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THE PITCHBLENDE OF CORNWALL, ENGLAND.

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Pitchblende has long been a well-known mineral, but has attracted a greatly increased interest since it became important as a source of radium. Among other localities, it occurs in many places in Cornwall, England, and though the writer is not so familiar with its occurrence there as he would wish, yet as only very brief accounts of it have been published, he ventures to offer the following article.[1] The material for the present paper is derived partly from a personal examination of some of the Cornish mines several years ago, partly from brief descriptions in the published literature on the region, and partly from information from persons who have recently sought pitchblende in Cornwall.

USES OF PITCHBLENDE.

Pitchblende has been used for many years as a source of uranium compounds in coloring glass and porcelain, and to a

[1] The pitchblende of Cornwall is mentioned in various articles in the *Transactions* of the Royal Geological Society of Cornwall, the Annual Reports and the *Journal* of the Royal Institute of Cornwall, the Reports of the Royal Cornwall Polytechnic Society, the *Transactions* of the Geological Society of London, the Memoirs of the Geological Survey of Great Britain, and in many other publications on the geology and mining of the region; but the references to it are usually very brief and often simply incidental to the discussion of some other subject.

small extent in photography, in reagents for chemical analysis, in mordants in dyeing and for other small purposes; but though of considerable market value for these uses, it did not become of very great importance until after the discovery of radium. The chief value of the ore is now in the radium it contains, but after the extraction of this, the remaining uranium has a value for the other uses mentioned.

NATURE AND MODE OF OCCURRENCE OF PITCHBLENDE.

The terms pitchblende and uraninite are often used synonymously to designate the same mineral, but more properly the term uraninite is a general name for all forms of the mineral and especially for the purer and distinctly crystalline variety, while the term pitchblende applies to the impure amorphous form. The two forms often occur together, but the latter is by far the more abundant. The term pitchblende arose from a certain pitchlike lustre which the mineral often displays, and was its original name in the old days before the discovery of uranium. At that time the mineral was vaguely supposed to be an ore of zinc, copper, iron or other metals. In 1789 Klaproth discovered a new metal in it, which he called uranium, and Haidinger[2] named the mineral uranin. J. D. Dana[3] later gave it the name uraninite, though in some earlier editions of his "System of Mineralogy" he used the term pitchblende. The amorphous form of the mineral is the one chiefly found in Cornwall, and as this paper treats particularly of that region, and as the name pitchblende has been established there by traditional custom, and appears throughout the literature of the region, the same name is used here. In an article on the mineral in general, the term uraninite would be better usage. In addition to the forms of the mineral included as uraninite or pitchblende, numerous other rarer varieties, differing somewhat in composition, have been described under the names of cleveite, bröggerite, and nivenite.

[2] Wilhelm Haidinger, "Handbuch der bestimmenden Mineralogie," 1845, p. 549.

[3] "A System of Mineralogy," 1869, pp. 154–155.

The mineral when crystalline belongs to the isometric system and when amorphous is in a massive form often with botryoidal surfaces and a conchoidal fracture. It is black or grayish-black in color, opaque and often has a submetallic, glossy or a pitch-like luster. It has a hardness of about 5.5 and a specific gravity of 9 or over when pure, but both these qualities vary when the mineral is impure. It is often remarkably lacking in distinctive characteristics, so that its presence in small quantities is frequently overlooked.

The mineral is very complex and somewhat uncertain in composition. It consists mostly of the uranium oxides UO_2 and UO_3, in which the UO_2 seems to act as a base and the UO_3 as an acid, forming a uranate of uranyl, or a proto-peroxide of uranium. The relative amounts of the two oxides, however, vary greatly in different specimens, and no definite formula can at present be given.[4] With these oxides are usually other bases including lead, thorium, zirconium, lanthanum, yttrium, cerium, nitrogen, helium, argon, etc. These materials are in small amounts and varying proportions; some of them may be essential constituents of the mineral and others may not. With them are also other more common bases which may be impurities, but which are often difficult to distinguish from the essential constituents, among them being iron, calcium, and other substances. A noticeable amount of water, which may possibly sometimes be in chemical combination, occurs in some forms of the mineral.

A marked distinction between the different forms of the mineral is that the crystalline uraninite and the allied cleveite, bröggerite and nivenite almost always contain a notable number of the rare earth elements mentioned above, while pitchblende usually contains few or none of them. This may possibly be due to some form of alteration in the pitchblende, or perhaps to the fact that the other minerals mentioned are usually original constituents of igneous rocks, while pitchblende usually occurs in vein formations, a condition which it may have reached by the

[4] The commercial analyses of the mineral to determine its value as an ore are usually stated in terms of $UO_2 \cdot 2UO_3$, briefly expressed as U_3O_8; but this is simply an arbitrary assumption used to determine its market value.

solution and redeposition of the uranium contents of the other minerals, while the rarer elements may have been left behind or deposited elsewhere.

A rare element, however, which is common to all forms of this remarkable mineral, whether in the form of crystalline uraninite, cleveite, bröggerite, nivenite or the common amorphous pitchblende, is radium. This element is a product of, and in nature always accompanies uranium, whether that material is in the form of the minerals in question or of any of the many other uranium minerals found in nature; and among the still rarer accompaniments of uranium minerals are polonium, actinium and other new elements, the discovery of which has followed in the wake of that of radium. The amount of radium present in these minerals is, however, very small, and even in the purest forms of uraninite or pitchblende it is only between three and four grains per ton, and in the ordinary impure commercial forms, only a small fraction of a grain per ton, corresponding to a few centigrams or less.

Neither uraninite nor pitchblende have been found in large bodies in any one place. The crystalline uraninite occurs usually disseminated through certain igneous rocks, and pitchblende usually occurs as a subordinate mineral in veins of other ores, especially those of copper, silver and gold.

DISTRIBUTION OF PITCHBLENDE.

Radium was discovered in 1898 by M. and Mme. Curie in pitchblende from Joachimsthal, Bohemia, Austria, and the ores of that district soon became of great importance. Pitchblende, however, was known in many other places, and as soon as its value as a source of radium became known, they were carefully investigated. Among these localities were Przibram and elsewhere in Austria; several localities in Hungary; Schneeberg, Johanngeorgenstadt, Annaberg, and elsewhere in Germany; St. Just, St. Ives, Grampound Road, St. Austell, and many other places to be mentioned later, in Cornwall, England; and at several mines near Central City, Gilpin County, Colorado. Other

uranium minerals, such as autunite, torbernite, gummite, and various other forms, were known in most of these localities, but were generally in small quantities. In some places, however, these other minerals were found in sufficient quantities to encourage exploitation as a source of radium, as near Autun, France; Sabugal and Guarda, Portugal; near Mt. Painter, South Australia, and in other places. Finally, the carnotite of western Colorado and eastern Utah suddenly came into importance as an ore of radium and is now the world's chief source of it. Carnotite has also been found and exploited at Radium Hill, near Cutana Railroad Station, in South Australia.

Of all the pitchblende localities mentioned, Joachimsthal, Cornwall and Central City, are the only ones that have become of any considerable importance as commercial sources of radium, though other mines in Austria and Germany have for many years past regularly produced small quantities of pitchblende which were used for other purposes in the arts. Many of the mines that were exploited for pitchblende in the excitement following the discovery of radium, have since been closed as unprofitable, but this mineral is by no means a negligible source of radium, and there is always the possibility that it may somewhere be found in much larger quantities than at present known.

GROWTH OF KNOWLEDGE CONCERNING PITCHBLENDE IN CORNWALL.

In the early part of the nineteenth century uranium minerals were but little known in Cornwall, and William Phillips,[5] writing in 1815, stated that until within a few years the only locality known to have yielded "the oxyd of uranium" was the "Carharack" mine, south of "St. Die." He then described several other localities where he had found uranium minerals, which he referred to as "oxyd of uranium," though many of them seem to have been autunite or torbernite.

[5] William Phillips, "On the Oxyd of Uranium, the Production of Cornwall, together with a Description and Series of its Crystalline Forms," *Trans. Geol. Soc.*, London, Vol. III., 1816, pp. 112–120.

Somewhat later the nature of uranium minerals became better understood, but even in 1843, W. J. Henwood[6] reported that pitchblende

"occurs in great abundance among the copper ores of Weal Trenwith, and was long carefully collected, and thought to be black copper ore. The low prices obtained for the ores with which it was mixed, and the inferiority of the metal they yielded, equally disappointed the miner and the copper smelter; .... The ores were then inspected, and pitchblende being discovered among them, its nature and prejudice to the copper ores were explained to the workmen, by whom it has been, of course, since rejected."

Before long, however, uranium began to have a value in the arts, and in 1871 Richard Pearce,[7] in a letter from Swansea, England, describing a specimen of pitchblende which he had collected in Gilpin County, Colorado, said:

"It is the first time, I believe, that the mineral has been found in America."

Continuing he said:

"I found about 2 cwt., which had been thrown away on the refuse heap, and the person in charge of the property told me that it caused them a great deal of inconvenience, as it had come into the lode and cut the copper out. You may imagine his surprise when I told him it was worth in England about £400 per ton!"

In the early days of copper mining in Cornwall, however, pitchblende not only had no market value, but an extra smelting charge was imposed on ores containing any considerable quantity of it because of its deleterious effects. The miner, therefore, avoided it as much as possible, and left it untouched in the mine, or sorted it from the ore and threw it on the waste-dump. Later, however, when the use of uranium compounds in the arts gave it a market value, it was saved, and many of the old waste-dumps were sorted for it; while about the year 1889 a vein in

[6] W. J. Henwood, "On the Metalliferous Deposits of Cornwall and Devon," *Trans. Roy. Geol. Soc. Cornwall,* Vol. V., 1843, p. 19.

[7] Richard Pearce, "Memorandum on Pitchblende in Colorado," *Trans. Roy. Geol. Soc. Cornwall,* Vol. IX., Pt. I., 1875, p. 102.

the South Terras mine, which was unusually rich in pitchblende, was worked especially for that mineral. When still later pitchblende became important as a source of radium, much more attention was paid to saving it. Many of the old waste-dumps were again sorted for it on account of its greatly increased value, and several of the old copper mines which were known to have contained unusual quantities of pitchblende in the early days, were reopened, and the pitchblende that had once been carefully avoided was now just as carefully sought.

MODE OF OCCURRENCE OF PITCHBLENDE IN CORNWALL.

The pitchblende of Cornwall occurs mostly as one of the minerals of the copper deposits, though it occurs also with the tin deposits and in still other associations. With it are generally associated in addition to the copper, iron and other commoner materials, the rarer minerals of the region, such as native bismuth, nickel and cobalt minerals, sometimes lead and silver minerals, arsenic in the form of mispickel, and fluorspar. In some localities, however, the pitchblende occurs without these rarer accompaniments. With it also are sometimes associated various other uranium minerals, such as autunite, torbernite, zippeite, uraconite (uranochre), and other compounds, probably the products of the alteration of pitchblende. In fact, all the ores near the surface are more or less altered and the pitchblende is apt to be coated with, or even entirely replaced by, alteration products; but below, the unaltered black pitchblende appears, associated with sulphides and other unaltered minerals.

The most active days of copper mining in Cornwall have long since passed, and many of the larger mines have been exhausted, so that it is now often difficult to see just how the pitchblende occurred; but much information can be gotten from the old workings and the waste materials on the dumps and elsewhere. It rarely occurs in well-defined bodies, though J. H. Collins[8] describes a "leader" of it which had been traced for several

[8] J. H. Collins, "Observations on the West of England Mining Region," 1912, pp. 242–243.

hundred feet, and Richard Pearce[9] describes it as occurring commonly in small veins intersecting the main veins. In other cases it occurs as an impregnation throughout the copper ore and in the walls of the vein. Sometimes it forms thin lenses or incrustations on the walls, ranging from a mere film to a fraction of an inch, and in rarer cases to several inches, in thickness. In whatever form it occurs it is of very uncertain and sporadic distribution, and is rarely continuous for any considerable distances.

Pitchblende and other uranium minerals are very generally found in most of the copper mining districts of Cornwall, but are more abundant in some mines than in others. They occur in notable quantities at the Trenwith and the Providence mines in the St. Ives district and at the South Terras and other mines near Grampound Road, as well as at the St. Austell Consols mine, and other mines near St. Austell. They also occur in mines of the St. Just district, in the Dolcoath and other mines near Camborne, in mines near Redruth, Gwennap, Illogan, St. Blazey, Liskeard, at the Gunnislake mine near Callington, and in fact, in many other localities throughout Cornwall. In most of these places they are only in small quantities and are simply mineralogical curiosities; but in others they occur in important quantities.

THE TRENWITH MINE, CORNWALL.

A few years ago The British Radium Corporation began work at the old Trenwith mine, about two miles from St. Ives, with the object of mining pitchblende and extracting radium from it. The Trenwith mine was formerly worked for copper and to some small extent for tin; and it had always been noted for the quantity of pitchblende that it contained. At this locality the granite dips under the slates at a low angle of about 30°, and the country is intersected by greenstone dikes. The mine is on a vein which strikes easterly and westerly and dips almost vertically, with a slight inclination to the north. The upper workings are in the slates and the lower workings in the granite; and,

[9] Richard Pearce, "Note on Pitchblende in Cornwall," *Trans. Roy. Geol. Soc. Cornwall*, Vol. IX., Pt. I., 1875, pp. 103–104.

as common in Cornwall, the part of the vein in the slates carries copper ores, and the part in the granite carries tin ores. The mine was worked profitably in former days for copper, but when the workings extended into the granite the tin did not prove profitable, and the mine had been closed for many years at the time The British Radium Corporation took possession.

The pitchblende occurs especially on the walls of the vein, where it was left by the former copper miners, in the "horses" of rock within the vein, in the old waste-dumps and in the waste material used years ago to fill the old workings. The quantity of pitchblende in the parts of the mine containing tin ores is as yet problematical, as the latter have not been much worked; but the writer was shown by one of the directors of the Company a piece of feldspathic rock containing pitchblende from the tin-bearing part of the vein, so that the mineral seems to occur, at least to some extent, in the granite.

The pitchblende ore from the Trenwith mine consists mostly of a mixture of pitchblende, iron and copper minerals, and various gangue materials. It contains from a fraction of one per cent. of uranium oxides, commercially expressed in terms of U_3O_8, to 40 or more per cent., but the average produced is from 2 to 3 per cent., though higher grades of from 10 to 18 per cent. can be produced for special purposes. The British Radium Corporation extracts the radium from the pitchblende in the form of bromide, and has paid dividends on the enterprise. Aside from the radium contents of the pitchblende, the uranium is also a source of profit.

THE SOUTH TERRAS MINE, CORNWALL.

The South Terras mine is near Grampound Road in the Parish of St. Stephens, and has produced copper, tin, hematite, magnetite, and other ores. Several veins occur on the property, and one of them, long known for the uranium minerals it contained, is called the Uranium Lode. It strikes approximately north and south and varies from two to four feet in width, containing uranium minerals in a seam from a mere film up to seven or

eight inches or even a foot or more in width.[10] In the upper part of the vein the uranium occurred mostly as autunite, torbernite and zippeite, with disseminated particles of pitchblende; but with depth the pitchblende increased in quantity and the other uranium minerals decreased, finally being completely replaced by pitchblende, thus suggesting that they had been originally derived from pitchblende by surface alteration. Collins[11] states that at a depth of 30 fathoms pitchblende only was found. The depth of such transition in different districts will doubtless be found to vary according to the topography, drainage and other surface conditions.

About 1889, when there was considerable demand for pitchblende as a source of uranium compounds, before radium was known, the Uranium Lode was actively worked and was said to be the only mine in Great Britain at that time operated for uranium ores alone.[12] About five hundred tons of ore were sold up to 1907 and some was still left in the dump.[13] Since that time production has continued intermittently. When the value of uranium ores as a source of radium became known, a French company, known as Société Industrielle de Radium, commenced operations at the mine with the plan of shipping the crude ore to their laboratory at Gif, near Paris, for treatment. Financial and other complications have hampered the activities of this company, though they are said to claim to have produced some radium.

Uranium minerals have been found in more than usual quantities at the Engloshellan mine north of the South Terras mine and at the New Crow Hill mine south of it.

[10] J. H. Collins, "Observations on the West of England Mining Region," 1912, pp. 242–244.

[11] J. H. Collins, "Observations on the West of England Mining Region," 1912, p. 243.

[12] J. A. Phillips and Henry Louis, "A Treatise on Ore Deposits," 1896, p. 220.

[13] J. H. Collins, "Observations on the West of England Mining Region," 1912, pp. 243–244.

THE ST. AUSTELL CONSOLS MINE, CORNWALL.

Uranium minerals were at one time quite abundant at the St. Austell Consols mine near St. Austell, where they occurred in a series of veins intersecting a tin-bearing and copper-bearing vein in a north and south direction.[14] The uranium ores are here associated with nickel and cobalt minerals. This and other mines in the St. Austell district are reported by the government geological survey to have produced about 576 tons of uranium ores in the years 1854 to 1863; 1873–1881; 1890–1906.[15]

OTHER MINES CONTAINING PITCHBLENDE IN CORNWALL.

Many other instances of deposits containing pitchblende in Cornwall might be described, but those mentioned above represent the different modes of occurrence and are among the localities where it has been most abundantly found.

[14] R. H. Williams, "Note on the Occurrence of Nickel and Cobalt at St. Austell Consols Mine," 39th Rept. Roy. Inst. Cornwall, Appendix VII., 1858, p. 32, cited in "The Geology of the Country around Bodmin and St. Austell," by W. A. E. Ussher, G. Barrow, and D. A. MacAlister, A. R. S. M., Memoirs of the Geological Survey, London, 1909, pp. 155–156.

[15] "The Geology of the Country around Bodmin and St. Austell," by W. A. E. Ussher, G. Barrow, and D. A. MacAlister, A. R. S. M.; Memoirs of the Geological Survey, London, 1909, p. 135.