

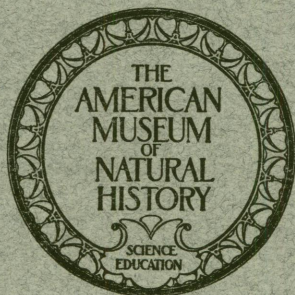
CATALOGUE OF
MINERAL PSEUDOMORPHS IN
THE AMERICAN MUSEUM

BY CLIFFORD FRONDEL

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Article IX.—CATALOGUE OF MINERAL PSEUDOMORPHS IN THE AMERICAN MUSEUM OF NATURAL HISTORY¹

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INTRODUCTION

DEFINITION.—A pseudomorph is defined as a mineral which has the outward form proper to another species of mineral whose place it has taken through the action of some agency.² This precise use of the term excludes the regular cavities left by the removal of a crystal from its matrix (*molds*), since these are voids and not solids,³ and would also exclude those cases in which organic material has been replaced by quartz or some other mineral because the original substance is here not a mineral.

The general usage of the term is to include as pseudomorphs both petrifications and molds, and also: (1) Any mineral change in which the outlines of the original mineral are preserved, whether this surface be a euhedral crystal form or the irregular bounding surface of an embedded grain or of an aggregate. (2) Any mineral change which has been accomplished without change of volume, as evidenced by the undistorted preservation of an original texture or structure, whether this be the equal volume replacement of a single crystal or of a rock mass on a geologic scale. The condition of no volume change here carries with it a connotation of no change in the dimensions of the surface.

The plane-sided, hollow objects formed by the infiltration of quartz into openings left between crystals due to their interference during

¹Manuscript submitted June 19, 1933.

²Dana, E. S., and Ford, W. E., 1932, 'Textbook of Mineralogy,' 4th Ed., pp. 205, 357. Roth, J., 1879, 'Allgemeine und Chemische Geologie,' Berlin, I, p. 61.

³Schaller, W. T., 1932, U. S. Geol. Surv. Bull. 832, p. 22.

growth have been described as "false pseudomorphs"¹ although the analogous bodies formed by the infiltration of quartz into a regular cavity left by the dissolution of a crystal are classed as infiltration pseudomorphs. There is no reason why these casts should be separated so far as the application of the word pseudomorph is concerned; both are bodies which reflect a previously existing surface. Haidinger speaks of a plaster of Paris statue or bust formed by pouring into a mold as being a pseudomorph from a mineralogical point of view.²

To avoid confusion in the future, it is advisable, since all of these things tend to become associated in the mind because they possess a form inherited from a pre-existing substance or structure and because they have a community of origin, to extend the definition of the term pseudomorph to include *any substance or structure of definite or characteristic form which is represented or defined³ by another substance to which the form does not properly belong*. This broad usage is in accordance with the etymology of the word itself. Petrifications, casts, molds, paramorphs, alteration pseudomorphs, etc., are then special kinds of pseudomorphs that can be recognized in a general classification.

LITERATURE.—The only general works dealing with pseudomorphs are those of Blum, Bischoff, and Roth, cited below. All of these catalogues are greatly out of date and a large amount of data on pseudomorphs has accumulated in the literature during the fifty-odd years since the publication of the fourth and last appendix to the original work of Blum. Much of this material is not available through indices or bibliographies. The most useful modern source for the literature of pseudomorphism is in Hintze's *Handbuch der Mineralogie*. Shorter papers dealing in a more or less general way with pseudomorphs or with particular aspects of the subject are included in the following list.

- BISCHOFF, G., 1863–1866, 'Lehrbuch der chemischen und physikalischen Geologie,' 2d Ed., Bonn (3 vols.). Also an English translation of the 1st edition published by the Cavendish Society.
- BLUM, J. R., 1843, 'Die Pseudomorphosen des Mineralreichs,' Stuttgart, with four appendices in 1847, 1852, 1863, and 1879.
- ROTH, J., 1879, 'Allgemeine und chemische Geologie,' I, Bildung und Umbildung der Mineralien. Berlin. Also an appendix to Vol. I, in 1890.
- BECK, L. C., 1843, 'On Some Pseudomorphous Minerals of the State of New York,' Assoc. Amer. Geologists and Naturalists, Rpt. of 3d Meeting, pp. 241–253.

¹Hidden, W. E., 1885, School of Mines Quart., VII, pp. 334–338 (quartz after interstices from North Carolina). Chalcedony after interstices from Chester County, Pa., has been described by Vaux, G., 1926, Proc. Acad. Nat. Sci. Phil., LXXVIII, pp. 17–19; graphite after interstices from Ceylon by Moses, A. J., 1892, School of Mines Quart., XIV, p. 51, and from Travancore by Tupper, G. H., 1920, Rec. Geol. Surv. India, LI, p. 28.

²Haidinger, W., 1829, Edinburgh Jour. Sci., X, p. 92.

³A mold is defined by its matrix.

- A discussion of pseudomorphism, following Haidinger, illustrated by examples from New York State.
- BREITHAUP, A., 1815, 'Ueber die Aechtheit der Krystalle,' Freiberg, 63 pp. An early discussion of pseudomorphs.
- CURRIE, J., 1901, 'Scottish Pseudomorphs,' In Heddle's *Mineralogy of Scotland*, I, pp. xxxvii-xlix. A list of occurrences.
- DANA, E. S., 1884, 'A Crystallographic Study of the Thinolite of Lake Lahontan,' U. S. Geol. Surv. Bull. 12, 34 pp. Discussion of the thinolite and pseudogaylussite problems.
- DANA, J. D., 1845, 'Observations on Pseudomorphism,' Amer. Jour. Sci., Ser. 1, XLVIII, pp. 81-92. Discussion of the classification and formation of pseudomorphs. This paper is preceded by an extended review of the catalogue of Blum.
- DELESSE, M., 1859, 'Recherches sur les pseudomorphoses,' Annales des Mines, XVI, pp. 317-392; Abstr. in Zeits. Deuts. Geol. Gesell., 1860, XII, pp. 277-280. A thoroughgoing treatment of pseudomorphism. Lengthy tables of pseudomorphs are given.
- GEINITZ, F. E., 1876, 'Studien über Mineral-Pseudomorphosen,' Neues Jahrb., pp. 449-504; abstr. in Jour. Chem. Soc. London, XXXI, 1876, pp. 691-700. Discussion of the character and classification of pseudomorphs, particularly those by substitution, with a microscopical study of thirty specimens.
- GEINITZ, F. E., 1880, 'Zur Systematik der Pseudomorphosen,' Tschm. Min. Petr. Mitth., II, pp. 489-498. A further discussion of the origin and classification of pseudomorphs.
- GRAVENHORST, J. L. C., 1816, 'Die anorganischen Naturkörper, nach ihren Verwandtschaften und Uebergängen betrachtet und zusammengestellt,' Breslau (not seen).
- HAIDINGER, W., 1831, 'On the Parasitic Formation of Mineral Species, depending upon Gradual Changes which take place in the Interior of Minerals, while their Exterior Form remains the same,' Trans. Royal Soc. Edinburgh, XI, pt. 1, pp. 73-113. Also in Edinburgh Jour. Sci., 1827, VII, pp. 126-133; 1828, IX, pp. 275-292; 1829, X, pp. 86-95; and in Schweigg. Jour., 1829, LV, pp. 257-317. The first general account of pseudomorphism.
- HAIDINGER, W., 1844, 'Ueber die Pseudomorphosen und ihre anogene und katogene Bildung,' Pogg. Annalen der Physik u. Chemie, LXII, pp. 161-183, 306-324. An attempt to classify pseudomorphs into groups on the basis of opposite electrochemical affinities.
- HOFMANN, C. A. S., 1811, 'Handbuch der Mineralogie,' Freiberg, I, pp. 115-117. A brief statement of the nature and criteria of pseudomorphism summarizing the knowledge of the Wernerian school.
- JAMESON, R., 1805, 'Treatise on the External Characters of Minerals,' Edinburgh, pp. 33-35. A distinction is made between true crystals and supposititious crystals (pseudomorphs) with criteria for their separation. The formation of the latter is ascribed only to the infilling of molds or to incrustation and removal. "Transmuted" wood is also mentioned.
- LACROIX, A., 1915, 'Collection de Minéralogie Muséum National D'Histoire Naturelle,' Paris, 132 pp. This guide contains a list of 80 pseudomorphs and 69 mineral alterations and mixtures that have been erroneously described as distinct species.

- LANDGREBE, G., 1841, 'Ueber die Pseudomorphosen im Mineralreich und verwandte Erscheinungen.' Kassel (not seen).
- LAUBMANN, H., 1921, 'Studien über Mineralpseudomorphosen,' Neues Jahrb., I, pp. 15-34 (I); II, pp. 35-49 (II); 1922, II, pp. 1-17 (III). A detailed study of 26 pseudomorphs with literature.
- MIERS, H. A., 1897, 'On Some British Pseudomorphs,' Min. Mag., XI, pp. 263-285. A list with localities and in part with description of 147 recognized British pseudomorphs and 72 of doubtful occurrence.
- MORGAN, P. G., 1925, 'The so-called "pseudomorphous" quartz of the Tertiary gold-silver veins,' Econ. Geol., XX, pp. 203-207. Discussion of the quartz pseudomorphs after calcite and barite common in the epithermal veins of the western United States and other regions.
- MÜGGE, O., 1903, 'Die regelmässigen Verwachsungen von Mineralen verschiedener Art,' Neues Jahrb., Beil. Bd., XVI, pp. 335-475. Many examples of the orientation of the later mineral to the original mineral in pseudomorphs are cited.
- PATTON, H. B., 1901, 'Synopsis of paper on the development of pseudomorphs' Proc., Colo. Sci. Soc., VII, pp. 103-108. A classification for pseudomorphs is given and illustrated by some common examples (with photographs of specimens).
- PILIPENKO, P. P., 1915, 'Mineralogy of the western Altai,' Bull. Imp. Tomsk Univ., No. 63, Chapter 13, pp. 678-699 (through Mineral Abstracts, II, pp. 109-115).
- ROGERS, A. F., 1910, 'Notes on some pseudomorphs, petrifications, and alterations,' Proc. Amer. Phil. Soc., XLIX, pp. 17-22. Brief description of some 25 pseudomorphs, mostly from the United States.
- SCHALLER, W. T., 1932, 'The Crystal Cavities of the New Jersey Zeolite Region,' U. S. Geol. Surv. Bull., 832, 90 pp., 32 Pls., 33 figs. Description of the pseudomorphs (molds) after glauberite and anhydrite common in the diabase of this region.
- SCHAEERER, TH., 'Ueber Pseudomorphosen, nebst Beiträgen zur Charakteristik einiger Arten derselben,' Pogg. Annalen der Physik u. Chemie, 1853, LXXXIX, pp. 1-38; 1853, XC, pp. 315-323; 1853, XCI, pp. 378-401; 1854, XCII, pp. 612-623; 1854, XCIII, pp. 95-115. Particular reference is made to paramorphism.
- SCHAEERER, TH., 1854, 'Der Paramorphismus und seine Bedeutung in der Chemie, Mineralogie und Geologie,' Braunschweig (not seen).
- SCHAEERER, TH., 1856, Article under "After-Krystalle" in Liebig's Handwoerterbuch der reinen und angewandten Chemie (Liebig, J., Poggendorf, J. C., and Wöhler, Fr.), Braunschweig, 2te Aufl., Bd. I, pp. 339-375. This contains a concise systematic treatment of pseudomorphism with mention of most examples known at that time; 28 examples of artificial alteration pseudomorphs are cited.
- SPEISS, G., 1878, 'Zur Geschichte der Pseudomorphosen,' Leopoldina, XIV, pp. 28-32, 40-48, 53-61. A historical review with description of the many classifications proposed to that time.
- VAN CALKER, F. J. P., 1897, 'Beitrag zur Kenntniss des Pseudogaylussite und über dessen Vorkommen in Holland,' Zeits. Kryst., XXVIII, pp. 556-572. A discussion, with literature, of the pseudogaylussite problem.
- VAN HISE, C. R., 1904, 'A Treatise on Metamorphism,' U. S. Geol. Surv. Monograph 47. Treatment of the alterations of minerals with a tabulation of the sources and products of alteration, the supposed chemical reactions and volume changes involved, and an analysis of this data (Tables A to D, pp. 369-408).

- VOLGER, G. H. O., 1854, 'Studien zur Entwicklungsgeschichte der Mineralien, Zürich, 548 pp. This work is largely concerned with pseudomorphs.
- WINKLER, G., 1855, 'Die Pseudomorphosen des Mineralreichs,' München (not seen).

In the descriptive part of this catalogue, reference will be made to the original description only, for occurrences in the United States, Canada, and Mexico.

NEW PSEUDOMORPHS. The present catalogue includes 255 different pseudomorphs represented by over 800 specimens. The greater part of these pseudomorphs are of old and well known occurrence, and a detailed description may be found in Blum or with the aid of Roth or Hintze's 'Handbuch.' Pseudomorphs from the collection which appear to have been hitherto unreported are:

Brochantite after Azurite. Good Springs, Nevada
Cerussite after Fremontite. Cañon City, Colorado
Delafossite after Copper (?). Bisbee, Arizona
Chalcocite after Sphalerite. Butte, Montana
Grossularite after Diopside. Vaskö, Hungary
Gypsum after Aragonite. Bastennes, France
Magnetite after Brookite. Magnet Cove, Arkansas
Pyrite after Chalcocite. Cornwall, England
Quartz after Diopside. Pierrepont, New York
Quartz after Prehnite. Auvergne, France
Malachite after Brochantite. Tintic, Utah

A considerable number of new localities are also cited, including many pseudomorphs which have not been previously described from the United States.

METHOD OF DESCRIPTION

In order to facilitate the description of the specimens, use will be made of a descriptive scheme based on: (1) The presence or absence of an original solid enveloping medium around the pseudomorphosed substance. (2) The formation, or not, of an envelopment concomitantly with the pseudomorphism. (3) The general nature of the process by which the pseudomorphism was accomplished. The detailed arrangement is given in Table I. Each pseudomorph in the collection will be cited by name, locality, specimen number, and referred by the suitable symbol to its position in the scheme. A number of pseudomorphs were observed which did not fit into this method of description; these were mostly specimens resulting from the successive action of different processes. A brief description is appended to such specimens in the list.

TABLE I
DESCRIPTIVE SCHEME FOR PSEUDOMORPHS

NATURE OF ENVELOPMENT	PROCESS OF FORMATION
I. Free crystals; the original surface of the crystal, as developed by unhindered growth into an opening, being preserved in the pseudomorph.	A. Removal (<i>molds</i>)
II. Originally enveloped crystals; the pseudomorphosed crystal being originally embedded in a solid matrix.	B. Deposition, either by: 1. Infiltration (<i>casts</i>) 2. Super-deposition: a. The incrustated crystal being removed forming a mold by incrustation (<i>epimorphs</i> or <i>incrustation pseudomorphs</i>). b. The incrustated crystal being simultaneously removed and substituted for with no volume change (special type of incrustation or substitution pseudomorph). 3. Substitution (<i>substitution pseudomorphs</i>).
III. Concomitantly enveloped crystals; an original free crystal becoming enveloped, very generally by a thin drusy crust, during the formation of the pseudomorph with the crystal itself at the same time being removed, or being removed and substituted for, by the depositing mineral.	C. Alteration: 1. By paramorphism (<i>paramorphs</i>). 2. By chemical alteration (<i>alteration pseudomorphs</i>).

If the formation of an alteration or substitution pseudomorph has been accompanied by an observable decrease in volume, the letters *vd* (volume decrease) will be attached to the symbol describing the specimen.

Discussion of Groups Based on the Process of Formation.

- A. Removal; the original crystal may be removed by solution, peptization, or mechanical disintegration, yielding a hollow cavity or mold. A pre-existing envelopment (II) is necessary in order to define the form.
- B. Deposition; the later mineral being emplaced by direct crystallization from solution or by the deposition of particles from a colloidal suspension. The original crystal may be represented by a mold, as in 1, below, or the crystal itself may be simultaneously removed and substituted for as in 2 and 3, below.
 1. Infiltration; a pre-existing cavity (envelopment of type II) becoming infilled by deposition, yielding casts.

2. Super-deposition; an original free crystal receiving super-deposition as evidenced by the drusy surface of the pseudomorph, or, in the case where the later mineral is of colloidal origin, by a colloform crust covering the original surface (envelopment of type III). The incrustated crystal is at the same time removed or substituted for; two cases exist according to the relative importance of removal and deposition:
 - a. Volume decrease, the volume of material removed being more than that deposited, yielding a hollow incrustation pseudomorph (epimorph).
 - b. No volume change, the incrustated crystal being simultaneously removed and substituted for by an equal volume of the depositing mineral (solid pseudomorph by incrustation—a special type of substitution pseudomorph).
3. Substitution. Pseudomorphs by substitution comprise those cases in which there has been a gradual removal of the original mineral and a simultaneous replacement by another without any chemical reaction between the two, and further, in which there is no (visible) evidence of super-deposition. Either free crystals (I) or originally enclosed crystals (II) may be substituted for in this way; in the former often without distortion or volume change and with exact preservation of surface details such as etch pits, striations, etc. Pseudomorphs by super-deposition (envelopment of type III) can be considered as a special kind of substitution pseudomorphs, the two differing only in the degree of preservation of original surface. Pseudomorphs which belong, in general, to those by deposition usually form both incrustation and substitution pseudomorphs, and different specimens may show all gradations between the two.

A volume change accompanying the substitution is sometimes observed. Different specimens of the same pseudomorph may vary greatly in this respect. A decrease in volume usually results in the development of a cavity in the interior of the crystal with the surface and walls of the crystal apparently being replaced without volume change. In alteration pseudomorphs, a volume decrease is usually shown by the development of a porous structure.

- C. Alteration. Alteration pseudomorphs include: (1) Paramorphs, in which there has been an inversion to a different crystallographic modification without change in chemical composition or loss of outward form. (2) Pseudomorphs in which the later mineral has been formed from the original mineral by a process of chemical alteration. This may be through: (a) the loss of a constituent—e.g., native copper

after cuprite or azurite, (b) the gain of a constituent—e.g., gypsum after anhydrite and malachite after cuprite, and (c) by a partial exchange of constituents as in galena after pyromorphite and limonite after pyrite.

Recently x-ray studies have served to show that a crystal can lose certain of its chemical constituents without the lattice structure breaking down and with preservation of the outward form. Artificial alteration pseudomorphs of this kind have been described for MgO after brucite,¹ hematite after goethite,² the calcination products of parisite and synchisite,³ CaO after calcite,⁴ for natural occurrences of brucite after chrysotile⁵ and manganite after pyrochroite,⁶ and for other species.

ORIGIN OF SUBSTITUTION AND INCRUSTATION PSEUDOMORPHS

COLLOIDAL ORIGIN: ADSORPTION AND PEPTIZATION.—The formation of substitution pseudomorphs is ascribed to the mechanical exchange of minute particles, a particle of the later mineral displacing a particle of the original substance without a chemical reaction taking place.⁷ It should be noted, however, that this method of formation was advanced in the first place, not because minute particles were believed to possess special properties but because the alternative—that of chemical reaction between molecules—was confronted by intolerable difficulties. These difficulties are (a) in finding a plausible chemical reaction that will express the change, as in quartz after barite, (b) in finding any strictly chemical explanation at all, as in petrifications, and (c) in accounting for the condition of no volume change frequently observed in pseudomorphs. If the minute particles postulated by Blum are now credited with the properties of colloidal matter, a theory of origin for substitution pseudomorphs can be outlined which obviates these difficulties and allows a separation of substitution pseudomorphs into groups or types which can each be correlated with experimentally known processes in colloid chemistry. These types, which can hardly be more than indicated here, are as follows.

¹West, C. D., 1932, *Amer. Min.*, XVII, p. 316.

²Böhm, J., 1928, *Zeits. Kryst.*, LXVIII, p. 567; Goldsztaub, S., 1931, *Compte. rendu des Séances de l'Acad. Sciences*, CXCIII, pp. 533-535.

³Aminoff, G., 1920, *Geol. För. Förh. Stock.*, XLII, pp. 291-300 (with a general discussion).

⁴Rinne, F., 1928, 'Festschrift Victor Goldschmidt,' Heidelberg, pp. 213-220; also West, C. D., *op. cit.*

⁵Berman, H., 1932, *Amer. Min.*, XVII, p. 313.

⁶Aminoff, G., 1919, *Geol. För. Förh. Stock.*, XLI, pp. 473-491. Also *ibid.*, pp. 407-430, 534-538.

⁷Roth, J., *op. cit.*, p. 63, discussing Blum (1843, p. 8).

(1) *Adsorption and deposition of a mineral on a mineral homoio-morphous with it, accompanied by the peptization of the adsorbent* (Dolomite after calcite type, also tetrahedrite after chalcopyrite, siderite and rhodochrosite after calcite, albite after adularia, aragonite after witherite, chalcopyrite after sphalerite.) Adsorption¹ of this kind is known from the work of Marc² who concluded that crystals adsorb such substances as are isomorphous or homoimorphous with themselves, e.g., sodium nitrate on calcite and potassium nitrate on aragonite. Pseudomorphs of the dolomite after calcite type are characterized by a drusy surface, proving the direct deposition of the later mineral, with a parallel orientation of the later mineral to the original crystal. The interiors of the pseudomorphs are frequently hollow; this volume change varies greatly among different specimens of the same pseudomorph.

(2) *Specific cases of adsorption and deposition in which a substance is strongly adsorbed by another, accompanied by the peptization of the adsorbent.* (Quartz after calcite type; also quartz or chalcedony after barite, celestite, dolomite, fluorite, and barytocalcite.) The very common pseudomorphs of quartz and chalcedony after calcite are apparently to be correlated with the marked tendency of silica to adsorb calcium ion.³ The presence of hydroxyl ion (as would be the case in nature) further increases the adsorption of Ca and facilitates the coagulation. Ordinarily hydroxyl ion is strongly adsorbed on silica and peptizes it. The adsorption of suspended calcium carbonate by colloidal silica is said to be hydrolytic, carbon dioxide being set free from the carbonate. Barium and strontium ion are also strongly adsorbed by silica.

Pseudomorphs of calcite after quartz are not known, although calcite is very commonly found as an ordinary incrustation on quartz. The reason for this behavior follows from the point that the peptization of a substance requires the expenditure of energy furnished by the adsorbate in overcoming the cohesion of the adsorbent. The adsorption of silica on calcium carbonate is evidently able to do enough work to peptize the calcite and yield a pseudomorph. On the other hand, while calcium carbonate is strongly adsorbed on quartz, the energy yielded is not sufficient to overcome the cohesion of the quartz and only an incrustation results.

¹The adsorptive processes appealed to in this and the succeeding types of pseudomorphs can not be treated in detail here. For a general discussion of adsorption on crystalline surfaces, see: Taylor, H. S., 1932, 'Treatise on Physical Chemistry,' New York, II, Chapter XX (E. O. Kraemer), pp. 1670-1674.

²Marc, R., 1911, *Zeits. physik. Chem.*, LXXV, p. 710; 1913, LXXXI, p. 641.

³Bancroft, W. D., 1932, 'Applied Colloid Chemistry,' New York, CXLII, pp. 312-313; Jolibois, P., and Chassevent, L., 1929, *Compte rendu des Séances de l' Acad. Sciences*, CLXXXVIII, pp. 452-454; Hanley, J. A., 1927, *Kolloidchem. Beihefte*, XXV, pp. 281-299, and Sallinger, H., *ibid.*, pp. 360, 401.

(3) *Adsorption and deposition of a mineral on a mineral which has an element in common with it, accompanied by the peptization of the adsorbent.* (Calcite after aragonite by incrustation type; also incrustation pseudomorphs of witherite after barite, fluorite after calcite, cerussite after anglesite, calamine after sphalerite, dolomite after fluorite.) The strong tendency a substance has to adsorb its own ions¹ may control the formation of depositional pseudomorphs in which the later and original minerals have an element in common. The hollow incrustation pseudomorphs of calcite after aragonite, as distinct from the paramorphs of calcite after aragonite in which there has been no loss or gain of substance, are the best examples of this method of origin. Pseudomorphs of this type are closely related to those of the dolomite after calcite type and to those of the following type.

Certain of the pseudomorphs included here and in the following type are also undoubtedly formed at times by alteration. In determining whether a particular pseudomorph has been formed by alteration or by substitution, evidence of superdeposition, if present, should be taken as indicating an origin by substitution even if the compositions of the later and the original minerals of the pseudomorph show only a slight difference that can be explained by assuming a process of chemical alteration.

(4) *Cases of adsorption and deposition determined by the relative insolubility of the adsorption compound, with peptization of the adsorbent.* (Barite after celestite by incrustation type; also incrustation pseudomorphs of witherite after aragonite, anglesite after cerussite, barite after witherite, barite after gypsum.) The importance of the solubility of the adsorption compound in determining the adsorption of ions on crystal-line surfaces has been stressed by Paneth and Horowitz in their solubility rule for adsorption.² The relative ease of formation of parallel growths of various alkali halides on the surface of galena and of sodium nitrate on the rhombohedral carbonates likewise depends on the solubility of the adsorption layer at the interface.³

All depositional pseudomorphs in which the later mineral is of lesser solubility than the original mineral do not necessarily belong here. If the relative solubility alone determines the formation of depositional pseudomorphs, and the act of super-deposition is due only to accidental

¹The peptization of freshly precipitated silver halides by silver nitrate (Ag ion adsorbed) or by the corresponding potassium halide (the halide ion adsorbed) is an excellent example of this. See Lottermoser in Bancroft, W. D., op. cit., pp. 129, 209, 221.

²Discussion and literature in Taylor, H. S., op. cit., pp. 1671-1672. Also Fajans, K., and Erdey-Gruz, T., 1931, *Zeits. physik. Chem.*, 158A, pp. 97-151.

³Stranski, I. N., 1929, *Zeits. physik. Chem.*, 142A, pp. 453-466; Stranski, I. N., and Kuleliev, K., *ibid.*, pp. 467-475.

circumstances, as Bischoff and other early workers believed, it is difficult to explain the general absence of quartz pseudomorphs after the sulphide minerals and the heavy metal haloids, sulphates, etc. It is also to be noted that quartz does not incrust sulphide crystals and vice versa¹ (compare with calcite, rutile, octahedrite, scheelite, cassiterite, specularite, dolomite). The almost complete absence of quartz pseudomorphs after the heavy metal compounds, and the mutual antipathy in forming ordinary incrustations, seems to be connected with the negative adsorption shown by silica with the heavy metal cations, sulphate ion, etc., and in part to the fact that both quartz and sulphides form negatively charged sols. On the other hand, the alkaline earths are strongly adsorbed by silica, as shown under (2), which is why quartz and chalcodony pseudomorphs after calcite and barite and mutual incrustations are very common. Pseudomorphs of the quartz after calcite type, although the later mineral is of lower solubility, do not properly belong with the barite after celestite type because the adsorptive processes which determined the pseudomorphism are of different kinds.

(5) *Peptization of a substance by the adsorption of a peptized colloid*,² the colloid in part being coagulated and defining the pseudomorph. Pseudomorphs formed by natural colloids such as chalcedony, psilomelane, chrysocolla, limonite, malachite, etc., except where these clearly result from the alteration of the original mineral, may be suspected of this origin. The quartz and chalcedony pseudomorphs after calcite, barite, etc., could also be included here, since silica is generally transported in nature in the colloidal condition, and also pseudomorphs in others of the preceding types in cases where the later mineral was deposited from a sol.

Pseudomorphs which in general appear to be cases of peptization by the adsorption of peptized colloids are: quartz and chalcedony after calcite, barite, dolomite, fluorite, etc.; psilomelane, limonite (and hematite) and pyrolusite after calcite, fluorite, barite, aragonite, dolomite; wad after calcite; malachite after barite, calcite, cerussite, dolomite, gypsum; chrysocolla after barite, calcite, dolomite, siderite, cerussite; plumbogummite after barite; meta-colloidal incrusting types of pyromorphite after barite and calcite; also possibly the incrustation types of smithsonite after gypsum, calcite, galena; and calamine after dolomite, fluorite, galena, calcite, and pyromorphite. Certain of the pseudomorphs of chrysocolla after copper minerals such as azurite, liro-

¹Pointed out by Miers, H. A., 1897, *Min. Mag.*, XI, p. 263.

²Freundlich, H., 1926, *Colloid. . . . Chemistry*, pp. 601-607 and index; Bancroft, W. D., *op. cit.*, pp. 210, 322-332.

conite, atacamite, chalcophyllite, etc., in which the surface of the pseudomorph has a colloform crust of chrysocolla, may also be substitution pseudomorphs of this kind instead of by alteration.

In this type the adsorbed colloid may function as a "protecting" agent in the peptization of the adsorbent. It is also necessary that the colloid be in part coagulated and deposited in order to form the pseudomorph. No particular reason can be suggested which would account for this unless there is a partial solution of the original substance and the resulting electrolyte effects the coagulation of the sol.

Certain of the serpentine pseudomorphs from the Tilly Foster Mine, Putnam Co., N. Y., appear to have formed through the action of colloidal magnesium silicate. This is suggested by the serpentine pseudomorphs after free crystals of calcite described by J. D. Dana from this locality¹ in which the pseudomorphs are enveloped by a thick crust of colloform serpentine. Similar colloform crusts of serpentine covering serpentine pseudomorphs after free crystals of clinochlore, chondrodite, and periclase are shown by specimens from Tilly Foster in the Museum collection. These, too, may be pseudomorphs by substitution rather than by alteration. A colloidal origin involving magnesium silicate gel has also been advanced for the well known talc pseudomorphs after quartz and dolomite from Gopfersgrün, Bavaria.²

(6) *Through the direct coagulation of a sol on the surface of a dissolving mineral by adsorption of the electrolyte, the crystal being substituted for as solution advances.* Pseudomorphs of shattuckite and plancheite after calcite from Katanga have been ascribed to this method of formation, a colloidal solution of hydrous copper silicate being coagulated through the adsorption of calcium ion.³ Depositional pseudomorphs of natural colloids after minerals of relatively high solubility are more probably formed by simultaneous solution and coagulation than by direct adsorption and peptization (5) since the solubility of the original mineral would preclude the formation of a stable sol. Here would belong opal after glauberite; chalcedony and opal after thenardite, gypsum, and anhydrite; clay after halite; and, in part (?) pseudomorphs of limonite, psilomelane, and chalcedony after gypsum and calcite.

The pseudomorphs of opal and chalcedony after gypsum, glauberite, and anhydrite included here are similar to the pseudomorphs of the quartz after calcite type (2) in that the coagulation of the silica may have been effected by the adsorption of calcium ion.

¹Dana, J. D., 1874, Amer. Jour. Sci., Ser. 3, VIII, p. 379 and Plate vi, fig. 1.

²Enk, E., 1930, Kolloid-Zeits., LI, pp. 257-273.

³Hacquaert, A., 1926, Ann. geol. soc. Belg., XLIX, p. 90.

This process of pseudomorphism encounters a difficulty in the mechanism of getting a fresh supply of colloid to the solution surface through the layer of already deposited colloid. The same difficulty also exists in the preceding type and also the problem of getting the peptized substance out again through the deposited colloid.

CONDITIONS CONTROLLING PEPTIZATION.—The peptization, or colloidal dispersal of a substance can be accomplished by mechanical, electrical, or electrochemical disintegration, by the removal of an agglomerating agent, or by the addition of a peptizing agent. Only the last method would appear to be operative in the formation of pseudomorphs. The process is governed by the following conditions: (1) The particles of the substance to be peptized must be sufficiently small. (2) The surface tension at the solid-liquid interface must be lowered by adsorption, a low surface tension on the liquid side tending to disintegrate the solid and cause it to go into the liquid as an internal phase. The surface tension may be lowered by the adsorption of a liquid, non-electrolyte, ion, salt, or by a peptized colloid.

In the first condition an immediate difficulty arises since in nature we are dealing with crystals of considerable size and not, as in the experimentally investigated cases of peptization, with a freshly formed precipitate or gel the particles of which are already of colloidal dimensions. That the direct peptization of large crystals may be possible under suitable conditions is indicated by the recent discovery that crystals have a secondary structure superposed on the fundamental lattice arrangement of its constituent elements.¹ This secondary structure is shown as a mosaic or composite structure of the crystal, the crystal being composed of blocks whose size is of the order of 10^{-6} to 10^{-5} cms. Blocks of these dimensions are of a typically colloidal order of magnitude. The crystal forces making these blocks cohere to one another are obviously less than the cohesive forces acting between the lattice units composing each block. The recognition of the mosaic structure in fact arose from the observed difference between the theoretical strength of a crystal, calculated on the basis of the lattice forces, and the much smaller experimentally determined strength. The cohesion between liquid-block would be expected to approach that of block-block as the temperature and concentration of the liquid (solution) increased and as its composition approached that of the solid phase. In any case the important factor in

¹For a general discussion, see: Zwicky, F., 1932, *Phys. Rev.*, XL, pp. 63-77; 1931, *Proc. Nat. Acad. Sci.*, XVII, pp. 524-532; *ibid.*, 1929, XV, pp. 253-259, 816-822; Smekal, A., 1929, *Zeits. angew. Chem.*, XLII, pp. 489-494; 1929, *Zeits. Physik.*, LV, pp. 289-303; 1928, *Naturwiss.*, XVI, pp. 262-263.

promoting the dispersal of the crystal is in an adsorption on the surface of the blocks. The ways in which this adsorption may take place have been previously discussed.

The mechanism by which the particles of a mosaic crystal can be peptized is similar to that of the peptization of the particles of, say, a coagulum of copper sulphide by hydrogen sulphide. The difference between the two cases is solely one of degree, that is, of relative ease of peptization. In the latter case the coagulum consists of loosely aggregated colloidal particles randomly piled on one another. A sedimentation structure of this kind is relatively easier to disperse because the cohesive forces acting between the particles themselves are negligible. In the case of a crystal, the particles—or minute crystal blocks—are held together more or less securely in a vectorial structure by crystal forces which must also be overcome by the peptizing agent. The phenomenon of “aging” shown by sols, which seems to be due largely to the coalescence and aggregate crystallization of the original colloidal particles, shows that under laboratory conditions the cohesive forces acting between block-block in a crystal are in general of a greater order of magnitude than the forces which are available to disperse the blocks. The question is what relation may exist in the regions of chemical and physical environment that obtain under geologic conditions, particularly those of pneumatolytic and hydrothermal mineralization. The rôle played by colloidal processes in this field has been stressed by Lindgren,¹ Boydell,² and others, but from different lines of evidence.

“Water peptization” by a strongly adsorbed lower polymer of water stable at high temperatures may be important in effecting colloidal mineralogical changes not only in metasomatism but in thermal metamorphism and allied fields. This is shown to be likely by the experiments of Barus on the colloidal dispersal of glass under hydrothermal conditions.³ F. W. Clarke has already suggested that the ordinary rock-making silicates would behave similarly to glass at high temperatures and pressures.⁴

The growth of crystals in ordinary crystallizations by the accretion of particles of colloidal size is well known. According to von Veimarn,⁵ the ability to grow vectorially into large crystals is characteristic of

¹Lindgren, W., 1928, ‘Mineral Deposits,’ New York, 3d Ed. See index.

²Boydell, H. C., 1926, *Econ. Geol.*, XXI, pp. 1–55; 1925, *Trans. Inst. Min. Met. (London)*, XXXIV, Pt. 1, p. 145.

³Barus, C., 1900, *Amer. Jour. Sci.*, Ser. 4, IX, p. 161. This is similar to the water peptization of gelatin and some other substances. (Bancroft, W. D., op. cit., pp. 207–208, 311–312, 319–320).

⁴Clarke, F. W., 1924, *U. S. Geol. Surv. Bull.* 770, p. 299.

⁵Von Veimarn, P. P., 1928, *Kolloid-Zeits.*, XLIV, pp. 279–288; *ibid.*, 1929, XLIX, pp. 149–150 also *Chemical Abstracts*, 1930, XXIV, p. 539.

particles in all degrees of dispersion, and, further, the solution of crystals may similarly take place by the dispersal of minute blocks in the crystal formed by regularly spaced weak points in the lattice forces. This is the secondary structure of Smekal and Zwicky. Traube¹ in discussing the growth and solution of crystals through the loss or gain of submicroscopic particles identifies the particles with the Smekal blocks; a similar view is expressed by Ostwald and von Buzagh.²

The growth of the macro-composite structure, or "lineages," shown by galena and other crystals has been discussed from the viewpoint of the mosaic crystal idea by Buerger.³

VOLUME RELATIONS.—In pseudomorphs formed by the substitution of colloidal particles for the original substance, the amount of colloid deposited depends on the size of the particles, the amount and origin of the charge on the particles, and on the nature of the process causing the coagulation. As these factors vary, a volume change accompanying the pseudomorphism may also vary; there is in no sense a rigid stoichiometric relation to be observed as in a chemical equation. The substitution of free crystals without loss of volume is possible on this basis since the colloid is in indefinite excess and a small amount of foreign substance may by adsorption cause the deposition of a very large amount of colloid.

DESCRIPTION OF SPECIMENS

"Achteragdtite." See unknown after helvite

"Aglaite." See albite after spodumene

"Albin." See calcite after apophyllite

Albite after Spodumene: *II, C 2*¹

Chesterfield, Massachusetts, 20619⁶ (*aglaite*)⁶

"Algerite." See muscovite (pinite) after wernerite

Ampangabeite after Euxenite: *II, C 2*

Tritriva, near Antsirabe, Madagascar, 18179–80–1–2

Analcite after Leucite: *II, C 2*

Magnet Cove, Garland Co., Arkansas, 9492

Anglesite after Cerussite: *III, B 2 b*

Broken Hill Mine, New South Wales, 16364–6–7–9, 16371–2

¹Traube, J., 1929, *Zeits. Elektrochem.*, XXXV, pp. 626–627; 1929, *Kolloid-Zeits.*, XLVII, pp. 45–47.

²Ostwald, Wo., and von Buzagh, A., 1929, *Kolloid-Zeits.*, XLVII, pp. 314–323.

³Buerger, M. J., 1932, *Amer. Min.*, XVII, pp. 177–191.

⁴For explanation of this and similar references, see Table I: Descriptive Scheme for Pseudomorphs, page 394.

⁵This and similar numbers designate specimens in the collection of minerals in The American Museum of Natural History.

⁶Julien, A. A., 1879, *Ann. New York Acad. Sci.*, I, p. 318.

Ankerite after Calcite: *III, B 2 a*

Guanajuato, Mexico, 8060

"Anomalite." See unknown after jeffersonite

Apatite after Wagnerite: *II, C 2*

Werfen, Germany, 15177

Argentite after Silver: *I, C 2*

Himmelsfürst, near Freiberg, Saxony, 800; "Peru," 330

"Aspasiolite." See muscovite (pinite) after cordierite

"Atheriastite." See chlorite after wernerite

Barite after Gypsum

Navajo, Arizona, no Spec. No.; radially fibrous gypsum nodules in clay replaced by barite.

Barite after Witherite: *I, C 2*

Fallowfield, Northumberland, 8495; Alston Moor, Cumberland, 8508

Bassanite after Gypsum: *I, C 2*

Mt. Vesuvius, Italy, 20401. Opaque white crystals occurring in a vesicular lava.

Bismutosphärite after Wulfenite: *I, B 3*

Guanajuato, Mexico, 8967. Small, nearly equant tetragonal crystals with a prism and a low pyramid, the faces slightly warped and the edges serrated. The habit is very similar to the wulfenite from the Sierra de los Lamentos, Chihuahua (19834). Scheelite and wulfenite have previously been suggested as the original mineral.¹

Bornite after Chalcocite: *I, C 2*

St. Ives, Cornwall, 1471. See further under pyrite after chalcocite.

Brochantite after Azurite: *III, B 2 b*

Good Springs, Nevada, 11798, 13748-9. With malachite; the interior of the crystals malachite mixed with brochantite, the exterior parts brochantite with a drusy crust of the same mineral. Possibly a pseudomorph after malachite (after azurite). A pseudomorph of brochantite after malachite is mentioned by Hintze.²

"Cacoclasite." See grossularite after sarcolite

Calamine after Calcite: *III, B 2 a*

Granby, Missouri, 12194, 18029; Joplin, Missouri, 12198, 12181 (pseudomorphous after a coral), 368

Calamine after Galena: *III, B 2 a*

Joplin, Missouri, 12195

¹Frenzel, A., 1873, *Neues Jahrb.*, pp. 801, 946.

²Hintze, C., 1930, 'Handbuch der Mineralogie,' Bd. I, Abt. 3, Pt. 2, p. 4214.

Calamine after Pyromorphite: *III, B 2 a*

Cumberland, England, 12168

Calcite after Apophyllite: *I, B 3*

Aussig, Bohemia, 12596 (*albin*). Other so-called albins from Bergen Hill, West Paterson, and Great Notch, New Jersey, Cap d'Or, Nova Scotia, and India are contained in the collection. These are simply apophyllites in which Ca or Mg has been introduced into the crystal lattice by "zeolitic base exchange," the crystals becoming white and opaque. The original *albine* of Werner was a calcite pseudomorph from Aussig.

Calcite after Aragonite

Fort Collins, Larimer Co., Colorado, 20264, 6821 (*II, C 1*). These are sometimes erroneously made pseudomorphs after hanksite. Quartz pseudomorphs after these crystals have also been noted. Also after similar pseudohexagonal twins from Baroda, Kansas, 18283 (*II, C 1*); Vesuvius, Italy, 8435 (*I, C 1*). Specimens from the following localities are hollow incrustation pseudomorphs of calcite after aragonite and not true paramorphs in which there has been no loss or gain of substance: Girgenti, Sicily, 8388; Caltanissetta, Sicily, no Spec. No.: Cianciana, Sicily, 8384-5-6, 8375-6, 8393, 8374-5-7; Herregrund, Hungary, 8395; Cumberland, England, 8454. In the Caltanissetta specimen thin septa of calcite mark the twin planes of the pseudohexagonal prism; the interior of each segment is hollow.

Calcite after Celestite: *II, C 2*

Eiderstadt, Prussia, 6305; Obersdorf, Thuringia, no Spec. No. These are the "barleycorn" pseudomorphs.

Calcite after Dolomite: *III, B 2 a*

Guanajuato, Mexico, 6720, 18009

Calcite after Glauberite: *II, C 2*

Rosenegg, Württemberg, 20638. The habit of these glauberite crystals differs largely from that of the New Jersey glauberite crystals (see quartz after glauberite). Some crystals appear like rhombs with *c*(001) and *m*(110) only.

Calcite after Gypsum: *II, C 2*

Little Colorado River, near Cameron, Arizona, 20441. After aggregates of lenticular gypsum crystals.

Calcite after Mizzonite: *II, C 2*

Bagnères, Hautes Pyrénées, France, 18884

Calcite after Orthoclase: *II, C 2*

Manebach, Thuringia, 6255

Calcite after Thenardite: *II, C 2*

Rosenegg, Württemberg, 20620

Calcite after Unknown: *I, B 2 a*Mono Lake, California, 8071, and Pyramid Lake, Nevada, 6894 (*thinolite*¹)¹Dana, E. S., 1884, U. S. Geol. Surv., Bull., 12.

Calcite after Wood: *II, B 3*

Mumford, near Caledonia, New York, 10152

"Cantonite." See covellite after galena

Carnotite after Wood: *II, B 3*

Naturita, Colorado, no Spec. No.; Yellow Cat Wash, near Thompsons, Utah, 18614

Cassiterite after Bismuthinite: *III, B 2 b*

Cornwall, England, 5365. After needle-like crystals of bismuthinite; in iron-stained, cavernous quartz.

Cassiterite after Orthoclase: *II, B 3*

St. Just, Cornwall, 5364

Cassiterite after Quartz

Cornwall, England, 5385. Although labeled a pseudomorph, no evidence of pseudomorphism was observed on the specimen; quartz crystals saturated with co-deposited cassiterite.

"Cataspilite." See muscovite (pinite) after cordierite

Celadonite after Augite: *II, C 2*

Vicenza, Italy, 14022

Celadonite after Heulandite

Poonah, India, 13956. Originally heulandite crystals saturated with co-deposited celadonite. The leaching away of the heulandite has left a porous mass of celadonite with the form of the original crystal.

Cerussite after Anglesite: *III, B 2 b*

Wheatley Mines, Chester Co., Pennsylvania, 8606-7; Broken Hill, New South Wales, 8600; Sidi Amor ben Salem, Tunisia, 19225, 19622; Cartagena, Spain, 8565 (in this specimen the original surface of the crystal has been preserved by a film of black Mn oxide, *I, B 3*).

Cerussite after Calcite: *I, C 2 vd*

Granby, Missouri,¹ 20627. Small calcite scalenohedrons on chert.

Cerussite after Fremontite: *II, B 3*

Cañon City, Fremont Co., Colorado, 18064. A large well-formed pseudomorphosed crystal of fremontite (natrambygonite) embedded in a matrix of quartz, lepidolite, and pink feldspar.

Cerussite after Leadhillite: *I, C 2*

Leadhills, Scotland, 17626

Cerussite after Linarite: *I, C 2*

Cromford, Derbyshire, England, 8685. A thin film of galena covers the surface of the crystals; the interior is solid cerussite.

¹Rogers, A. F., 1910, Proc. Am. Phil. Soc., XLIX, pp. 17-23.

Cerussite after Phosgenite: *I, C 2*

Dundas, Tasmania, 8587; Tarnowitz, Silesia, 8678

Cervantite after Antimony: *I, C 2*

Kern County, California, 17240, 18383 (*stibioconite*?)

Cervantite after Stibnite: *I, C 2*

Tlalpujehua, Mexico, no Spec. No.; Braunsdorf, Saxony, 4510; Charcas, San Luis Potosi, Mexico,¹ 17478-9; "Borneo," 4511-2 (*I, C 2 vd*)

Chalcedony after Analcite: *I, B 3*

Blair Junction, Esmeralda Co., Nevada, 20258

Chalcedony after Aragonite: *III, B 2 a*

Guanajuato, Mexico, 3742-6

Chalcedony after Barite: *III, B 2 b*

Rico, Colorado, 4179; near Grand Junction, Colorado, 20180 (jasper)

Chalcedony after Calcite: *III, B 2 a*

Rico, Colorado, 4147-8-9, 4151-2-3-5-6, 4179; Guanajuato, Mexico,² 3746; East Pool Mine, Camborne, Cornwall, 3636; Schneeberg, Saxony, 3561-2-3; locality unknown, 4243.

Also pseudomorphous after coral, gastropod shells, etc., from Ballast Point, Tampa Bay, Florida, 4029-30-1-2-4-8, 2023.

Chalcedony after Datolite: *I, B 3*

Haytor, Devonshire, 11657, and Bergen Hill, New Jersey, 11661 (*haytorite*).

Also known from Paterson, New Jersey,³ Chester County, Pennsylvania,⁴ and Cornwall, England.

Chalcedony after Fluorite: *III, B 2 a-b*

Rico, Colorado, 4150; Liskeard, Cornwall, 3620; Devonshire, England, 3640; Treszytan, Transylvania, 4243, 3494 (*small blue chalcedony*).

Chalcedony after Wood: *II, B 3*

Chalcedony Park, near Holbrook, Apache Co., Arizona, a large suite of polished sections; Teller County, Colorado, 19875-7; Placer County, California, 4475; Ellensburg, Washington, 4268; Livingston, Montana, no Spec. No.; near Guatemala City, Guatemala, 17495; Antigua, West Indies, 4418; Martinique, West Indies, 3604; Las Vellas, Cuba, no Spec. No.; Tsuno, Buzen, Japan, 7029; "Van Diemen's Land" (Tasmania), 3222; Alberta, no Spec. No.

Chalcocite after Covellite: *I, C 2*

Butte, Montana, 17247. After a large aggregate of well formed covellite crystals.

Chalcocite after Galena: *I, C 2*

¹Ford, W. E., 1912, Amer. Jour. Sci., Ser. 4, XXXIV, p. 184.

²Rogers, A. F., op. cit.

³Dana, E. S., 1893, 'Cat. of Amer. Localities of Minerals.'

⁴Vaux, G., 1926, Proc. Acad. Nat. Sci. Phil., LXXVIII, pp. 17-19.

Wheal Falmouth, Truro, Cornwall, 1120 (*harrisite*¹); Kelly, New Mexico, 20622.

The chalcocite in this specimen has a perfect cubic parting inherited from the galena cleavage.

Chalcocite after Pyrite: *I, C 2*

Cornwall, England, 1093

Chalcocite after Sphalerite: *I, C 2* or *I, B 3*?

Butte, Montana, 20623 (two specimens). The pseudomorphism in one of these specimens is remarkably perfect. This specimen is a group of large complexly developed sphalerite crystals with surface striations and etch pits sharply preserved by the chalcocite. The chalcocite has a ready dodecahedral parting inherited from the sphalerite cleavage. No volume change accompanied the pseudomorphism. In the other specimen sphalerite of dodecahedral habit is pseudomorphosed by chalcocite but without retention of the cleavage. A small group of covellite crystals on the surface of this specimen are also pseudomorphs in chalcocite.

Chalcocite after Wood: *II, B 3*

Little Wichita River, Archer County, Texas, 1132

Chalcopyrite after Pyrrhotite: *I, C 2*

Knappenwald, Tyrol, 1442. A stout hexagonal prism, 6 cm. long, with a rounded termination. The crystal contains a core of unreplaced pyrrhotite.

Chalcopyrite after Tetrahedrite: *III, B 2 b*

Gilpin County, Colorado, 1564

Chlorite after Garnet: *II, C 2*

Spurr Iron Mine, Lake Superior, Michigan,² 10824-5; Salida, Chaffee Co., Colorado,³ 10858 (*aphrosiderite*)

Chlorite after Magnetite: *II, C 2*

Fahlun, Sweden, 13657-8 (*prochlorite*)

Chlorite (?) after Wernerite: *II, C 2*

Arendal, Norway, 11058, 11062, 11130 (*atheriastite*)

"Chlorophyllite." See muscovite (pinite) after cordierite

Chrysocolla after Azurite: *III, B 2 b*

Copperopolis Mine, Tintic, Utah, 14102

Cimolite after Augite: *II, C 2*

Hradisko Mt., near Bilin, Bohemia, 13995-6-7

Cinnabar after Barite: *I, B 3 vd*

Reddington Mercury Mine, Lake County, California,⁴ 1374

Calc after Halite: *I, B 3*

¹Originally described from Canton, Ga., and Ducktown, Tenn., by C. U. Shepard. See Genth, F. A., 1862, Amer. Jour. Sci., Ser. 2, XXXIII, p. 194; *ibid.*, 1857, XXIII, pp. 415-417.

²Pumpelly, R., 1875, Amer. Jour. Sci., Ser. 3, X, p. 17, and the following reference.

³Penfield, S. L., and Soerry, F. L., 1886, Amer. Jour. Sci., Ser. 3, XXXII, p. 307.

⁴Durand, Emile F., 1873, Proc. Calif. Acad. Sci., IV, p. 211.

Commern, Eifel, Germany, 20624. Hopper-shaped crystals on clay shale simulated by clay.

Cookeite after Orthoclase (?): *III, B 2 a*

Bennett's Quarry, Buckfield, Maine, 19452-4. With quartz.

Copper after Aragonite: *I, B 3*

Corocoro, Bolivia, 401-7-8

Copper after Azurite: *I, C 2 vd*

Potosi and Copper Glance Mines, near Georgetown, Grant County, New Mexico,¹ 406-8-9; Copper Rose Mine, Santa Rita, New Mexico, 20625. With malachite and cuprite.

Copper after Cuprite: *I, C 2*

Bisbee, Arizona,² 413, 18342, 18379. Possibly by substitution.

Copper after Laumontite: *I, B 3 vd*

Hancock, Houghton County, Michigan,³ 484, 534, 539, 17920

Corundum

The following minerals were observed forming alteration rims around corundum crystals:

Cyanite: Swannanoa Gap, Buncombe Co., North Carolina, 4684, Smyrna, Asia Minor, 4632

Damourite: Barsovka, Kyshtym District, Urals, 17883; Belts Bridge, Iredell Co., North Carolina, 4696, 4701-2-3-5-6-7-8-9, 4710-2-1-3-4; Haywood County, N. C., 4694-5; Chester County, Pennsylvania, 4669

Diaspore: Campo Longo, Switzerland, 4655-6; Unionville, Chester Co., Pennsylvania, 4671-3

Margarite: Unionville, Chester Co., Pennsylvania, 4669, 4769, 5271, 18748; Newlin, Penn., 4670

Muscovite: Belts Bridge, Iredell Co., North Carolina, 4697; Unionville, Chester Co., Pennsylvania, 4675; Burke County, N. C., 4682; Haywood County, N. C., 5274

Ripidolite: Franklin, Macon Co., North Carolina, 4729, 4757-8

Sillimanite: Burke County, North Carolina, 4681-2-3

Spinel: Franklin, Macon Co., North Carolina, 5275, 5083-4; Hindustan, 5086

Willcoxite: Shooting Creek, Clay Co., North Carolina, 4691

Zoisite: Buck Creek, Chunky Gal Mt., Clay Co., North Carolina, 4688

Many of these alterations have been described by Genth.⁴

Covellite after Galena: *I, C 2*

Cornwall, England, 1386 (*cantonite*). Chalcocite as an intermediate product.

¹Yeates, W. S., 1889, Amer. Jour. Sci., Ser. 3, XXXVIII, pp. 405-407.

²Rogers, A. F., op. cit.

³Pumpelly, R., 1871, Amer. Jour. Sci., Ser. 3, II, p. 245.

⁴Genth, F. A., 1873, Proc. Amer. Phil. Soc., XIII, p. 361; *ibid.*, 1882, XX, p. 381; 1890, Amer. Jour. Sci., Ser. 3, XXXIX, p. 47.

Cuprite after Atacamite: *I, C 2*

Burra Burra, Australia, 3142

Cuprite after Brochantite: *II, C 2*

Chuquicamata, Chile, 15350. After fibrous veins of brochantite cutting gossan.

"Cymatolite." See muscovite and albite after spodumene

Damourite after Spodumene: *II, C 2*

Kararfvet, Sweden, 13276. See also muscovite after spodumene.

Damourite after Tourmaline

Packard's Quarry, Hebron, Maine, 18048

Delafossite after Copper (?): *III, B 2 b*

Bisbee, Arizona, no Spec. No. (six specimens). Tentatively included here pending further study. In part only incrusting wire copper; with cuprite and possibly pseudomorphous after an earlier generation of that mineral.

Diaspore after Quartz

Chester, Massachusetts, 5870. Although labeled a pseudomorph, no evidence of pseudomorphism was observed on the specimen.

Dolomite after Calcite: *III, B 2 a-b*

Guanajuato, Mexico, a large suite of specimens, notably 6720, 8032-4; Frizington, England, 6442, 8030; Schemnitz, Czechoslovakia, 3479; Kremnitz, Czechoslovakia, 16002; Briza, Hungary, 6307; Freiberg, Saxony, no Spec. No. The dolomite in all specimens is oriented in parallel position to the original calcite.

Dolomite after Orthoclase: *II, C 2 ?*

Kokomo, Colorado, 20627. After orthoclase phenocrysts from a granitic rock.

Epidote after Oligoclase: *I, C 2*

Arendal, Norway, 11821

Epidote after Vesuvianite: *II, C 2*

Achmatovsk, South Urals, 11165

Epidote after Wernerite: *II, C 2*

Franklin, New Jersey, 11867; Lake Clear, Renfrew Co., Ontario, 11834; Arendal, Norway, 11060-4

"Esmarkite." See muscovite (pinite) after cordierite

"Fahlunite." See muscovite (pinite) after cordierite

Fassaite after Monticellite: *II, C 2*

Fassathal, Monzoni, Tyrol, 9575

Galena after Chalcopyrite: *I, C 2* ?

Victoria Mine, Müsen, Westphalia, 890; Littfeld, Prussia, 889. In both specimens the galena forms a single crystal oriented parallel to the original chalcopyrite crystal.

Galena after Pyromorphite: *I, C 2*

Ems, Nassau, 14980-7; Kautenbach, between Bernkastel and Trarbach, on the Moselle River, Baden, 886-7-8, 14938, 18272, 19139; Huelgoat, Brittany, 14952, 15034; Cornwall, England (Wheal Hope, Truro ?), 927; Broken Hill, New South Wales, 15023.

"Gieseckite." See muscovite (pinite) after nephelite

"Gigantolite." See muscovite (pinite) after cordierite

Glauberite molds in shale: *II, A*

Dollington, Pennsylvania,¹ 18318, also from Blackwell's Mills, New Jersey,² no Spec. No. In part these are calcite after glauberite: *II, B 1*.

Glaucconite after Augite: *II, C 2*

Fassathal, Monzoni, Tyrol, 13960

Gold after Calaverite: *I, C 2 vd*

Cripple Creek, Colorado,³ 278; Victor, Colorado, 280. The gold forms brown spongy skeletons after calaverite.

Grossularite after Diopside: *III, B 2 b*

Vaskö, Hungary, 14309, 17569. Incrustation pseudomorphs after small, pale green, transparent diopside crystals in drusy aggregates on a quartz rock.

Grossularite after Sarcosite: *II, C 2 or C 1*

Wakefield, Quebec, 11159-60 (*cacoclasite*)⁴

Gummite after Uraninite: *I, C 2*

Mitchell County, North Carolina, 16195-6-8, 16200-3, 17832. Large (1.5 cm.) cubes and cubo-octahedrons; showing the sequence uraninite—clarkeite—gummite—uranophane.

Gypsum after Aragonite: *II, C 2*

Bastennes, Pyrénées, France, 18038. A stout twinned prism with smooth faces replaced by granular gypsum. Pseudomorphs of aragonite after gypsum are not uncommon⁵; these sometimes show a mutual orientation.

Gypsum after Halite: *II, B 3*

Jamaica, West Indies,⁶ 2542; Provence, France, 16638.

Gypsum after Wood: *II, B 3*

Birney, Montana, 19865-72

¹Wherry, E. T., 1916, *Amer. Min.*, I, pp. 37-42, and Stose, G. W., *ibid.*, 1919, IV, pp. 1-4.

²Hawkins, A. C., 1928, *Amer. Min.*, XIII, pp. 238-239.

³Lindgren, W., and Ransome, F. L., 1906, *U. S. Geol. Surv. Prof. Paper* 54, pp. 114-115.

⁴Bowen, N. L., 1919, *Amer. Jour. Sci.*, Ser. 4, XLVIII, p. 440.

⁵Hintze, C., 1930, 'Handbuch der Mineralogie,' Bd. I, Abt. 3, Pt. 1, p. 2984; Pt. 2, p. 4294.

⁶Hovey, E. O., 1897, *Amer. Jour. Sci.*, Ser. 4, III, p. 425.

Halite after Carnallite: *I, B 3*

Westeregeln, Saxony, 2539

"Hampshirite." See serpentine after chrysolite

"Harrisite." See chalcocite after galena

Hausmannite after Calcite: *I, B 3 vd*

Ilmenau, Thuringia, 5234-5

"Haytorite." See chalcedony after datolite

Hematite after Calcite: *I, B 3 vd*

Sundwig, Westphalia, 4897-8; Langenberg, Schwartzenberg, Saxony, 17573;
Ilmenau, Thuringia, 6158

Hematite after Magnetite (Martite): *I, C 2* or *II, C 2*

Twin Peaks, Millard Co., Utah,¹ 4965-6-7-8-9-70-1, 5179; Marquette, Marquette Co., Michigan, 4949; Carroll County, Virginia, 4942; Digby Neck, Nova Scotia, 4960, 5180; Cerro de Mercado, Durango, Mexico,² 4963; Itambé, Minas Geraes, Brazil, 4962; Mont Dore, Auvergne, France, 4961. Crystals from the Utah locality sometimes measure 8 cm. on an octahedral edge with the splendid luster of the original magnetite preserved in the pseudomorph.

Hematite after Siderite: *I, C 2 vd*

Crystal Peak, Teller Co., Colorado,³ 18344-6

"Houghite." See hydrotalcite after spinel

Hydromagnesite after Lansfordite: *I, C 2*

Lansford, Pennsylvania, 8953-5-4

Hydrotalcite after Spinel: *II, C 2*

Antwerp, Jefferson Co., New York, 6134-5; Rossie, St. Lawrence Co., New York,⁴ 6137; "Ontario," 6138; Snarum, Sweden, 17482

Hydrotitanite after Perovskite: *II, C 2*

Magnet Cove, Garland Co., Arkansas,⁵ 17839

"Hydrophilite." See muscovite (pinite) after oligoclase

"Hypochlorite" after Calcite: *III, B 3*

Schneeberg, Saxony, 12576. Hypochlorite is a colloidal mixture, in appearance somewhat like chrysocolla.

Kaolinite after Leucite: *II, C 2*

Caldas, Brazil, 222

Kaolinite after Orthoclase: *II, C 2*

Treverbyn, Cornwall, 17602-3-4; "Cornwall," 9171-2-3; Ilmenau, Thuringia, 9158

¹Patton, H. B., 1907, Colorado School of Mines Quart., II, No. 2.

²Foshag, W. F., 1929, Proc. U. S. Nat. Mus., LXXIV, Art. 23.

³Smith, W. B., 1885, Proc. Colo. Sci. Soc., II, p. 108.

⁴Johnson, S. W., 1851, Amer. Jour. Sci., Ser. 2, XII, p. 361.

⁵Koenig, G. A., 1876, Proc. Acad. Nat. Sci. Phil., pp. 82-84.

Kaolinite after Spodumene: *II, C 2*

Greenwood Mine, Noyes Mt., Greenwood, Maine, 19455, 14706

"Killinite." See muscovite (pinite) after spodumene

Laumontite after Apophyllite: *I, C 2*

Great Notch, New Jersey, 18019-20-1-2. Large tabular crystals with the laumontite in fibers perpendicular to the surfaces; associated with prehnite, calcite and pectolite.

Leadhillite after Calcite: *I, C 2* and *III, C 2 vd*

Beer Cellar Mine, Granby, Missouri,¹ 16480-3-4

Leadhillite after Galena: *III, C 2 vd*

Beer Cellar Mine, Granby, Missouri,² 16477

Lepidolite after Phenacite

Berry's Mine, Poland, Maine, 18041

"Liebnerite." See muscovite (pinite) after nephelite

Limonite after Ankerite: *I, C 2 vd*

Catawba County, North Carolina, 6016

Limonite after Barite: *I, B 3*

Cumberland, England, 5994

Limonite after Calcite: *III, B 2 a*

Württemberg, Germany, 5969

Limonite after Cuprite: *I, B 3*

Causersteinal, Westerwald, Germany, 5964

Limonite after Gypsum: *I, B 3 vd*

Tintic, Utah, 6038

Limonite after Magnetite: *I, C 2*

Jarilla Mts., New Mexico, 6019-20 (as an alteration of *martite*)

Limonite after Marcasite: *I, C 2*

Mineral Point, Iowa Co., Wisconsin, 6022; Richland County, Wisconsin,³ 17579, 17688, 17718, 19561; Galena, Illinois, 1958; Grund, Harz, Germany, 5979; Schwartzenberg, Saxony, 5983; locality unknown, 19561.

Limonite after Pyrite: *I, C 2* and *II, C 2*

Pelican Point, Great Salt Lake, Utah, 6032-3-4-5-6-7; Blair Junction, Esmeralda Co., Nevada, 20259; Copper Mt., Sulzer, Alaska, no Spec. No.; Rock County, Wisconsin, 17578; Wrightsville, York Co., Pennsylvania,⁴ 6014, 10794; "Russia," no Spec. No.; Rio, Elba, 5988-9-90-1-2, 1622 (a

¹ Foote, W. M., 1895, Amer. Jour. Sci., Ser. 3, L, p. 99.

² Idem.

³ North, H. B., 1913, Amer. Jour. Sci., Ser. 4, XXXV, pp. 270-272.

⁴ Holden, E. F., 1919, Amer. Min., IV, pp. 68-69.

13 cm. pyritohedron); Vlotho, Westphalia, 5960; St. Gotthard, Switzerland, 5984; "Germany," 5963; Xaaga, Oaxaca, Mexico, 5998; Columbia, Pa., 6010; North Texas, Lancaster Co., Pa.,¹ 6013; Carter County, Tennessee, no Spec. No.

Limonite after Pyromorphite: *I, B 3*

"Siberia," 14945

Limonite after Pyroxene: *II, C 2*

Monroe, Orange Co., New York, 9720

Limonite after Siderite: *I, C 2 vd*

Pikes Peak, 6026-7-8-9-30-1, and Cheyenne Canyon, 6201, 6023-5, Teller Co., Colorado²; Hüttenberg, Carinthia.

Magnetite after Amphibole: *II, B 3*

Succasunna, New Jersey, 5159. After a large coarse crystal of typical cross-section.

Magnetite after Brookite: *I, B 3 (?)*

Magnet Cove, Garland Co., Arkansas, 5174-5-6. Pseudomorphs after crystals of the *arkansite* variety of brookite with m(110), e(122) and very minor 1(210); the habit is similar to the crystal figured by Dana.³ The crystals are remarkable for their large size: the vertical axis of one measures 12 cm., and another specimen is a fragment of a much larger crystal. The magnetite is of the lodestone variety.

Magnetite after Hematite: *I, C 2*

French Creek Falls, Chester Co., Pennsylvania, 5160-1-2-3-4-5-6; Valais, Binnenthal, Switzerland, 4789-90-1-4, 5126-8, 5132-3-6. Only one of these specimens, a rosette-like aggregate of crystals from French Creek, was definitely a pseudomorph of magnetite after hematite. The rest of the specimens, although labeled as pseudomorphs, consisted of parallel growths and oriented incrustations of magnetite and hematite. The Binnenthal material showed all gradations between magnetite dodecahedrons with included plates of hematite (parallel to (111)) to tabular hematite crystals with a drusy oriented incrustation of magnetite. Pseudomorphs of magnetite after hematite are known from Antwerp, New York,⁴ and from a number of other localities.

Magnetite after Siderite: *II, C 2*

Siegen, Prussia, 5146

Melachite after Azurite: *I, C 2*

Copper Queen Mine, Bisbee, Arizona, 8735, 8741, 8776, 8885, 19122, 19163 19594, 19793; Old Dominion Mine, Globe, Arizona, 8759, 8761, 8765-6

¹Willig, H. L., 1919, *Amer. Min.*, IV, p. 2.

²Smith, W. B., *op. cit.*

³Dana, E. S., 1900, *System of Mineralogy*, 6th Ed., p. 242, fig. 4.

⁴Moses, A. J., 1893, *School of Mines Quart.*, XIV, p. 52.

Clifton, Arizona, 4766, 8765, 8831-5-6, 8898, 8746; Elkhorn Mine, Elkhorn, Montana, 18011; Morenci, Arizona, 8821; Burra Burra, South Australia, 8715; Broken Hill Mine, New South Wales, 8815; Chessy, near Lyon, France, 8775-6-7-9, 8787, 8795; Laurion, Greece, 8810; Nizhne Tagilsk, South Urals, 8705; Tomsk, Russia, 8704; Tsumeb, near Otavi, South West Africa, 19794.

Malachite after Brochantite: *I, C 2*

Tintic, Utah, 8772. Pseudomorphous after divergent groups of small bladed prismatic crystals of brochantite. See also under brochantite after azurite.

Malachite after Calcite: *III, B 2 a-b*

Mammoth Mine, Tintic, Utah, 8732; Eureka, Nevada, 8733; Copper Queen Mine, Bisbee, Arizona, 18386 (in form of brachiopods).

Malachite after Cuprite: *I, C 2*

Chessy, near Lyon, France, 4524-5-6-7-8, 4576, 8698; Broken Hill Mine, New South Wales, 4519; "New Mexico," 4545; Cheyenne, Wyoming, 14095; Bisbee, Arizona, 4554; Matahambre, Pinar del Rio, Cuba, 19384.

Malachite after Gypsum: *III, B 3 vd*

Tintic, Utah, 8729-30-1. After crystals and stalactites of gypsum.

Marcasite after Pyrrhotite: *I, C 2*

Leoben, Carinthia, 1445, 1929; Freiberg, Saxony, 1440; Felsöbánya, Roumania, 1921. See further under pyrite after pyrrhotite.

Massicot after Galena: *II, C 2*

Boggy Camp, New South Wales, 4617

Metaheiwittite after Wood: *II, B 3*

Montrose, Colorado, 18618

Meyerhoffite after Inyoite: *I, C 2*

Mt. Blanco District, Inyo Co., California,¹ 20295

Mimetite after Anglesite: *I, C 2*

Mina del Diablo, Durango, Mexico,² 15035

Minium after Cerussite: *I, C 2*

Broken Hill Mine, New South Wales, 18294

Minium after Galena: *II, C 2*

Stone Mine, Leadville, Colorado,³ 5245

Muscovite after Andalusite: *II, C 2*

Wicklow, Ireland, 13256

Muscovite (Pinite) after Anorthite: *II, C 2*

Aker Södermanland, Sweden, 13385 (*rösite*); Tunaberg, Sweden, 13386-7 (*polyargite*), and 13388 (*pyrrholite*)

¹Schaller, W. T., 1916, U. S. Geol. Survey Bull., 610, pp. 35-55.

²Genth, F. A., and von Rath, G., 1887, Proc. Amer. Phil. Soc., XXIV, p. 33.

³Hawkins, J. D., 1890, Amer. Jour. Sci., Ser. 3, XXXIX, p. 42.

Muscovite (Pinite) after Cordierite: *II, C 2*

Auvergne, France, 13366-7-8-9; Schneeberg, Saxony, 13370-4; Tammela, Finland, 13376 (*gigantolite*); Langban, Sweden, 18035, 13398 (*cataspilite*); Flögfoir, 10412, and Kragerö, 10403, Norway (*aspasiolite*); Bamle, 10407, and Brevig, 10408, Norway (*praseolite*); Fahlun, Sweden, 10411-4 (*fahlunite*); Helsingfors, Finland, 10415, 13394 (*pyrargillite*); Persberg, Sweden, 18056 (*persbergite*); Brevig, Sweden, no Spec. No. (*esmarkite*).

Also for *chlorophyllite*; Unity, Maine, 10423; Haddam, Connecticut, 10417-9-20; Waterbury, Conn., 13371-2; Litchfield, Conn., 13373.

Muscovite (Pinite) after Nephelite: *II, C 2*

Diana, 13377, 13381, and Natural Bridge,¹ 13378-9-80-2, Lewis Co., New York (*gieseckite*); Fleimsthal, Tyrol, 13383-4, 10454 (*liebnerite*).

Muscovite (Pinite) after Oligoclase (?)

Wettin, Germany, 13389 (*hydrophilite*).

Muscovite (Pinite) after Orthoclase: *II, C 2*

"Germany," 20629. After phenocrysts in a quartz porphyry.

Muscovite (Pinite) after Spodumene: *II, C 2*

Norwich, Connecticut, 17842, and Chesterfield, Massachusetts,² 20628; Killiney Bay, near Dublin, Ireland, 9779, 13392-3 (*killinite*). See also damourite after spodumene.

Muscovite after Spodumene: *II, C 2*

With albite (*cymatolite*),³ Branchville, Connecticut, 20626 (7 specimens); also for *pihlite*,⁴ which is similar: Norwich, Conn., 9789, Goshen, Massachusetts, 14155, and Fahlun, Sweden, 14144. See also albite after spodumene.

Muscovite after Tourmaline: *II, C 2*

Near Texas, Lancaster Co., Pennsylvania, 13281.

Muscovite (Pinite) after Wernerite: *II, C 2*

Wilsonite: Bathurst, Ontario, 11131, 13390, Rossie, St. Lawrence Co., New York,⁵ 11103, Burgess, Ontario, 13391, L'Amable, Ontario, 19265. Also Franklin, New Jersey, 11133-4 (*algerite*).⁶ Incipiently altered wernerites are represented by specimens from Eganville, Bob Lake, and Bathurst, Ontario, Pierrepont, New York; Franklin, New Jersey; Arendal, Norway; Bolton, Massachusetts; Pargas and Laurinkari, Finland. Not all of these alterations tend toward pinite; in part they tend toward a talcose or toward a claylike substance (Finland).

¹Brush, G. J., 1858, Amer. Jour. Sci., Ser. 2, XXVI, pp. 64-68.

²Julien, A. A., 1879, Ann. New York Acad. Sci., I, p. 318. See also Connolly, J. P., 1922, Proc. South Dakota Acad. Sci., VI, p. 42, and Schwartz, G. M., and Leonard, R. J., 1926, Amer. Jour. Sci., Ser. 5, XI, p. 257.

³Brush, G. J., and Dana, E. S., 1880, Amer. Jour. Sci., Ser. 3, XX, p. 257.

⁴Julien, A. A., op. cit.

⁵Root, E. W., 1868, Amer. Jour. Sci., Ser. 2, XLV, p. 47.

⁶Hunt, T. S., 1849, Amer. Jour. Sci., Ser. 2, VIII, p. 103.

Nesquehonite after Lansfordite: *I, C 2*Lansford, Pennsylvania,¹ 8953-4-5Opal after Aragonite: *III, B 2 a*Racalmuto, Sicily, 4367. Brown opaline silica, in part chalcedonic, with adsorbed sulphur compounds (*melanophlogite*).Opal after Glauberite: *I, B 3*White Cliffs, New South Wales, 2376-7, 4371-2 (*precious opal*). These are the "pineapple" pseudomorphs.Opal after Siderite: *II, B 3*Hüttenberg, Carinthia, 4404 (*cachalong opal*).Opal after Wood: *II, B 3*Virgin Valley, Humboldt Co., Nevada, a suite of superlatively fine polished specimens in the Morgan Gem Collection (*precious opal*); Yellowstone National Park, Wyoming, 632 (*precious opal*); Clover, Lincoln Co., Idaho, 643; White Cliffs, New South Wales, 17680, 4371-2 (*precious opal*); Middle Park, Grand Co., Colorado, 4457.

Pseudomorphs of precious opal after gastropod shells and fragments of bone, from White Cliffs, 2308, 2367, are also shown in the collection; after a brachiopod, Giessen, Germany, 4400.

Orthoclase after Leucite: *II, C 2*Magnet Cove, Arkansas,² 9254-5-6, 9489-90; Oberwiesenthal, Saxony, 9138, 9486-7-8-9. With nephelite (*pseudoleucite*).Pachnolite after Crysolite: *II, C 2*

Ivigut, Greenland, 3176. With hagemannite and gearksutite as associated alteration products.

"Persbergite." See muscovite (pinite) after cordierite

"Pihlilite." See muscovite and albite after spodumene

Plumbogummite after Galena: *II, C 2*

Canton, Georgia, 15745

"Polyargite." See muscovite (pinite) after anorthite

Powellite after Molybdenite: *II, C 2*

Clifton, Utah, 18706

"Praseolite." See muscovite (pinite) after cordierite

Prehnite after Anhydrite. See quartz after glauberite

Prehnite after Glauberite. See quartz after glauberite

Prehnite after Laumontite: *III, B 2 a*¹Genth, F. A., and Penfield, S. L., 1890, Amer. Jour. Sci., Ser. 3, XXXIX, p. 121.²Kunz, G. F., 1886, Proc. Amer. Assn. Adv. Sci., XXXIV, pp. 243-246.

Duluth, Minnesota, 20630; Brevig, Norway, 11960. The latter specimen shows stalactite-like growths of prehnite with an interior cavity having a nearly square rhomb-shaped cross-section. The former specimen is a hollow incrustation pseudomorph after small prismatic crystals of laumontite, likewise with a rhomb-shaped section. The base of this specimen shows altered laumontite in pulverulent masses. Both specimens are very similar to the prehnite after glauberite pseudomorphs from New Jersey; the rhomb-shaped cross-section is here due to the development of the prism $m(110)$.

Prehnite after Unknown: *III, A ?*

"Lake Superior," 12016. A radial group of thin, platy crystals, molded in prehnite, incrusting a red copper-bearing conglomerate. The lamellar cavities in prehnite, after anhydrite, from New Jersey, are similar, and the original mineral may also be anhydrite in this specimen.

"Pseudoleucite." See orthoclase after leucite

Psilomelane after Calcite: *III, B 2 a*

Ilmenau, Thuringia, 6158; Iserlohn, Westphalia, 6157

Psilomelane after Manganite: *I, C 2*

Warwickshire, England, 6146

Purpurite after Triphylite: *II, C 2*

Hagendorf, Bavaria, 19782

"Pyrrallolite." See talc after diopside

"Pyrargillite." See muscovite (pinite) after cordierite

Pyrite after Chalcocite: *III, B 2 b ?*

Cornwall, England, 1721. An aggregate, on quartz, of large elongated crystals of chalcocite, flattened parallel c , with this face grooved parallel to the elongation; in part cruciform twins on (032). The original surface of the crystals is covered by a thin colloform layer of pyrite. The chalcocite in the bornite after chalcocite specimen (which see) has a similar habit.

Pyrite after Polybasite: *I, C 2*

Przibram, Bohemia, 1704

Pyrite after Pyrrhotite: *I, C 2*

Caradon Mines, Liskeard, Cornwall, 1720; Rio, Elba, 1634; Freiberg, Saxony, 1440, 1709; Leoben, Carinthia, 1445; Rodna, Roumania, 1681-2; Przibram, Bohemia, 2464. These pseudomorphs contain a considerable amount of marcasite (see also marcasite after pyrrhotite). In some of the specimens it is evident that the marcasite was formed in hot alkaline solutions since the pseudomorphism was followed by the deposition of quartz, dolomite, calcite, and hypogene sulphides. The marcasite must have been stabilized in some manner by the pyrrhotite since it is ordinarily formed only in acid solutions at relatively low temperatures. This may be connected with the excess of sulphur found in pyrrhotite.

A marcasite pseudomorph after pyrrhotite from Osnabrück, Prussia, has been described by Pogue¹.

¹Pogue, J. E., 1911, Proc. U. S. Nat. Mus., XXXIX, pp. 576-579 (with literature).

Pyrite after Tetrahedrite: I, C 2

Laurion, Greece, 1644

Pyrolusite after Calcite: III, B 2 b

Ilmenau, Thuringia, 5823-4; Ihlfeld, Harz, 5833; Morgenrothe (mine?), Schneeberg, Saxony, no Spec. No.

Pyrolusite after Manganite: I, C 2

Platten, Czechoslovakia, 5835-6-7; Giessen, Germany, 5821; "Mexico," 5844; Jackson Mine, Marquette, Michigan, 5847; Canaan, Connecticut, 5845; Sierra Grande Mine, Lake Valley, New Mexico, 5851; Ilmenau, Thuringia, 6195.

Pyrolusite after Unknown: I, -

Specimens from Elgersburg, Thuringia, 5829, and Horhausen, Germany, 5822, show pyrolusite pseudomorphous after unidentified minerals.

Pyrophyllite after Andalusite: II, C 2

Scania, Sweden, 18002 (*westanite*).

"Pyrrhotite." See muscovite (pinite) after anorthite

Quartz after Anhydrite. See quartz after glauberite

Quartz after Apophyllite: I, B 3

Bergen Hill, New Jersey, 3890; Fassathal, Mt. Monzoni, Tyrol, 17672, 18212.

Quartz after Aragonite

Guanajuato, Mexico, 3742 (*III, B 2 a*); Clayton, Rabun Co., Georgia, 4026 (*I, B 3*).

Quartz after Asbestos: II, B 3

McCormick, South Carolina, 13367. With psilomelane which is in part pseudomorphous after asbestos.

Quartz after Barite: III, B 2 a-b

Silverton, San Juan Co., Colorado, 4163-4-5; Cripple Creek, Teller Co., Colorado, 18407; Barstow Mine, Ouray Co., Colorado,¹ 20632; Butte, Montana, 20631; Pachuca, Hidalgo, Mexico, 3733-5; Liskeard, Cornwall, 2261, 2393-5; Schemnitz, 3471, and Kremnitz, 15875, Czechoslovakia; Felsöbánya, Roumania, 3483.

Quartz after Beryl: II, A

Uruguay, 3666-7. Tubular hexagonal cavities measuring 1 to 3 cm. in cross-section and up to 26 cm. in length, the mold being preserved by a thick incrustation of amethyst quartz.

Quartz after Calamine: III, B 2 b

Organ Mts., Doña Ana Co., New Mexico, 4205. After small prismatic calamine crystals, associated with fluorite and wulfenite (quartz pseudomorphs) on altering galena. Previously reported only from Nirm, near Aachen, Prussia.²

¹Patton, H. B., 1907, Colorado School of Mines Quart., II, No. 2.

²Blum, J. R., op. cit., App. II, p. 96.

Quartz after Calcite: *III, B 2 a-b*

Yellowstone National Park, Wyoming, 4185; "Colorado," 19870 (*amethyst quartz*); Lancaster County, Pennsylvania, 3902; Real de Monte, Hidalgo, Mexico, 824; El Chico, Hidalgo, Mexico, 3730-1-2; Zacatecas, Mexico, 3752-3-4; Guanajuato, Mexico, 3736, 17858; Schneeberg, Saxony, 3560-1; East Pool Mine, Redruth, Cornwall, 3622; Vaugirard, near Paris, France, 18869; Sau Alpe, Tyrol, 3516; Schemnitz, Czechoslovakia, 3471; Puy-de-Dôme, Auvergne, France, 3596 (*I, B 3*).

Also quartz "box-work" pseudomorphs formed by the penetration of quartz along cleavage planes of calcite: Port Leyden, Lewis Co., New York, no Spec. No., and Guanajuato, Mexico, 6673. See also quartz after interstices.

Quartz after Celestite: *III, B 2 a*

Cripple Creek, Teller Co., Colorado,¹ 4166.

Quartz after Crocidolite: *II, B 3*

Griqualand-West, South Africa, 10131-5-7 (golden brown), 10143 (deep red brown), 10132, 19263 (blue), 4022 (brown); Orange River, South Africa, 3224-5. With goethite.

Quartz after Diopside: *II, B 3*

Pierrepont, St. Lawrence Co., New York, 3839. With unaltered tourmaline in crystalline limestone. Possibly after a serpentine after diopside pseudomorph.

Quartz after Dolomite: *III, B 2 a*

Guanajuato, Mexico, 17681; "Syria," 3248

Quartz after Fluorite: *III, B 2 a to I, B 3*

Lake City, Hinsdale Co., Colorado, 4161; St. Just, Cornwall, 3625, 3652; Debra Mine, Derwent, Cumberland, 3613, 1224; "Cornwall," 6413.

Quartz after Glauberite

San Bernadino County, California (Borax Lake ?), 640 (*I, B 3*); Rosenegg, Württemberg, 3544 (*II, B 3*); Umberat anaDistrict, S. Australia, 3220 (*II, A*).

A large number of quartz pseudomorphs after glauberite, from West Paterson, Great Notch, Upper Montclair and other localities in the diabase region of New Jersey, are contained in the collection. Some of these specimens are figured in the paper by W. T. Schaller² on the glauberite and anhydrite pseudomorphs from these localities. The quartz after anhydrite and prehnite after glauberite and anhydrite pseudomorphs from the New Jersey localities are also abundantly represented in the collection. Unaltered glauberite has been found recently (Sept., 1932) for the first time in these occurrences at West Paterson. The habit is identical with that of the pseudomorphs.

Hintze cites many further localities for pseudomorphs of calcite, gypsum, quartz, and aragonite after glauberite,³ and of gypsum, quartz, calcite, siderite,

¹Lindgren, W., and Ransome, F. L., op. cit., p. 124.

²Schaller, W. T., 1932, U. S. Geol. Surv. Bull., 832, 85 pp.

³Hintze, C., 1930, 'Handbuch der Mineralogie,' Bd. I, Abt. 3, Pt. 2, p. 3712. Also gypsum after glauberite from Spain: Fernandez-Navarro, L., 1919, Bol. Soc. española Hist. Nat., XIX, pp. 260-266 (1920, Rev. Géol., I, pp. 179-180; also ibid., pp. 223, 269, 378).

marcasite, etc., after anhydrite.¹ See also prehnite after unknown and the localities cited above, of which the California occurrence is new.

Quartz after Gypsum: *I, B 3*

Rosenegg, Württemberg, 3544; Vaugirard, near Paris, France, 3595-8, 18869 (with *quartzine*).

Quartz after Interstices: *II, B 1*

Near Statesville, Iredell Co., North Carolina, 4002-3-5; Alexander County, N. C., 3944; Onslow County, N. C., 4025; Debra Mine, Derwent, Cumberland, 3612; Guanajuato, Mexico, 3736-7; Felsöbánya, Roumania, 3484; Paterson, New Jersey, 3886. These objects represent the infilling of cavities formed by the intersection of crystals during growth.² Calcite, in thin tabular crystals, was the bounding mineral in all cases except 3612 which was bounded by fluorite. The surface of the pseudomorphs is smooth and plane, sometimes with 8 or 10 faces (without symmetry), and the interior hollow with drusy walls. See also under quartz after calcite. Sometimes found filled with water.

Quartz after Prehnite: *I, B 3 vd*

Auvergne, Dauphiné, France, 3578. Quartz pseudomorphous after isolated globules of prehnite on a quartz rock. The globules are hollow with drusy walls.

Quartz after Serpentine: *II, B 3*

Loudoun County, Virginia, 3909. After coarsely fibrous veins of the picrolite variety of serpentine.

Quartz after Siderite: *III, B 2 a*

Gilpin County, Colorado, 1815; Camborne, Cornwall, 3626, 3634, 8138; Findelén Glacier, Valais, Switzerland, 3442 (*I, B 2 a*).

Quartz after Spodumene: *II, B 3*

Peru, Oxford Co., Maine, 3791

Quartz after Thenardite: *II, B 3*

Rosenegg, Württemberg, 3546

Quartz after Tridymite: *I, C 1*

Euganean Hills, Italy, 4352-3.

Quartz after Unknown: *III, B 2 a*

Greenwood, Maine,³ 19462-3-4-5. Bertrandite has been suggested as the original mineral.

Quartz after Wollastonite: *II, B 3*

Santa Fé Mine, Chiapas, Mexico,⁴ 17558

¹*Idem*, pp. 3757-3759.

²Hidden, W. E., 1885, *School of Mines Quart.*, VII, pp. 334-338 (North Carolina localities and Upson County, Georgia).

³Palache, C., and Landes, K. K., 1925, *Amer. Min.*, X, pp. 405-409.

⁴Collins, H. F., 1903, *Min. Mag.*, XIII, p. 362.

Quartz after Wood. See chalcedony after wood

Quartz after Wulfenite: *III, B 2 b*

Organ Mts., Doña Ana Co., New Mexico, 4202-3-4. Incrustation pseudomorphs of yellowish quartz after thin tabular crystals of wulfenite. Some of the larger crystals (1 cm.) have a corroded core of wulfenite. Previously reported only from Przibram, Bohemia.¹

"Reinite." See wolframite after scheelite

"Rensselaerite." See talc after diopside

Rhodochrosite after Barite: *III, B 2 b*

Nagyag, 8247, and Kapnik, 8130, Roumania; "Westphalia," 19800. The rhodochrosite in the former specimens is a colloform ferri-ferrous variety.

Rhodochrosite after Calcite: *III, B 2 a*

Freiberg, Saxony, 8242, 8236; "Hungary," 8277. In 8242 the rhodochrosite is oriented parallel to the original calcite.

"Rösite." See muscovite (pinite) after anorthite

Rutile after Brookite: *I, C 1*

Magnet Cove, Garland Co., Arkansas,² 5430, 5797-8, 5801-2-3-4-5, 5814. The rutile is oriented to the brookite.

Serpentine after Brucite: *II, C 2*

Hoboken, New Jersey, 19016

Serpentine after Chondrodite: *II, C 2*

Tilly Foster Mine, near Brewster, Putnam Co., New York,³ 12039, 12065-6, 12072, 13820-1-2-3, 13813, 13830; Grand Calumet Island, Quebec, 13825; Nordmark, Sweden, 13826-7-8-9, 13775.

Serpentine after Chrysolite: *II, C 2*

Snarum, Sweden, 13774-6, 13888; Pelham, Massachusetts, 17999 (*villarsite*); Middlefield, Mass., 13943 (*hampshirite*).⁴

Serpentine after Clinocllore: *II, C 2*

Tilly Foster, New York, 13815, 13820-4.

Serpentine after Dolomite: *II, C 2*

Tilly Foster, New York, 13816-9.

Serpentine after Enstatite: *II, C 2*

Bamle, Sweden, 8136, 9503-4-5; Tilly Foster, New York, 13818. This latter specimen is a long thin tabular crystal with a(100), c(001), and m(110) and apparently corresponds to the pseudomorphs after an unknown orthorhombic mineral described by J. D. Dana from this locality.

¹Blum, J. R., op. cit., App. IV, p. 134.

²von Rath, G., 1877, *Naturh. Ver. Preuss. Rheinl., Verh.*, XXXIV, p. 178.

³Dana, J. D., 1874, *Amer. Jour. Sci.*, Ser. 3, VIII, pp. 371, 447. The other serpentine pseudomorphs from this locality cited here are also described.

⁴Palache, C., 1907, *Amer. Jour. Sci.*, Ser. 4, XXIV, pp. 491-495.

Serpentine after Hornblende: *II, C 2*

Tilly Foster, New York, 13814

Serpentine after Monticellite: *II, C 2*

Pesmeda Alp, Mt. Monzoni, Tyrol, 13806, 13812

Serpentine after Periclase (?): *II, C 2*

Tilly Foster, New York, 13763-5-6-7, 13816-7-18644. According to Friedel the cubic structure belongs to the serpentine itself (Bull. Soc. Franc. Min., XIV, 1891, p. 120). It is more likely that the perfect cubic parting of the specimens is caused by a parallel orientation of the serpentine (antigorite) fibers to the original periclase (Mügge).

Serpentine after Ripidolite: *II, C 2*

Tilly Foster, New York, 13817

Serpentine after Tremolite: *II, C 2*

Russell, St. Lawrence Co., New York, 13810-1.

Serpentine after Wernerite: *II, C 2*

Russell, St. Lawrence Co., New York, 13811.

Siderite after Barite: *III, B 2 a*

Virtuous Lady Mine, Tavistock, Devonshire, 8181-2, 8166.

Siderite after Calcite: *III, B 2 a*

Antwerp, Jefferson Co., New York, 8211; Guanajuato, Mexico, 14301. The siderite in both specimens is oriented parallel to the original calcite. See also ankerite after calcite.

Silver after Proustite: *I, C 2*

Przibram, Bohemia, 317.

Silver after Pyrargyrite: *I, C 2*

Zacatecas, Mexico, 333.

Silver after Stephanite: *I, C 2*

Przibram, Bohemia, 316; Zacatecas, Mexico, 332.

Smithsonite after Calcite

Mineral Point, Iowa Co., Wisconsin,¹ 8322, 8350-1-2-3-4-5-6-7-8-9 (*I, C 2 vd*); Moresnet, Belgium, no Spec. No.; Nouvelle Montagne, Engis, Belgium, no Spec. No.; Laurion, Greece, 8298 (*I, C 2 vd*), 8302 (*III, B 2 a ?*); "Czechoslovakia," 8325.

Smithsonite after Dolomite: *I, C 2 vd*Granby, Missouri,² 8049.Smithsonite after Galena: *III, B 2 a*Mineral Point, Wisconsin,³ 20633.

¹Hobbs, W. H., 1895, Bull. Univ. Wisconsin, Sci. Ser., I, No. 4, p. 121.

²Rogers, A. F., op. cit.

³Colton, C. A., 1879, School of Mines Quart., I, p. 84.

Smithsonite after Gypsum: *III, B 2 a*

Laurion, Greece, 8301.

Smithsonite after Sphalerite: *I, C 2*

Bonanza, Arkansas, 20634.

"Stevensite." See talc after pectolite

Stilpnomelane after Unknown: *III, B 2 b*

Antwerp, Jefferson Co., New York, 8213. Pseudomorphs of the chalcodite variety of stilpnomelane after an unknown mineral occurring as elongated rectangular plates. Associated with siderite, hematite, and calcite. This pseudomorph is probably the same as the stilpnomelane pseudomorph after rectangular tables of an unknown mineral mentioned by Genth¹ from this locality.

Talc after Diopside: *II, C 2*

Warwick, Orange Co., New York, 13934; Russell, St. Lawrence Co., New York, 13931 (*rensselaerite*); Diana, Jefferson Co., N. Y., 13932; Pargas, Finland, no Spec. No. (*pyralloite*).

Talc after Dolomite: *II, B 3*

Göpfersgrün, near Wunsiedel, Bavaria, 13916-7-8.

Talc after Enstatite: *II, C 2*

Snarum, Sweden, 9506.

Talc after Epidote: *I, C 2*

Keweenaw County, Michigan, 13933.

Talc after Pectolite: *I, C 2*

Bergen Hill, New Jersey, 9837; Weehawken, N. J., 19708-9; West Paterson, N. J., 9848, 19381, 17496, 19674, 20450 (*stevensite*)².

Talc after Phlogopite: *II, C 2*

Perth, Ontario, 11348.

Talc after Quartz: *II, B 3*

Göpfersgrün, near Wunsiedel, Bavaria, 13919-20-1.

Talc after Spinel: *II, C 2*

Grand Calumet Island, Quebec, 13935; Mt. Monzoni, Tyrol, 13925-6.

Talc after Staurolite: *II, C 2*

Patrick County, Virginia, 20174; Henry County, Va., 20636. The latter specimen contains a considerable amount of muscovite.

Talc after Tourmaline: *II, C 2*

Hebron, Maine, 18047.

¹Genth, F. A., 1885, Proc. Amer. Phil. Soc., XXIII, p. 44. Also noted by Brush, G. J., 1858, Amer. Jour. Sci., Ser. 2, XXV, p. 199.

²Glenn, M. L., 1916, Amer. Min., I, p. 44.

Talc after Tremolite: *II, C 2*

Fowler, 14052, and Gouverneur, 17597, St. Lawrence Co., New York; York, Pennsylvania, 13948; Nordmark, Sweden, 13779-81, 13923.

Talc after Wernerite: *II, C 2*

Russell, St. Lawrence Co., New York, 13931.

Tetrahedrite after Chalcopyrite: *III, B 2 b*

Freeland Mine, Idaho Springs, Colorado, 20637. Oriented.

Thaumasite after Anhydrite: *II, C 2*

Paterson, New Jersey, 18199, 18221.

"Thinolite." See calcite after unknown

Titanite after Rutile: *II, C 2*

Lampersdorf, Silesia, 14226.

Topaz after Orthoclase: *II, C 2*

Saubach, near Muldenberg, Saxony, 19352. Large orthoclase phenocrysts replaced by topaz.

Unknown after Helvite: *II, C 2*

Achtaragda and Vilui Rivers, Lake Baikal, Siberia, 18488, 19415, 19421 (*achtaragdite*). Trigonal tristetrahedrons (helvite) altered to a gray clay-like substance; found embedded in a matrix of the same substance associated with grossularite and a boron containing variety of vesuvianite.

Unknown after Jeffersonite: *II, C 2 vd*

Sterling Hill, New Jersey, 17078 (*anomolite*). An extremely light and porous substance consisting of pyrolusite and kaolinite (?), pseudomorphous after a manganese-zinc pyroxene.

Valentinite after Stibnite: *I, C 2*

Constantin, Algeria, 5311.

Vanadinite after Calcite: *II, A ?*

"South of Bright Angel," Arizona, no Spec. No. (5 specimens). Hollow incrustation pseudomorphs of brown vanadinite after calcite scalenohedrons; in part only incrusting calcite.

Vanadinite after Wulfenite: *III, B 2 b*

Old Yuma Mine, near Tucson, Arizona, 18716.

"Villarsite." See serpentine after chrysolite

Wad after Siderite: *I, C 2 vd*

Allevard, Isère, France, 6169.

"Westanite." See pyrophyllite after andalusite

"Wilsonite." See muscovite (pinite) after wernerite

Wolframite after Scheelite: *I, C 2*

Monroe and Trumbull, Connecticut,¹ 16880-1-2-3-4, 16947-8, 17047; Kimbusan, 17045, 18125, 20551, Otomezaka, 17046, Kurosawa, 17488, Kai, Japan (*reinite*).

Wollastonite after Diopside: *II, C 2*

Pitcairn, St. Lawrence Co., New York, 9825 (this locality probably should be Harrisville, near Lake Bonaparte, Lewis Co., N. Y.). After large poorly developed crystals of diopside in crystalline limestone. This pseudomorph is doubtful and may be simply wollastonite in composite crystals. The wollastonite common in this region has a habit closely resembling diopside. A pseudomorph of pyroxene after wollastonite is known from Diana, Lewis Co., N. Y.²

Xanthitane after Titanite: *II, C 2*

Green River, Henderson Co., North Carolina,³ 11359, 14292.

Zoisite after Anorthite: *II, C 2*

Franklin, New Jersey,⁴ 9231, 9471-2-3.

¹Warren, C. H., 1901, Amer. Jour. Sci., Ser. 4, XI, p. 371. Hobbs, W. H., 1901, U. S. Geol. Surv., 22d Ann. Rept., Pt. 2, p. 7.

²Smyth, C. H., 1897, Amer. Jour. Sci., Ser. 4, IV, p. 309.

³Eakins, L. G., 1888, Amer. Jour. Sci., Ser. 3, XXXV, p. 418.

⁴Roepper, W. T., 1878, Amer. Jour. Sci., Ser. 3, XVI, p. 364. Warren, C. H., 1901, Amer. Jour. Sci., Ser. 4, XI, p. 369 (anorthite described).

