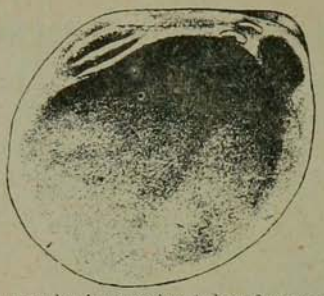


Fig. 19. View of a gutta percha impression taken from a mould of the interior of a left valve of *Cypricardites obtusifrons*, n. sp.

The gutta percha impression illustrated in fig. 19, was prepared from the cast of the interior represented by fig. 18, *c* and *d*. It shows that the hinge plate was strong, nearly flat in the central part, with three strong lateral teeth, and two small anterior cardinal teeth. Just in front and beneath the latter is the large and strongly impressed anterior muscular scar.

In some respects this species is like *C. sardesoni*, which is also associated with it in the limestone, but a comparison of the figures here given of the two species will show so many striking differences that there is really no danger of confusion between them. Some resemblance is also to be noted to species like *C. obtusus* Hall, *C. saffordi* Hall, and *C. haynianus* Safford, but they are all really quite different internally, and in having the umbones more prominent. *C. niota* Hall, occupying a similar position in Wisconsin, is likewise to be compared. It is a more erect shell, and differs in other particulars as well.

Formation and locality:—Collected by Prof. C. W. Hall, of the State University, in the upper beds of the Trenton limestone, at Minneapolis, Minnesota.

CYPRICARDITES GLABELLUS, n. sp.

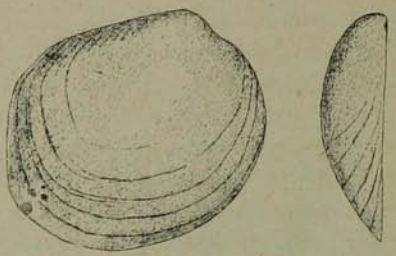


Fig. 20. *Cypricardites, glabellus*, n. sp. Lateral and anterior views of a right valve.

Shell scarcely reaching medium size, broad-ovate or subquadrangular in outline, with the back straight, the posterior margin sloping forward in the upper fifth, straightened and

nearly vertical in the middle, and curving forward below into the broadly rounded ventral margin; anterior side convex, short. Beaks small, the umbonal region full, very slightly prominent, with the line of greatest convexity—not sufficiently defined to be called a ridge—extending obliquely across the valves from the beaks toward the postero-ventral edge; point of greatest convexity very near the center of the shell. Cardinal slope flat, rather abrupt; between this and the undefined umbonal ridge the surface is again slightly flattened; anterior and basal slopes gently convex. Surface nearly smooth, near the margins marked simply with a few lines of growth. Internal characters unknown.

The outline of this species is about intermediate between *C. ventricosus* Hall, and *C. niota* Hall, but the relations between them are, I am satisfied, quite remote. Both those species are at once distinguished by the greater prominence of their umbones.

Formation and locality:—Rare in the middle third of the Trenton shales, at Minneapolis, Minn. A cast of the interior from the "Buff limestone" at Beloit, Wis., now before me, may belong to this species.

CYPRICARDITES CINGULATA, n. sp.

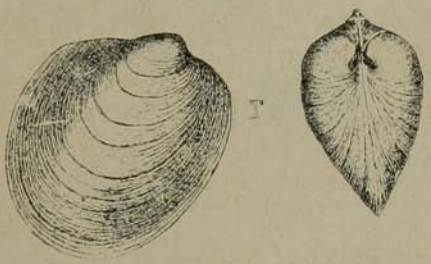


Fig. 21, *Cypricardites cingulata*, n. sp. Lateral and anterior views of a nearly perfect specimen of this species, nat. size.

Shell scarcely reaching the medium size, ventricose, oblique, the outline, excepting a slight prominence at the postero-cardinal edge, regularly ovate, but narrow anteriorly and broadly rounded posteriorly; hinge line rather short posterior to the beaks, slightly convex; beaks of good size, strongly incurved, projecting well above the hinge, situated one fifth of the entire length from the anterior extremity; umbones prominent, full, with an obtuse ridge or line of greatest altitude running from the beaks toward the postero-basal side; anterior and cardinal slopes both slightly concave, the latter descending more abruptly. Point of greatest convexity near the middle of a line

drawn parallel with, and one-third of the height of the shell beneath the hinge. Surface marked with very fine concentric lines, easily abraded, and distant irregular lines or wrinkles of growth. Shell substance thin. Internal characters unknown.

This species seems to be rather closely related to *Cyrtodonta canadensis* Billings, but is more erect, comparatively higher posteriorly, and has its outline more produced and more sharply rounded in the postero-cardinal region. *C. ventricosus* Hall, is not so wide posteriorly, and on the whole has a different outline, being, besides, more ventricose. *C. grandis* Ulrich, is a larger and almost circular shell.

Formation and locality:—Middle third of the Trenton shales, at Minneapolis, Minnesota.

CYPRICARDITES GERMANUS, n. sp. or var.

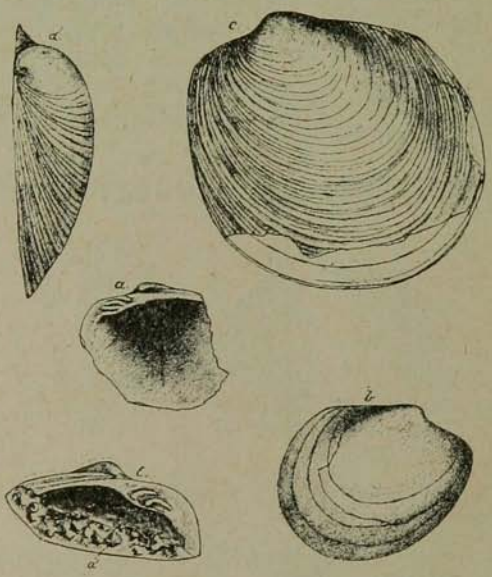


FIG. 22, *a* and *b*.

FIG. 22, *a* and *b*. *Cypricardites germanus*, nov. nom. *b*, fragment of a right valve of this species or variety, restored, nat. size; *a*, interior of same, showing the thin hinge, anterior teeth, and the faintly impressed muscular scar; *c*, *d*, and *e*, lateral and anterior views, and the greater part of the hinge of a small left valve of *Cypricardites grandis* Ulrich, from the upper Trenton near Danville, Kentucky. Introduced for comparison with *C. germanus* and *C. tenellus*.

Of this form I have several fragmentry shells, none of them better than the one above illustrated. Ordinarily, I would not consider such material as sufficient to justify description and naming, but in the present instance it has seemed right to set good custom aside. The specimens, namely, exhibit a

striking departure from usual *Cypricardites* in the great projection beyond the beaks of the anterior end of the shell. In most species the anterior end is very short,—occasionally the beaks are quite terminal—but in *C. grandis* Ulrich (Amer. Geol., vol. 6, p. 387, 1890) of which a small and unusually oblique example is illustrated in fig. 22, *c*, *d*, and *e*, it is longer than in any other species heretofore described, while in the proposed *C. germanus* the projection is comparatively greater yet.

The shell in *C. germanus* is very thin, so that even the anterior muscular impression is scarcely recognizable, the hinge too is very thin, while the anterior teeth are small and drawn out to an unusual distance in front of the beaks. Excepting that the teeth are less curved and the hinge plate less expanded where they occur, the characters of the form are not greatly different from *C. grandis*. It is very likely merely a small variety of that species. Both are found in the upper beds of the Trenton near Danville, Kentucky, the small form a few feet higher in the series than the large *C. grandis*. I have seen also a number of internal casts, in the lower part of the Galena limestone and in the shales immediately beneath them, at localities in Goodhue and Fillmore counties, Minnesota, that may belong to one or the other of these forms, but they are all too illy preserved to admit of determining their relations with certainty.

CYPRICARDITES TENELLUS, n. sp.

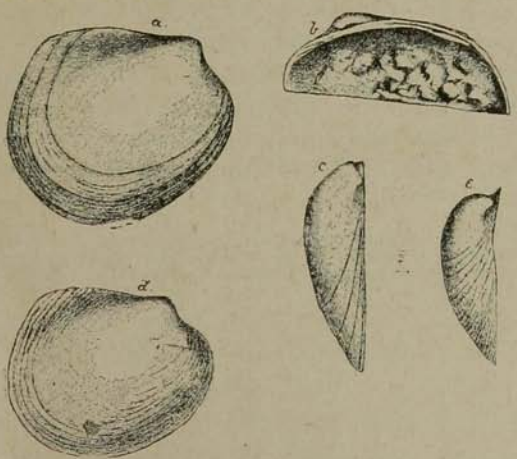


Fig. 23, *Cypricardites tenellus*, n. sp. *a*, right valve, with strongly marked lines of growth; *b*, hinge of same; *c*, anterior view of same; *d*, a smaller valve with finer surface markings and wider anterior end; *e*, anterior view of same; all of the natural size.

Shell of medium size or less, moderately ventricose, not very oblique, subovate, widest posteriorly, slightly alate and subangular or sharply rounded in the postero-cardinal region. Hinge line long, slightly arcuate; posterior margin straightened in the upper half, broadly rounded and produced a little in the lower half; ventral margin rather strongly convex, and most prominent a little behind the middle; anterior end more or less narrowly rounded. Beaks small, incurved, projecting moderately beyond the hinge line; situated about one-fourth of the entire length behind the anterior extremity; umbones full, prominently rounded. Cardinal slope slightly concave. Surface marked with rather fine concentric striæ, and sometimes with strong, distant lines of growth as well.

Shell substance very thin. Hinge plate almost linear when compared with the majority of the species of the genus; with two very slender posterior lateral teeth in the right valve, and probably only one in the left; anterior teeth obscure in the specimen, consisting apparently of one or two slight longitudinal folds in the margin of the shell. Muscular impressions very faint.

In this species the hingement is reduced to the minimum of strength so far noticed in the genus. It is possible that this reduction has gone beyond the just limits of *Cypricardites*, but in view of the fact that the species is approached in this respect by *C. germanus*, which, as well as several other undoubted species of the genus, as now understood, it also resembles in the general expression of its shells, it did not seem to me worthy now of greater recognition than specific.

C. cingulata, from a lower horizon in the shales, is a more ventricose shell, with the umbonal ridge stronger, and the outline a little different, being longer from the beaks to the postero-ventral margin, with both the anterior end and the hinge line shorter.

Formation and locality: - Upper third of the Trenton shales, about six miles south of Cannon Falls, Minnesota. A cast of the interior, collected by Mr. Wm. H. Scofield from the lower part of the Galena Limestone, at Wykoff, Fillmore county, probably belongs here.

CYPRICARDITES NANUS, n. sp.

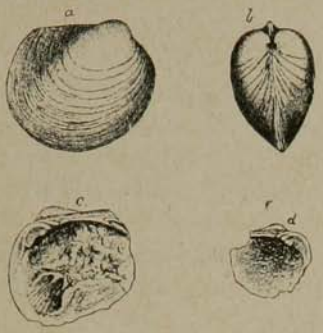


Fig. 24, *Cypricardites, nanus*, n. sp. *a* and *b*, side and anterior views of a silicified specimen, nat. size; *c*, anterior part of the hinge of a small left valve; *d*, hinge of a right valve.

Shell small, ventricose, slightly oblique, the outline subcircular, a little the widest posteriorly, with the hinge line straight or very slightly arcuate, and the anterior end produced a little beyond the line of the circular curve formed by the posterior and ventral margins; height and length respectively as five is to six; postero-cardinal border subangular. Beaks small, strongly incurved, projecting well above the hinge; situated about one-fifth of the entire length from the anterior extremity; umbones full, prominent, with a strongly rounded ridge traceable from the beak nearly to the postero-ventral margin. Cardinal slope rather strongly concave. Surface marked with fine lines of growth. With age a few strong marginal wrinkles may be formed. Shells ubstance thin.

Hinge of moderate strength, considering the size of the shell, with two anterior teeth in each valve, the lower and forward one forming the sharp upper boundary of a narrow and horizontally extended muscular impression. Posterior teeth not well shown in the material at hand; probably two or three, and much like those of *C. haynianus* Safford.

This species is closely related to *C. haynianus* Safford, a common species of the Trenton of Kentucky and Tennessee, but is smaller, more ventricose, with the outline more nearly circular, the beaks less nearly terminal, the umbonal ridge stronger, and the shell thinner. It has also only two instead of three or more anterior hinge teeth. None of the other species known to me are very closely related.

A similar, though not a strictly identical species, is indicated by a cast of the interior, collected by Mr. Wm. H. Scofield, at

Wykoff, in Fillmore county of this state, where he found it at the base of the Galena limestone. This cast belonged to a larger shell than has been noticed of *C. nanus*. Its outline is also a little different, being too wide posteriorly, and more sharply curved at the postero-basal border, while the beaks are more nearly terminal. In short, the outline is more nearly like that of *C. haynianus* (see fig. 25*b*), slightly longer, perhaps, but I am satisfied that it is distinct from Safford's species, having obviously been formed by a thinner shell in which the internal ridge, which is always present in his species, was absent or, as is the case with *C. nanus*, too illy defined to leave a certain mark on the casts.

Formation and locality:—The nine, more or less defective specimens of this species contained in my cabinet, were collected from the upper beds of the Trenton, in Mercer county, Kentucky.

CYPRICARDITES HAYNIANUS (?) Safford.

Cyrtodonta hayniana SAFFORD, 1869. Geol. Tenn., pl. F., fig. 1.

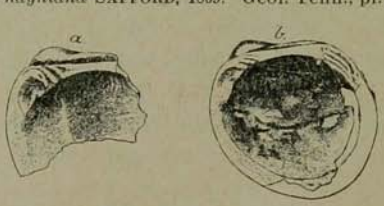


Fig. 25. *Cypricardites haynianus* Safford. Upper Trenton, near Danville, Kentucky; *a*, a well preserved fragment of a right valve, showing the anterior part of the hinge, with its teeth, the muscular impression, and the internal ridge; *b*, the interior of a smaller right valve with the anterior teeth disposed more horizontally than usual in this species.

I am nearly convinced that this species is represented in the Galena shales of Minnesota, but all of the specimens seen by me are internal casts, and none of these are sufficiently well preserved to permit an unequivocal determination of their relations. The internal ridge and the compressed beaks (they are concave on the inner side) required by casts positively known to belong to the species, are determinable in some of the specimens, but each of these is either incomplete or has suffered compression in the shales, so that the original shape of the shells is left in doubt. Under the circumstances I thought it well to call the attention of Minnesota collectors to the forms, in the hope that some of them may find better specimens.

Among some lamellibranch shells received from Mr. Wm. H. Scofield, there is a fragment of a *Cypricardites* that he obtained

from the upper third of the Trenton shales, at the locality six miles south of Cannon Falls that has furnished so many interesting shells of this class. This specimen consists of the anterior third of the shell itself, showing about half of the hinge with three anterior teeth and a muscular impression beneath them. Every point that is preserved corresponds so nearly with fig. 25 *a*, that it would surprise me greatly if it turned out to be distinct from *C. haynianus*.

MATHERIA RUGOSA, n. sp.

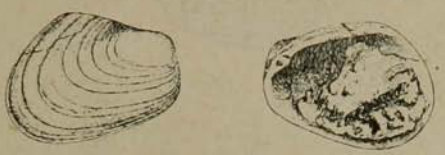


Fig. 26, *Matheria rugosa*, n. sp External and internal views of the only specimen seen, nat. size. The posterior part of the hinge is broken away and that portion of the figures is to be regarded as a restoration.

Shell large for the genus, trapezoidal, widest posteriorly, with the beaks nearly terminal, small, incurved, projecting slightly above the hinge; a strongly convex umbonal ridge. Anterior end descending abruptly from the beaks, below rounding sharply into the nearly straight ventral border; posterior margin produced and strongly rounded in the lower half, obliquely subtruncate above and probably forming an obtuse angle at the junction with the hinge line; the latter very gently arched. Surface marked with strong, concentric wrinkles, and finer lines of growth. Shell substance of moderate thickness.

Hinge plate strong, flat, slightly arcuate, the upper half of the width, posterior to the beaks, finely striated lengthwise. Cardinal teeth small, situated just beneath the beaks, directed toward the postero-basal margin, with one in the right valve and, on each side of it, a deep socket for the reception of the two teeth of the left valve. Anterior muscular scar rather distinct, subcircular, situated immediately beneath the teeth. Posterior extremity of hinge wanting in the specimen, probably without teeth.

This species is almost certainly a true *Matheria*, a genus described by Billings for a single species occuring in the Trenton rocks of Canada and Kentucky, and which he called *M. tener*.*

*Can. Nat. and Geol., vol. 3, p. 440, 1858.

Several other species, as yet undescribed, are known to me from the same rocks in Kentucky, but all are smaller and less wide posteriorly. *M. tenera* has the dorsal and ventral margins nearly parallel.

Formation and locality:—Upper third of the Trenton shales, six miles south of Cannon Falls, Minnesota.

ISCHYRODONTA OVALIS, n. sp.

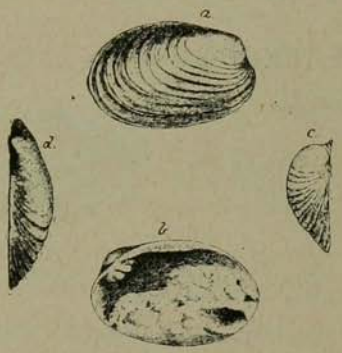


FIG. 27. *Ischyrodonta ovalis*, n. sp. *a*, and *b*, external and internal views of a right valve; *c*, and *d*, anterior and cardinal views of the same; nat. size.

Shell small, moderately ventricose, almost regularly elliptical in outline, with the greatest width and thickness midway between the ends; width and length about as two is to three. Beaks small, situated near the anterior extremity, compressed by a flattening of the surface which, expanding, extends over the greater part of the ventral slope. Edges of valves meeting at the center of the ventral margin, apparently gaping a little at the ends. Umbonal ridge prominently rounded, cardinal slope abrupt, very little concave. Surface marked with strong lines of growth and a few finer concentric striae, both inclining to be irregular.

Hinge plate arcuate, widening posterior to the beaks, grooved as for the reception of an internal ligament. Cardinal teeth two, projecting downward and backward from the hinge plate, which is thin at this point, and supported by an internal process that seems to extend up into the cavity of the beak, and projects on each side of the teeth so as to give the whole the appearance of a quadrifid tooth. Anterior muscular scar rather small, occupying the anterior extremity of the shell.

This species is not strictly congeneric with the types of *Ischyrodonta* (Amer. Geol., vol. 6, pp. 173-175), but there is no other established genus known to me offering a closer agree

ment, and before I can consider the erection of a new genus as fully justified, I wish to see the main peculiarties of the shell confirmed in other species. The uncertainty of the position of the species is increased by the fact that it might be referred, with equal propriety perhaps, to the genus *Matheria*, of Billings. I infer therefore that we are dealing with an undescribed generic type having somewhat intermediate relations between *Matheria* and *Ischyrodonta*.

Formation and locality:—At present known only from Richmond, Indiana, where it was found in the upper beds of the Cincinnati group. Equivalent strata are exposed in the vicinity of Spring Valley, Minnesota.

PLETHOCARDIA, n. gen.

(*Pletho*, to be full; *kardia*, heart, in allusion to the shape of the closed valves.)

Shell thin, inequilateral, oblique, tumid, with the margins closed; beaks large, prominent, spirally enrolled, and curving forward. Cardinal margin, posterior to the beaks, with a narrow, but deep escutcheon or lunette. A strong and large, bifid, cardinal tooth projects forward and downward from the thin edge of the straight hinge plate; one strong linear, lateral tooth, or thickened internal cartilage support, beneath the posterior extremity of the hinge line, and close to the margin. Anterior muscular scar strongly impressed, situated in the antero-dorsal angle, margined on the inner side by a curved ridge extending from the under side of the cardinal tooth. In casts of the interior the filling of the anterior impressions forms a small but sharply defined lobe. Posterior muscular scars and pallial line unknown. Type: *P. umbonata*, n. sp.

The shells of this genus present considerable external resemblance to those of *Whitella*, Ulrich. As a rule they will probably prove shorter, more erect and comparatively more ventricose. I believe also that *Whitella* offers closer affinities than any other genus yet known, and I can see that it may prove difficult in some cases to distinguish species of the two genera, when the internal characters are not available. Of course, such difficulties cannot obtain when the diagnostic characters of the hinge are preserved, since the strong cardinal tooth of *Plethocardia* is too marked a feature to be overlooked in comparing the two genera. Good casts of the interior even are easily distinguished by the presence of the small lobe beneath and in front of the beaks of *Plethocardia*, the muscular impressions being very much less distinct in the casts of *Whitella*. In the

posterior part of the hinge, however, the two genera are practically the same.

It is possible that this genus represents an early type of those heavy and otherwise peculiar shells which Zittel has embraced in his family *Megalodontidæ*. A general resemblance is to be noted yet I doubt very much that any true relationship existed between them.

PLETHOCARDIA UMBONATA, n. sp.

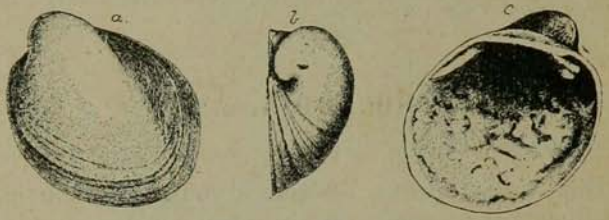


Fig. 28. *Plethocardia umbonata*, n. sp. *a* and *b*, lateral and anterior views of a left valve; *c*, inner side of same, showing the escutcheon, the bifid cardinal tooth, anterior muscular impression, and the internal ridge-like thickening of the shell just within the postero-dorsal border; natural size.

Shell rather small, moderately oblique, strongly ventricose, widest posteriorly, subovate in a side view. Beaks large, very prominent, inrolled; umbonal ridge angular, traceable to the postero-basal margin. Cardinal slope narrow, rather sharply defined, concave. Anterior end very short, nearly vertical, rather sharply rounded above; dorsal margin arcuate, graduating into the posterior curve; the latter is produced slightly in the lower part and quickened as it turns into the broadly convex ventral margin. Surface marked with concentric lines of growth, some of them strong.

Escutcheon narrow, extending backward from the beaks nearly to the posterior extremity of the hinge. Cardinal tooth large, bifid, projecting obliquely forward from the lower side of the hinge line. A strong, ridge-like thickening of the shell, probably representing the support of an internal ligament, occurs just within the postero-cardinal margin. Anterior muscular scar situated in a cup-like depression formed by a curved ridge which proceeds from the underside of the cardinal tooth, and the antero-cardinal margin of the shell.

It is possible that this species is not distinct from the *Cyrtodonta cordiformis* of Billings. His figures of that species look so much like the Minnesota shell above described that I am nearly satisfied that they must be congeneric at least. It might be a

Whitella but it is not a true *Cypricardites*. Compared with *P. umbonata* it appears that in the Canadian shell the beaks are situated farther back from the anterior extremity, the umbonal ridge is rounded instead of angular and the outline different, especially that of the posterior end, which is also wider.

Formation and locality:—Upper third of the Trenton shales, six miles south of Cannon Falls, Minnesota. Collected by Wm. H. Scofield.

PLETHOCARDIA SUBERECTA, n. sp.

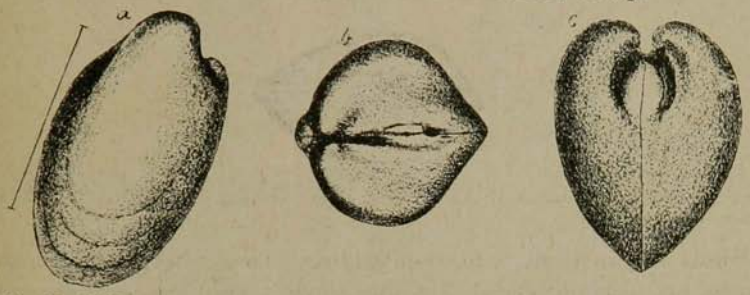


Fig. 29. *Plethocardia suberecta*, n. sp. *a*, *b*, and *c* lateral, dorsal, and anterior views of a cast of the interior; natural size.

Shell small, but little oblique, exceedingly ventricose, short, subelliptical in a side view, with the dorso-ventral diameter much the longest. Beaks very prominent, large, strongly incurved, nearly terminal, umbonal ridge strong, sharply rounded, with the cardinal and posterior slopes very abrupt, and nearly flat. Anterior end very short, the part in front of the beaks of casts consisting chiefly of the sharply defined, lobe-like filling of the anterior muscular impressions. Anterior and posterior margins gently convex, subparallel; ventral edge sharply rounded. Hinge line short, scarcely extending posterior to the umbonal ridge, as seen in a side view. In the casts there is a depression beneath the beaks that is prolonged on each side around the muscular scar. The escutcheon seems to have been narrow, but the internal ligament supports at the posterior end of the hinge line have left two strong grooves, one on each side.

This species, though clearly congeneric with *P. umbonata*, is so readily distinguished from that species that comparisons are unnecessary.

Formation and locality:—Galena shales, near Cannon Falls, Minnesota.

WHITELLA PRÆCIPTA Ulrich.

Whitella præcipta ULRICH, 1890. The American Geologist, vol. vi, p. 386.

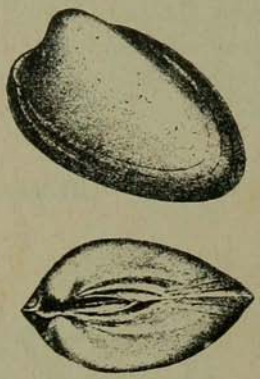


Fig. 30, *Whitella præcipta* Ulrich. Lateral and cardinal views of a cast of the interior; nat. size.

Shell of medium size, ventricose, very oblique, elongate-ovate, or subrhomboidal in a side view, produced and sharply rounded in the postero-basal region. Beaks of moderate size, prominent, strongly incurved, umbones full; umbonal ridge well marked, traceable almost to the posterior extremity. Anterior end small, very short, narrowly rounded; ventral margin gently convex; posterior end produced and narrowly rounded in the lower part; from the point of greatest extension to the posterior side of the projecting umbones, the outline is gently and almost uniformly convex. Hinge line comparatively short, its length less than half the length of the shell, the edge inflected to form a distinct escutcheon, extending somewhat in front of the beaks. In casts of the interior the internal cartilage supports have left distinct impressions of unusual width, on each side and behind the impression produced by the escutcheon. A low and obscurely defined ridge is also to be seen running through the middle of the cardinal slope. Anterior muscular scar faint, subovate, acuminate below, situated very near the anterior extremity. Pallial line represented by a thin raised line, running near and parallel with the margin of the cast. It can be traced from the anterior scar to the impressions of the internal ligament supports.

This species is very similar to *W. obliquata* Ulrich, from the upper beds of the Cincinnati group, yet I do not doubt that they are really quite distinct species. That species grows to a larger size, is less elongate, wider posteriorly, with the beaks

and umbones smaller, and the anterior end larger. The impressions of the internal ligament supports also are very much less distinct.

Formation and locality:—Galena shales, near Cannon Falls, Minnesota.

WHITELLA CONCENTRICA, n. sp.

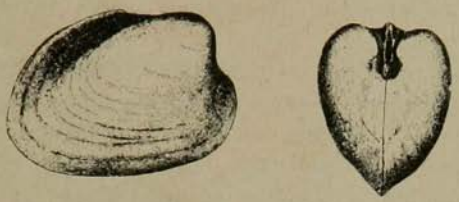


Fig. 31, *Whitella concentrica*, n. sp. Lateral and anterior views of a cast of the interior, nat. size. The beak of the left valve has been restored.

Shell rather beneath the medium size, oblique, ventricose, widest posteriorly, trapezoidal; beaks large, prominent, in curved; umbones full, with a sharply rounded ridge or line of gibbosity extending backward from the beaks to the posterior extremity of the shell. Anterior end short, narrowly rounded; ventral edge very gently convex; posterior end produced and sharply rounded in the lower half, more gently convex and sloping forward rapidly above, merging gradually into the curve of the dorsal side. Cardinal and posterior slopes slightly concave. Hinge line about half as long as the shell, with the edge inflected so as to form a narrow escutcheon, extending but little if at all in front of the beaks. Internal ligament supports leave a distinct impression on each side of the postero-cardinal margin in casts of the interior. Anterior muscular scars distinct though faintly impressed, situated in the antero-dorsal angle. Surface of casts, especially in the lower and posterior parts, marked with fairly distinct, rounded, concentric folds.

The concentric marks of growth are stronger in this species than in any other known to me. It is shorter than *W. præcipta* more ventricose than *W. compressa*, and has much fuller umbones than *W. obliquata*.

Formation and locality:—Middle third of the Trenton shales, at Minneapolis, Minnesota

CUNEAMYA SULCODORSATA, n. sp.

Fig. 32, *Cuneamya sulcodorsata*, n. sp. Lateral and anterior views of the type specimen, nat. size.

Shell small, moderately convex, oblong, subquadrate, with the dorsal and ventral margins subparallel and gently convex, the posterior end truncate, very slightly produced and sharply rounded, almost angular at the base; anterior end very short, narrowly rounded. Beaks subterminal, full, decumbent, strongly incurved, projecting forward rather than upward: umbonal ridge moderately prominent, not angular. Dorsal slope with a distinct, expanding sulcus; ventral and anterior slopes gently and uniformly convex. Hinge line posterior to the beaks long, the edge inflected so as to form a well-marked escutcheon. In front of and beneath the beaks a deep lunule. Surface marked with regular, concentric folds, obsolete on the cardinal slopes, and by two or three times more numerous fine striæ, which seem to have extended over all parts of the surface.

This neat shell, though seeming to be a true species of *Cuneamya*, cannot be confounded with any species of the genus so far described.

Formation and locality:—At the top of the Hudson River group, Spring Valley, Minnesota.

PUBLICATIONS OF THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

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THE FOURTH ANNUAL REPORT, FOR 1875. 162 pp., 8vo.; with four county maps and a number of other illustrations. By *N. H. Winchell,* assisted by *M. W. Harrington.* Also in the Regents' Report for 1875. Out of print.

THE FIFTH ANNUAL REPORT, FOR 1876. 248 pp., 8vo.; four colored maps and several other illustrations. By *N. H. Winchell;* with reports on Chemistry by *S. F. Peckham;* Ornithology, by *P. L. Hatch;* Entomology, by *Allen Whitman;* and on Fungi, by *A. E. Johnson.* Also in the Regents' Report for 1876. Out of print.

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THE NINTH ANNUAL REPORT, FOR 1880. 392 pp.; 8vo.; three Appendixes, two wood cut illustrations and six plates. By *N. H. Winchell.* Containing field descriptions of 442 crystalline rock samples, and notes on their geological relations, from the northern part of the state, new brachiopoda, the water supply of the Red River valley, and simple tests of the qualities of water; with reports on the Upper Mississippi region, by *O. E. Garrison;* on the Hydrology of Minnesota, by *C. M. Terry;* on the Glacial Drift and its Terminal Moraines, by *Warren Upham;* Chemical Analyses, by *J. A. Dodge;* a list of the birds of Minnesota, by *P. L. Hatch;* and of the winter birds, by *Thomas S. Roberts.* Also in the Regents' Report for 1879 and 1880. Out of print.

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THE FOURTEENTH ANNUAL REPORT, FOR 1885. 354 pp.; two plates of fossils and two wood cuts. By *N. H. Winchell.* Containing summary report, notes on some deep wells in Minnesota, descriptions of four new species of fossils, a supposed natural alloy of copper and silver from the north shore of Lake Superior, and revision of the stratigraphy of the Cambrian in Minnesota, with the following papers by assistants, viz.: List of the Aphididæ of Minnesota, with descriptions of some new species by *O. W. Oestlund;* Report on the Lower Silurian Bryozoa, with preliminary descriptions of some new species, by *E. O. Ulrich;* Conchological notes, by *U. S. Grant;* Bibliography of the Foraminifera, recent and fossil, by *Anthony Woodward.*

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THE SIXTEENTH ANNUAL REPORT FOR 1887. 504 pp., 8vo.; two plates and 83 other illustrations. Contains reports on the original Huronian area, the Marquette iron region, on the Gogebic and Penokee iron-bearing rocks, on the formations of northeastern Minnesota (including the physical aspects, vegetation, quadrupeds and other vertebrates), the geology of the region northwest from Vermillion lake to Rainy lake and of the Little and Big Fork rivers; also notes on the Molluscan fauna of Minnesota.

THE SEVENTEENTH ANNUAL REPORT FOR 1888. pp., 280; 8vo.; ten text illustrations. Contains: Report of *N. H. Winchell;* the crystalline rocks of Minnesota, a general report of progress made in the study of their field relations, with a bibliography of recent works on the crystalline rocks; report of *H. V. Winchell,* field observations in the iron regions; report of *Uly. S. Grant,* geological observations in northeastern Minnesota.

THE EIGHTEENTH ANNUAL REPORT FOR 1889. Report of further field observations in the regions of the crystalline rocks of the state and in the area of the original Huronian, by *N. H. Winchell,* and a review of American opinion on the older rocks, by *Alexander Winchell.* Octavo, pp. 234.

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III. MISCELLANEOUS PUBLICATIONS.

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No. 7. The Mammals of Minnesota. *C. L. Herrick*. In press.

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