NOTES ON SOME PSEUDOMORPHS, PETRIFACTIONS AND ALTERATIONS.

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The writer wishes to place on record some interesting cases of pseudomorphs, petrifactions and alterations observed by him in the last few years. Some of these are recorded for the first time, some are American occurrences of minerals known abroad, while others are good examples of commonly occurring pseudomorphs. While many examples of such pseudomorphs and alterations are of mineralogical interest only, some of them have a possible bearing on the origin of ores. My thanks are due to the gentlemen named in the several items who have kindly furnished me with the specimens which make this paper possible.

Pseudomorphs.

1. *Copper* after *Cuprite.*—Calumet-Arizona Mine, Bisbee, Arizona. Collected by Mr. E. W. Rice. Cubes of 4 mm. diameter, modified by faces of the octahedron and dodecahedron occur in cavities of a limonite gangue. The copper consists of dense aggregates of small imperfect crystals with smooth cube surfaces. No cuprite was observed in the specimen.

2. *Copper* after *Chalcanthite* (?)—Carlisle, Arizona. Collected by Mr. Harry Robertson. The specimen is a coarsely fibrous seam of native copper 2 cm. wide. There are no associated minerals to give a clue as to its origin and the mode of occurrence is unknown, but as copper is practically always a secondary mineral, and as the structure is exactly similar to well-known seams of chalcanthite from Arizona, it is believed to be a pseudomorph after chalcanthite.

Pseudomorphs of copper after cuprite from Cornwall have been described by Miers;[1] copper after azurite from New Mexico by Yeates;[2] and copper after aragonite from Bolivia by Forbes.[3]

3. *Chalcedony* after *Calcite*.—Guanajuato, Mexico. Obtained from the Foote Mineral Company. An excellent specimen of this pseudomorph consists of pale brown chalcedony in the form of hollow doubly terminated scalenohedrons (2131) of calcite about 1 cm. in length.

4. *Hematite* after *Marcasite*.—Lake Co., California. Collected by Mr. H. E. Kramm from the Baker mine, six miles from Lower Lake on the road to Knoxville. The specimen consists of small encrusting crystals giving a red streak. They have the same form as unaltered marcasite crystals from the same mine.

5. *Limonite* after *Chalcopyrite*.—Granby, Missouri. Small tetrahedra (2 mm.) of dark brown limonite on a specimen of dolomite, calamine, and smithsonite have been produced by the alteration of chalcopyrite. The author found similar pseudomorphs at Galena, Kansas, but it is a rare kind of pseudomorph.

6. *Limonite* after *Cerussite*.—Burke, Idaho. Collected by Mr. H. F. Humphrey at the Bunker Hill mine. At this mine cerussite is a prominent gossan mineral. Several specimens show prismatic crystal aggregates of cerussite with a coating of limonite. Other specimens show limonite of a form exactly similar to the cerussite and are undoubtedly pseudomorphs.

7. *Wad* after *Calcite*.—Echo Mine near Mojave, California. Collected by Mr. H. W. Young. Cavities in a quartz matrix with the shape of calcite scalenohedrons are occupied by a soft black mineral answering the tests of wad. These are not direct substitution pseudomorphs but probably represent quartz encrustation pseudomorphs after calcite in which the calcite was dissolved out and then the cavities filled with wad.

8. *Calcite paramorph* after *Aragonite*.—Patterson Pass, east of Livermore, California. A travertine deposit in buff Miocene sandstone consists of a banded, coarsely fibrous aragonite of an amber

[1] *Min. Mag.*, Vol. II., p. 266, 1897.
[2] *Am. Jour. Sci.*, Vol. 38, p. 405, 1889.
[3] *Quar. Jour. Geol. Soc.*, Vol. 17, p. 45, 1861.

color, often variegated. The material has been quarried out in large blocks and on the exterior these are often altered to calcite. The aragonite is compact columnar massive, while the calcite is porous, though crystalline and shows the cleavage faintly. As the calcite retains to some extent the columnar structure of the aragonite the specimens are paramorphs. Occasional calcite crystals are found in cavities. Sicily furnishes excellent specimens of calcite paramorphs after aragonite, but this is the first example found in this country, I believe.

9. *Smithsonite* after *Calcite.*—Granby, Missouri. This is one of our best known pseudomorphs. Steep rhombohedrons of the —2R form $(02\bar{2}1)$ implanted on dolomite have been replaced by a spongy mass of smithsonite, but the surfaces of the crystals are smooth.

10. *Smithsonite* after *Dolomite.*—Granby, Missouri. A massive cleavable dolomite specimen 2 cm. thick with warped rhombohedral crystals on one surface have been completely changed to smithsonite of a pale brown color.

11. *Cerussite* after *Calcite.*—Granby, Missouri. Scalenohedral $(21\bar{3}1)$ calcite crystals of 1 cm. diameter are completely changed to colorless cerussite with adamantine luster.

12. *Pyromorphite* after *Galena.*—Granby, Missouri. Crystals of ½ cm. square cross section on chert matrix consist of a little unaltered galena in the center, then cerussite and finally a border of green earthy pyromorphite.

13. *Calamine* after *Calcite.*—Granby, Missouri. Scalenohedral $(21\bar{3}1)$ calcite crystals 1 cm. in diameter on chert matrix have been replaced by calamine. When broken the crystals are found to be hollow and calamine crystals project into the hollow center.

14. *Muscovite* after *Tourmaline.*—Pala, California. A specimen 7 cm. long and 1.5 cm. in diameter represents an original tourmaline crystal, roughly trigonal in cross-section. It is now mostly white scaly muscovite in which is set a number of small black tourmaline crystals in parallel position with the large crystal.

15. *Talc* after *Actinolite.*—Apperson Creek, southeast of Sunol, Alameda County, California. Gray columnar, subradiating talc is

probably pseudomorphous after actinolite as it has the exact structure of the actinolite common in the schists of the Coast Ranges. The mineral has a greasy feel and is scratched by the finger nail. It is practically infusible and gives a little water in the closed tube. Cleavage flakes give a negative biaxial interference figure with a small axial angle. The axial plane is in the direction of the length of the columnar crystals.

16. *Chrysocolla* after *Cuprite*.—(*a*) Santa Margarita Mine, New Almaden, California (*b*) near Mammoth, Utah (Tintic district). At both of these localities chrysocolla is pseudomorphous after the chalcotrichite variety of cuprite, a variety that consists of crystal aggregates of elongated cubes crossing and branching at right angles. With polarized light, the chrysocolla exhibits an aggregate structure and the outside surface occasionally consists of concentric layers somewhat radiating. At New Almaden the cuprite occurs in seams in serpentine but it is believed to have its origin in copper-bearing pyrite which occurs in a nearby prospect shaft.

17. *Chrysocolla* after *Calcite*.—(*a*) Arlington, N. J. (*b*) Reward Gold Mine, Inyo County, California. Collected by Mr. C. E. Gilman.

(*a*) At Arlington chalcocite and secondary copper minerals occur at the contact between diabase and triassic sandstone. The pseudomorphs were found in cavities of the sandstone. They consist of small scalenohedrons ($21\bar{3}1$) completely replaced by chrysocolla.

(*b*) The Inyo County specimens are large prismatic quartz crystals coated with a crust of chrysocolla. Some of the chrysocolla is the form of acute rhombohedrons (—$2R$ or $02\bar{2}1$) with rounded edges which represents, no doubt, original calcite. The chrysocolla is made up of concentric layers, the inside ones of which are deeper greenish blue than the outside. Under the microscope the fine aggregate structure is in evidence. Associated cuprite is the source of the copper.

Petrifactions.

18. *Sphalerite* replacing *coral*.—Galena, Kansas. A conical coral, probably a *Zaphrentis*, 2 cm. in diameter, is replaced by dark granular sphalerite. Most of the fossils from the chert of this

district are molds or cavities from which the calcareous matter has been dissolved out. The specimen described is a cast probably formed by filling of the mold and not by direct replacement of the organism.

19. *Pyrite* replacing *Aviculopecten.*—Leavenworth, Kansas. Some excellent pyrite petrifactions were obtained from the Cherokee shales on coal mine dumps at this locality. The pyrite is bright brassy with purplish tarnish. The fossil is *Aviculopecten rectilaterarius,* which, in Kansas, is limited to this horizon.

20. *Limonite* replacing *gasteropod.*—Carnegie, Corral Hollow, California. Fossils of fresh-water gasteropods (probably a new species of *Melanea* according to Mr. Harold Hannibal) occur in Eocene sandstone exposed along the railroad track near Carnegie, San Joaquin County, California. The sandstone is composed of quartz grains with limonite cement. The shells are completely replaced by dense limonite .5 mm. thick.

21. *Limonite* replacing *twigs.*—Bingham, Utah. In Upper Bingham Canyon along the creek bed are found specimens of a porous mass of soft, earthy limonite. These evidently represent former plants as hollow, flattened stems are plainly visible.

22. *Malachite* replacing *cedar wood.*—Bingham, Utah. At the locality mentioned above, malachite with structure of the cedar wood common at the same place occurs. The mineral is porous and often has a mammillary surface in free spaces. The cell structure of the wood is visible with a hand lens. Selected pieces are completely soluble in hydrochloric acid showing complete replacement but in other cases there is simply a thin green coating of malachite.

23. *Barite* replacing *Productus.*—Elmont, Kansas. The writer is indebted to Dr. J. W. Beede for this specimen. A specimen of the brachiopod shell, *Productus punctatus,* has been completely replaced by pink barite and the surface markings characteristic of this species are preserved. A visit to the locality which is a limestone ledge two miles northwest of Elmont, Jackson County, Kansas, revealed a number of fossil pelecypods and gasteropods partially replaced by pink barite, but none so complete as the one described.

Alterations.

24. *Sulfur* from *Sphalerite.*—Galena, Kansas. Specimens of sphalerite and pyrite in chert breccia from the Templar ground, two miles southwest of Galena, Kan., show in an excellent manner the alteration of a sulfid to sulfur. The sphalerite is corroded and covered with pale yellow sulfur while the pyrite is fresh and free from sulfur. Evidently the sphalerite has furnished the sulfur.

25. *Strontianite* from *Celestite.*—Five miles from Austin, Texas, on the road between Mts. Barker and Bonnell. Collected by Mr. F. L. Hess. Massive cleavable celestite of a pale blue tint is much corroded and the cavities are occupied by tufts of small acicular crystals of strontianite. The crystals are flattened, tapering, six-sided crystals, the forms being a steep rhombic bipyramid (*hhl*) and a steep rhombic prism (*okl*). The crystals are often curved and in consequence give a wavy extinction. The elongation is parallel to the faster ray. The mineral contains some calcium in addition to strontium as the microchemical gypsum test shows. This is the best test for calcium in such a compound.

26. *Barite* from *Witherite.*—Northumberland, England. Colorless tabular barite crystals (*001, 110, 102*) are found in cavities of massive gray witherite. The barite is evidently a secondary product, formed from the witherite.

27. *Copiapite* from *Pyrite* and *Limonite* from *Copiapite.*—Five miles n. w. of San Jose, California. Altered pyrite crystals from chlorite-glaucophane schist boulders showed the following cross-section: The interior is hollow with small projecting bits of bright pyrite. The exterior is limonite while between these two is a soft compact yellow material which answers the blowpipe tests for copiapite. Under the microscope the copiapite is seen to consist of minute pseudo-hexagonal crystals. Here the pyrite has evidently altered to copiapite and then the latter to limonite.

28. *Hornblende* from *Hypersthene.*—Arroyo Bayo, twelve miles southwest of Livermore, California. These specimens were found in a large outcrop of norite or hypersthene gabbro. Grayish green hypersthene with faint cleavage has been altered around the borders to black hornblende with good cleavage. In fragments the hyper-

sthene has parallel extinction and characteristic pleochroism from pale reddish to greenish white while the hornblende has has an extinction angle[4] of about 14° and faint pleochroism from bluish green to yellowish green. The mineral occurs in large anhedra associated with light gray plagioclase.

29. *Sericite* from *Feldspars.*—New York City. Specimens of orthoclase and oligoclase from the pegmatites and pegmatite lenses of the schists in the upper part of New York City are often accompanied by secondary muscovite or sericite in the form of thin silvery scales. The scales occupy the cleavage planes but more especially planes of parting parallel to the unit prism faces (*110*).

[4] Determined on cleavage fragments.