

The Origin and Classification of Placers—I.

BY H. L. SMYTH.*

Of late years the attention of physical geographers has been largely directed to the analysis of the destructive and constructive effects of the elements on the earth's surface; that is to say, to the details of the processes by which the land is worn away, to the forms into which it is carved or built, and to the transportation, distribution and reconstruction of the eroded matter. From these studies certain deductions may be drawn concerning an important group of ore deposits, which are numbered among the products of these actions. In this article I shall try to show in a broad way—and quite frankly, from the standpoint of an amateur in physiography—how the distribution and concentration of the valuable particles in placers are dependent on some of the varying conditions under which erosion, transportation and deposition take place. The considerations that will be brought forward are obvious enough and many of them are familiar, but, so far as I am aware, some of them have not appeared in print before.

A placer may be defined as an unconsolidated accumulation of rock and mineral fragments—boulders, gravel, sand, clay, etc.—formed at the earth's surface and containing in important quantity particles of valuable minerals of clastic derivation. The valuable minerals may be non-metallic—for example, phosphate or gems—but commonly they are metallic, such as gold, platinum, tinstone, magnetite, limonite, etc. Before being incorporated in the placer, these particles have been imprisoned in the rock.

How are they set free? Evidently, either by the rapid breaking or abrasion of the matrix, whether in the bed or banks of an actively cutting stream, or along the margin of the sea, or beneath moving ice, or else by its incalculably slower decay and disintegration through solution, changes of temperature, frost, or the impact of the rain. Abrasion, no doubt, has been instrumental in supplying at least part of the metallic materials for many placers, particularly to those containing unaltered sulphides, or attackable metals. Thus some of the pyrite-bearing gravels of the Sierras, described by Whitney,² derived their pyrite from the bed-rock slates into which the stream trenches are cut. The silver, pyrite and galena mentioned by Spurr³ as occurring in several of the gold-bearing creeks of the American Yukon were probably ground out of their matrix by glaciers. This is undeniably the case

with the native copper found by Brooks⁴ in glacial gravels on the head waters of the White river in Alaska.

Rapid breaching and abrasion have unquestionably played a still more important rôle in the interesting group of shore placers, of which, however, we have but few examples. When the sea advances over a stationary or sinking land, it may cut deeply into the solid rock, and from the fragments form important placer deposits in the vicinity of the parent ledge. The gold-bearing Cambrian conglomerate⁵ in the neighborhood of the Homestake lode, in the Black Hills, probably derived much of its gold from the direct attack of the sea on the lode. The consolidated iron-ore detritus at the bottom of the Upper Marquette series, in Michigan, rests in many places on older deposits, from which it was broken mainly by the action of the waves along an encroaching shore.

But in comparison with slow disintegration, the rapid mechanical breaking and wear of the fresh rock is a relatively unimportant factor in effecting the release of the metallic constituents of placers; and disintegration itself comes merely as the physical culmination to the series of chemical changes that had previously gone on beneath the surface, all tending to the same end. Therefore, before proceeding to the process and consequences of disintegration, it is desirable to dwell on these underground changes.

The reagents chiefly effective in the subterranean decay of rocks and alteration of ore deposits, are oxygen and carbonic acid in air and water. Under their attack some minerals form soluble compounds, while others remain unchanged or alter to insoluble forms. Therefore, from the region where these changes mainly occur, namely, that lying between the sub-aerial surface and the protective level of the groundwater, certain elements tend to be removed, while others tend to accumulate within it. After long-continued decay, the common rocks, except those whose constituents had reached chemical stability in a previous cycle of erosion, finally pass into silicious and more or less ferruginous clay. In the alteration of deposits of the metallic sulphides, the base metals—zinc and copper, together with silver—in time may completely vanish from the upper portion of the zone of oxidation, while iron and manganese, which readily form inert higher oxides, and lead, which, from the sulphide, passes into practically insoluble sulphate and carbonate, in large part remain. According to the nature of the deposit and its enclosing rocks, they may be accompanied by gold, platinum, cassiterite,

*Professor of Mining and Metallurgy, Harvard University.

¹R. W. Raymond: 'A Glossary of Mining and Metallurgical Terms,' *Trans. A. I. M. E.*, Vol. IX.

²J. D. Whitney: 'Auriferous Gravels,' pp. 91, 390.

³J. E. Spurr: 18th Ann. Rept. U. S. Geol. Survey, Part III, pp. 323, 334, 344, etc.

⁴A. H. Brooks: 21st Ann. Rept. U. S. Geol. Survey, Part II, pp. 377, 378, 381.

⁵W. B. Devereux: *Trans. A. I. M. E.*, Vol. X, pp. 465-469, 473. J. D. Irving: 'Economic Resources of the Northern Black Hills,' Chap. II.

pecting has been done upon almost every island of the group, to the great credit of the pioneers who have laboriously blazed the trail; but capital for the development of prospects has been difficult to secure. It is hoped that the definite policy concerning the future of these islands, so earnestly desired by capitalists as a prerequisite to permanent investment, may soon be determined by the people of the United States, to the end that the Philippines may enter upon an undisturbed and prosperous career.

"A welcome feature of the present interest in Philippine mining is the increasing attention being given to the mineral resources by the natives of the islands. Their interests are those of all; with their hearty co-operation it is hoped that the labor required may be more rapidly secured, that they will realize the common benefit of all mining activity, and that they may in time point with pride to the work and worth of Philippine mines."

Replacement of Quartz by Pyrite.

The careful and elaborate proof of the substitution of quartz by pyrite, at least in some cases, is the substance of a scholarly paper by Professor C. H. Smyth, Jr., in the April number of the *American Journal of Science*. The occurrence is in beds of Oneida conglomerate in central parts of the State of New York. Briefly, the case is that of a sandstone, the quartz grains of which have been corroded, with ingrowing secondary pyrite crystals, into the corroded spaces of the quartz grain. Thus the relatively original and corroded quartz grain fit closely about the relatively secondary pyrite, as though the sharp pyrite crystals had pressed into the quartz. The description of the occurrence is carefully worked out by Professor Smyth both from the geologic and petrographic standpoint, and is a most valuable contribution to a growing subject. It will be remembered that W. Lindgren (*Transactions A. I. M. E.*, Vol. XXX, p. 615) has given some instances of the replacement of silicates by pyrite. W. H. Weed (United States Geological Survey, *Bulletin 213*, p. 178) has given instances of the replacement of silicates (hornblende and mica) by pyrite at Butte. In this JOURNAL (p. 169, January, 1905) there is described a possible chemical mode of replacement. J. D. Irving (United States Geological Survey, *Bulletin 260*, p. 65) describes "replacement deposits in quartzite at Ouray."

The paper of Professor Smyth is illustrated with several micro-petrographs in half-tones, and will rank at once as an original and classical contribution to the facts of ore deposition.

Metallic strontium may be prepared by the electrolysis of the fused chloride in a vessel with carbon sides and fire-clay bottom. The metal strontium has much the appearance of calcium; it is as white as zinc and as soft as lead.

magnetite, etc.—in a word, by minerals practically indestructible by the ordinary reagents from the surface.

While the zone of oxidation is, therefore, primarily a region of residual concentration for the stable elements, by reason of the subtraction of their less resistant associates, yet in places enrichment of a positive nature may occur, leading to the formation of new mineral aggregates through transportation, either mechanically or in solution, and re-deposition in favorable spots. Undoubtedly gold is sometimes transported in solution in the zone of oxidation, as is proved by the beautiful crystalline growths found mainly there; the conditions most favorable for this are probably those suggested by Pearce⁸ and by Don,⁹ where chlorine, a vigorous solvent of gold, is set free through the action of sulphuric acid and a salt solution on the higher oxides of manganese. The splendid gold crystals found in certain of the Leadville mines near California gulch were probably formed under these conditions.

Also, gold may be carried down mechanically in the zone of oxidation. When auriferous pyrite decomposes, the gold locked up in it is released in a state of division so fine that it is capable of sifting through minute openings. Thus working down with the aid of water from above, together with fine particles of other substances, it no doubt frequently constitutes a positive addition to the more open portions of veins. The clay seams containing free gold, described by Rickard¹⁰ as occurring over 100 ft. below the surface in the Rathgeb mine in California, perhaps owed part of their richness to such a mechanical settling of the metal from above. The same observer believes that the upper portions of some of the veins of Western Australia have been "enriched by the deposition of the gold left behind from lodematter, which was long ago disintegrated and removed by erosion."¹¹

But it is the oxides of iron that furnish the best examples of aggregated concentration in the zone of oxidation. Pyrite (and pyrrhotite and marcasite as well), when attacked by oxygen in water, yields ferrous sulphate, which oxidizes to limonite, or readily reacts with alkaline (or alkaline-earth) carbonates to form ferrous carbonate on the one hand, and an alkaline sulphate on the other.¹² The ferrous carbonate is so much less soluble than the sulphate that precipitation of a large proportion of the iron would take place in that form if it were not often nearly simultaneously oxidized and laid down as hydrated ferric oxide. The precipitated carbonate is also subject to the same

change. Transported then both as sulphate and as carbonate, iron is deposited as limonite where oxidation is going on most actively, namely, in the cracks and fissures of the surface zone. On the other hand, with abundant alkaline carbonate, its journey is shortened or altogether avoided, and it is for this reason that pyritiferous limestone, when weathered not only carries abundant pseudomorphs of limonite after pyrite, but yields residual clays nearly always highly colored by well-distributed iron-oxide. Oxide of manganese descended from the carbonate, or through the carbonate from the silicate, is likewise subject to positive concentration through aggregation in the surface zone.

Decay is nearly everywhere in progress above the water level, but is rarely, if ever, complete. It is most nearly complete where denudation proceeds most slowly, when the streams almost cease to corrode and the water-level to sink—in a word, under the stagnant conditions of topographical maturity and age. Where erosion progresses rapidly, the surface is stripped before the chemical changes can reach their limit; or, looked at in another way, these changes are farthest advanced at the surface and are just beginning at the water-level; with rapid erosion, the surface is therefore constantly forced down to an horizon of incomplete or inchoate change.

Since decay results from the movement of water and air through the rocks, it is promoted by their permeability, and is hindered by any cause that prevents the free movement of these agents. Natural differences in permeability, as well as in power of resistance, produce great inequalities in the extent to which the rocks and ore deposits are affected, both in depth and laterally. When the circulation of air and water is entirely cut off, as it is at present in the superficially frozen crust of portions of northern Siberia, the Yukon Valley, and the Seward Peninsula, there can be no subterranean rock decay.

The foregoing considerations may be summed up in a few words: The zone of oxidation is a region that may be greatly enriched in metallic substances in consequence of decomposition and of separation through solution. When carried to the limit, these processes, acting on the rocks, leave behind an insoluble residue composed of quartz, clay and the oxides of iron; when acting on deposits of the metallic sulphides or carbonates, they finally remove all metals, with few exceptions, that do not form higher insoluble oxides or carbonates, and leave behind a residue thoroughly adapted to its chemical environment. The chief metallic constituents that survive are the oxides of iron, more rarely the oxides of manganese, and—unimportant in weight, but in value frequently of overshadowing importance—

the precious metals—gold, platinum, etc. Chloride of silver and native silver are also found in this mantle under certain climatic conditions. Most of the metallic minerals just mentioned are relatively concentrated in the zone of oxidation, because of the removal of their soluble associates; but some of them, by undergoing transportation themselves, whether in solution or suspension, may also form aggregates of positive enrichment. As a whole, however, the mantle of decay is probably enriched mainly through residual concentration, rather than by outside contributions.

The end products are strongly contrasted in many physical characters, and especially in hardness, weight and size. Quartz is light, hard, brittle, and may occur in large masses; clay is light and soft and composed of the finest particles; the iron oxides are generally hard and always heavy. Of the other constituents of the metallic residuum, some are malleable, others are brittle, but all are heavy and generally occur in small particles. The one property in common is that all these substances successfully resist the attack of the air and carbonated water.

New Coinage for Mexico.

A recent official decree gives the following description of the new coins to be turned out by the Mexican mints:

The gold coins of 10 and 5 pesos will be as follows: On the obverse the national coat of arms, the inscription, 'Estados Unidos Mexicanos,' ornamental scroll work, etc.; on the reverse the bust of Hidalgo, with inscriptions showing the denomination of the coin, the year in which it was struck, etc.

The silver peso will remain the same as at present, at any rate for the time being, but on the obverse it will display the inscription 'Estados Unidos Mexicanos.' The silver 50-, 20-, and 10-cent pieces will have an obverse the same as the gold coins. The reverse will display the denomination in large figures followed by the word 'centavos,' and will have a Phrygian cap with rays and a wreath of laurel and oak. Along the milling of the 50-cent piece the words 'Independencia y Libertad' will be hollowed out. The milling of the 20- and 10-cent pieces will be only striated.

The nickel coins will have an obverse practically the same as the gold coins. The reverse will have an Arabic 'five,' the word 'centavos,' and the date of coinage, all inclosed in a grecque imitating the Aztec calendar.

The bronze coins will have an obverse similar to the gold coins; reverse, the figure indicating the value of the coin forming with the letter C (centavos) a monogram, surrounded by a laurel wreath.

All the coins will have on the reverse the initial of the mint at which they were coined.

⁸R. Pearce: *Proc. Col. Sci. Soc.*, Vol. I, 1883-4, p. 68.

⁹J. R. Don: *Trans. A. I. M. E.*, Vol. XXVII, 1897, pp. 598-601.

¹⁰T. A. Rickard: *Trans. A. I. M. E.*, Vol. XXXI, pp. 214-215.

¹¹*Trans. A. I. M. E.*, Vol. XXVIII, p. 508.

¹²J. Roth: *Allgemeine und Chemische Geologie*, I, pp. 234, 236, 237, 238.