URANIUM MINERALS FROM LUSK, WYOMING

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INTRODUCTION

The occurrence of uranium minerals at Lusk, Wyoming, was noted in 1919 by Lind and Davis[1] who tentatively proposed the name lambertite for one of the uranium minerals present, which they thought might be UO_3. This mineral has been definitely identified as uranophane and as the only other uranium mineral present showed no properties different from those of pitchblende, the name lambertite is found inapplicable to any uranium mineral yet found at Lusk. These minerals were studied when all three authors of this paper were members of the Geological Survey and as the first two have now left, it seems best to place on record the results obtained, even though it is recognized that a more detailed description of the uranium minerals could be given.

OCCURRENCE (F. L. H.)

In 1918 uranium minerals were discovered in a hill on the north of Lusk, Wyoming, a locality far removed from other known uranium deposits and, indeed, from any other important mineral deposit. The eminence, known as Silver Hill, is one of a small range of hills and rises about 200 feet (barometric measurement) above Niobrara Creek which has been cut through the range. The hills have here a nearly north-south trend, and have been formed by the doming of the rocks. The core of Silver Hill is formed by vertical eroded schists, apparently the same as those at Sunrise and Hartville, Wyoming, and over them lies unconformably a somewhat conglomeratic quartzite. These are evidently the rocks which were designated by Smith and Darton[2] as respectively, the Whalen group (Algonkian) and a member of the Guernsey formation (Mississippian). Pegmatites intruded the schists before the deposition of the quartzite, were earlier, and had no connection with the deposits of the uranium.

[1] Lind, S. C., and Davis, C. W., A new deposit of uranium ore: *Science*, N. S., **49**, 441–443, May 9, 1919.

[2] Smith, W. S. T., and Darton, N. H., The Hartville folio. *U. S. Geol. Survey, Geologic Atlas* **91**, 1903.

Silver Hill is cut lengthwise by a thrust fault having a dip of about 60° E. and a vertical movement of about 100 feet. The fault is probably due to the folding which formed the ridge, of which Silver Hill is near the northeastern end, and which trends southwesterly through Hartville. This is apparently an old line of disturbance, and at Hartville are great iron and copper deposits which were formed in the Algonkian rocks and eroded with them. The latest uplift along the ridge is said by Darton[3] to have taken place "toward or at the close of the Cretaceous period." The deposition of the ore at Lusk was probably associated with this movement but followed it, for the gouge along the fault prevented deposition on the hanging wall side.

At Lusk, in the quartzite on the under side of the fault, silver and copper had been mined in a small way some years ago. The primary minerals present are chalcocite and pitchblende, calcite (the principal introduced mineral), and probably some quartz. Secondary minerals present are: azurite, malachite, chrysocolla, uranophane partly in radiating tufts of tiny crystals, and a few very small masses of a red mineral not tested but almost surely gummite.

The solutions from which the minerals were deposited followed cracks and spread from the cracks into the quartzite, replacing its cement. That this took place after the silicification of the original sandstone is shown by the fact that many small cracks in the quartzite are unhealed. If solidification of the original sandstone had taken place after the cracking most if not all of the cracks would have been filled with quartz. From the manner of deposition it follows that the original uranium mineral or minerals were scattered between the sand grains, mixed with other minerals, so that pure material has not been found. Had the ore bearing solutions flowed longer or been more plentiful, so that the sand grains too were replaced, as in the lead deposits of the Coeur d'Alene district or some of the Andean tin deposits, larger masses probably would have been formed.

The gouge along the fault has prevented the deposition of the minerals on the upper side, and no uranium has been found in the schists with the exception of a little at the very top.

[3] *Loc. cit.*, p. 5.

IDENTITY OF LAMBERTITE WITH URANOPHANE (E.S.L. & W.T.S.)

The material to which the name of lambertite was given, had been previously referred to E. S. Larsen for optical examination and identification and had been reported to be uranophane. Lind and Davis, however, thought that their chemical work indicated a new mineral in spite of the identification reported. They say:—

"The chemical evidence of the writers on material not so pure as could be desired (about 80 per cent pure) indicates that the soluble bases and acids account for each other without reference to the uranium oxide at all. This was taken to indicate the existence of a free higher oxide, probably UO_3."

The material furnished by Lind and Davis sufficiently identified the "lambertite" as the well known mineral uranophane, and study of additional material collected by Frank L. Hess has fully confirmed this identification. It therefore seems advisable to place on record the facts obtained and to prevent, as far as possible, the introduction of the name "lambertite" into mineralogical literature.

The optical properties of the yellow uranium mineral (the so-called lambertite) from Lusk, Wyoming, sent in by Dr. Lind, are as follows: (determined by E. S. Larsen): Optically negative, with a slight varying optical angle, $2V_{Li} = 32°$ to $42°$, $2V_{Na} = 37°$ to $45°$.

Strong dispersion, $\rho < \nu$. The acute bisectrix, X, is sensibly normal to the flat face, and Z is parallel to the elongation. The optical relations indicate orthorhombic symmetry. The indices of refraction measured by the immersion method are: $\alpha = 1.642$, nearly colorless; $\beta = 1.665$, canary yellow, a little paler than γ; $\gamma = 1.672$, canary yellow. These values are identical, within the limits of error of measurement, with the indices of uranophane from other localities, as the following table shows, the last three sets of values being taken from Larsen's mineral tables.[4]

[4] Larsen, E. S., The microscopic determination of the non-opaque minerals: *U. S. Geol. Survey, Bull.* **679,** 149–150 (1921).

COMPARISON OF OPTICAL PROPERTIES OF URANIUM MINERAL (THE SO-CALLED LAMBERTITE) FROM LUSK, WYOMING, WITH THOSE OF URANOPHANE FROM THREE OTHER LOCALITIES

OPTICAL PROPERTIES	MINERAL FROM LUSK, WYOMING (LAMBERTITE)	URANOPHANE		
		SILESIA	SCHNEEBERG, SAXONY	NEUSTADT, SAXONY
α	1.642	1.643	1.645	1.642
β	1.665	1.667	1.665	1.666
γ	1.672	1.670	1.667	1.670
Opt. char.	Negative	Negative	Negative	Negative
2V	37° to 45° (Na)	Small	32° (Na)	Small
Dispersion	Strong	Marked	Extreme	Marked
Optical orientation	Elong. of fibers = Z	Elong. of fibers = Z	Elong. of needles = Z	Elong. of fibers = Z
	X ⊥ flat face		X ⊥ flat face	
Pleochroism	α nearly colorless β pale canary yellow γ canary yellow		α nearly colorless β pale canary yellow γ canary yellow	

Several specimens of a yellow uranium mineral from Lusk were collected by Frank L. Hess and comparison of its optical properties (determined by W. T. Schaller) with those (determined by E. S. Larsen) on the "lambertite" furnished by Lind and Davis, shows them to be the same mineral.

OPTICAL PROPERTIES OF MINERAL FROM LUSK COLLECTED BY F. L. HESS AND COMPARED WITH THOSE OF "LAMBERTITE"

	URANOPHANE COLLECTED BY F. L. HESS	"LAMBERTITE" FURNISHED BY LIND AND DAVIS
	Orthorhombic	Orthorhombic
α	1.643	1.642
β	1.665	1.665
γ	1.670	1.672
Elongation	Z	Z
Dispersion	Strong $\rho < v$	Strong $\rho < v$
Sign	Negative	Negative

The mineral collected by Hess has a moderate axial angle (2E), the axial plane is parallel to the elongation, B_{xa} (X) is normal to the flat face, and good cleavages are present in the prism zone.

There can be no question about the identity of the two minerals, whose optical properties are similar and the chemical analysis given later, shows one of them to have the composition of uranophane.

The rosettes of yellow crystals of uranophane on the specimen collected by Hess reach a diameter of about half a centimeter. The individual prismatic crystals are a millimeter or so long and about one-fifth as thick. A hand lens inspection suggested that many of the crystals would yield good reflections on the goniometer but it was soon seen that no good measurements could be obtained. No terminal faces could be definitely established for they were considerably rounded and dull and gave no reflections. Of the faces in the prism zone only the cleavage ones gave good single reflections, all the others being faint, multiple, and very poor. Several of the prismatic crystals, when measured on the goniometer gave values for faces in the prism zone and the values obtained on three such crystals are shown below. The broad faces (perhaps all cleavage faces on the crystals measured) are taken as the macropinacoid a (100) and the angular measurements taken against this face. All the other faces in the prism zone are narrow and vertically striated so that the relative size of the brachypinacoid b (010) as compared with those of the very close lying brachyprisms could not be determined.

The disposition of the faces on the first crystal suggests triclinic symmetry; those on the other two crystals, however, show that the distribution of the prism faces is very irregular and no importance can be attached to it. In fact the sets of crystal measurements yield no information as to their symmetry. It has been established though, from the results of the optical examination, that the mineral is orthorhombic and the crystal measurements in part verify this conclusion. The crystals have a face (the brachypinacoid) at right angles to the large (cleavage) face present on all crystals. This has been measured to be 90°44′, 89°10′, 89°45′, 90°15′ and 89°35′ inclined thereto, a very close approximation to 90°, considering the vary faint and striated reflections obtained from the crystal faces.

The interpretation of the prism faces is considerably in doubt; it is to be noted though that a considerable consistency is present in the angles, the ϕ angle falling into several distinct groups, as follows (the ϕ angle being measured from the branchypinacoid):

2°28′ on crystal 1.   4°42′ on crystal 2.   6°04′ on crystal 1.
2°55′   "   3.   4°39′   "   3.   6°38′   "   1.
3°33′   "   3.   4°45′   "   3.   6°46′   "   2.
2°02′   "   3.   Av. = 4°42′   6°14′   "   3.
3°04′   "   3.   Av. 6°26′
Av. = 2°48′

10°53′   "   1.   14°09′ on crystal 2.
9°54′   "   1.   14°42′   "   3.
9°17′   "   2.   Av. = 14°26′
8°45′   "   2.
8°15′   "   3.
Av. = 9°25′

That these angles are not altogether fortuitous but are related in some way, is evident by considering their cotangents which rather closely form the normal series N_3, as shown below.

CConstants of ϕ Angles of Prisms, Forming Normal Series

MEASURED ANGLE	MEASURED COTANGENT	CALCULATED COTANGENT	NORMAL SERIES	CALCULATED ANGLE
2°48′	20.45	18.09	3	3°10′
4°42′	12.16	12.06	2	4°44′
6°26′	8.87	9.05	3/2	6°19′
9°25′	6.03	6.03	1	9°25′
14°26′	3.89	4.02	2/3	13°58′
		3.02	1/3	18°21′
		2.01	1/3	26°27′

The last two members, ½ and ⅓, of the normal series, are missing but the other calculated angles (taking the form whose ϕ angle is 9°25′ as unity) show a fair agreement with the measured angles. The crystallography of uranophane, however, is so inadequately known, that these faces can not definitely be correlated with those of other crystals of the mineral. Although no terminal faces could be measured on the reflecting goniometer, microscopic observation of the material shows abundant terminated crystals. Some of the crystals show the traces of two symmetrical planes inclined about 90° to each other and inclined (as measured) from 42½° to 44½° to the elongation. The average of 7 measurements of this inclination is 43°. On other crystals the trace of a third plane normal to the elongation was observed. All these crystals or cleavage pieces showed parallel extinction.

The observations of Pjatnitsky[5] on the crystal form of this mineral as triclinic could not be verified on the material from Lusk.

A chemical analysis (by W.T.S.) made on a small quantity of the yellow mineral, mixed with calcite, gave the results shown below. Microscopic examination of the sample analyzed showed it to be about ⅓ calcite and ⅔ of the yellow mineral. The analysis of the sample is shown below.

ANALYSIS OF MIXTURE OF CALCITE AND URANOPHANE FROM LUSK, WYOMING

ANALYSIS		67.7% URANOPHANE CALCUL. FOR 30.3% CALCITE 2.1% QUARTZ	ANALYSIS WITH CALCITE AND QUARTZ DEDUCTED
UO_3	45.5	45.4	67.2
CaO	20.9	21.4	6.5
SiO_2 (sol.)	9.4	9.4	13.9
H_2O+CO_2(ign.)	22.2	21.8	(H_2O) 12.6
Quartz (insol.)	2.1	2.1	
	100.1	100.1	100.2

The identity of the yellow mineral, which when mixed with other minerals has shades of brown, black, and green, from Lusk, as uranophane, can not be doubted and the name lambertite should be stricken from the list of mineral names.

PITCHBLENDE (W.T.S.)

The black uranium bearing material seems to be of infiltration and replacement origin and is itself considerably replaced by its oxidation products as well as by secondary copper minerals. It is massive, opaque, and shows no distinct individualized properties. It was hand picked as far as possible and after being crushed to 100 mesh was then repeatedly concentrated by heavy solution (methylene iodide). Several grams of material were finally obtained which seemed to represent as pure a product as could be gotten under the circumstances. It was, however, very easy to demonstrate on polished specimens of quartzite containing the black mineral the presence of quartz, calcite, chalcocite, and an unidentified metallic mineral whiter than chalcocite, uranophane ("lambertite"), chrysocolla, and limonite. Metallic copper seemed

[5] Pjatnitsky, P., Ueber die Krystallform des Uranotil: *Z. Kryst. Min.*, **21**, 74–85 (1893).

to be present. It is very likely that other secondary minerals (copper carbonates, copper oxide, various secondary uranium minerals, etc.) were also present.

The analysis of the sample is given below.

ANALYSIS OF IMPURE SAMPLE OF PITCHBLENDE FROM LUSK, WYOMING

		PERCENTAGE	SOURCE
S	In in-	0.71	Chiefly as chalcocite
Cu	soluble	2.69	
Quartz	portion	18.02	Quartz
SiO_2 soluble		7.64	Uranophane and chrysocolla
CuO		7.23	Chrysocolla and other secondary copper minerals
CaO		8.91	Uranophane and calcite
MgO		0.46	Unknown
Fe_2O_3 total		0.63	Limonite
Al_2O_3		2.87	Unknown
BaO		0.15	Unknown
K_2O		0.35	Determination probably high
Na_2O		0.69	
P_2O_5		0.45	Unknown
CO_2		5.42	Calcite
PbO		0.23	Unknown, probably pitchblende
UO_2		18.64	Pitchblende
UO_3		17.06	
H_2O-		2.72	Secondary chrysocolla and uranophane, and probably some moisture
H_2O+		5.54	

100.41

The determination of PbO was made on a half gram sample and cannot be considered very accurate. Traces of zinc and of arsenic were noted but no reactions for the presence of sulphates, rare earths, or vanadium were obtained. Elements not recorded were not tested for. It is impossible to allocate the different bases as the form of combination is not known. The copper, for example, may be present as any part of the mineral association—copper, tenorite, cuprite, azurite, malachite, chrysocolla, and still other compounds. Moreover, it is not known in what combination the magnesia, alumina (determined by phenylhydrazine), or phosphoric acid, are present. Neither is it definitely known where the small quantity of lead belongs. The simplest interpretation of the analysis is to consider the two oxides of uranium to be the essential constituents of the black mineral. Not all the UO_3 belongs to this

black mineral, for secondary uranium compounds (uranophane, etc.) are present and a small quantity of UO_3 must be ascribed to them.   This leaves, as components of the black mineral, UO_2 with a slightly smaller quantity of UO_3, and the mineral would then be pitchblende. The ready solubility of the black mineral in HCl might seem to refute the conclusion that it is pitchblende, this mineral being considered insoluble in HCl.   Tests made on the solubility of pitchblendes from different localities however have shown that some are much more soluble in HCl than is generally recognized. One from Colorado, when tested, was found to be completely soluble in HCl if left standing on the steam bath for a day.

In conclusion, then, no evidence could be found which would refute the suggestion that the UO_2 and UO_3 in the black material from Lusk, Wyoming, are present essentially as pitchblende, and while at present it seems impossible to prove definitely its identity, the reference to pitchblende seems fully warranted.

AGE OF THE PITCHBLENDE (F.L.H.)

The known geology and the analysis of the pitchblende give an opportunity to adduce another bit of evidence concerning the age of the earth as shown by atomic disintegration. The theory that the age of uranium minerals may be determined by the quantity of lead present in the mineral is well known. It is based on the now universally accepted theory that uranium-lead having an atomic weight of 206, and which is an isotope of ordinary lead, is a product of the disintegration of uranium.

Based on the percentages of Pb and U as calculated from the analysis, the age of the mineral may be calculated.   Accepting tentatively the formula

$$\frac{Pb}{U}.79.10^8 = \text{years},$$

then the age of the mineral is

$$\frac{.21}{30.63}.79.10^8 = 54{,}000{,}000 \text{ years}.$$

This is a greater time than ordinarily has been considered to have elapsed since late Cretaceous time, and immediately raises the suspicion that possibly common lead may be mixed with the

uranium lead.   No lead minerals were recognized in a careful microscopic examination of the material, and it is believed that none were present. It is unfortunate that sufficient material was not at hand to separate the quantity of lead necessary for an atomic weight determination, and thus definitely settle the question.   Such determinations are important when age calculations are to be based on analyses. However, it seems probable that our ideas of geologic time must be lengthened rather than shortened.

DIRECTIONAL FACTORS IN RADIO CRYSTAL DETECTORS

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During experimentation with the various crystal detectors enumerated by Wherry in his recent excellent article,[1] it occurred to the writer that perhaps there might be some directional factor involved in the excellence of certain crystal detectors, i.e., that such detectors might transmit radio waves more readily in one or more directions than in others, said directions depending upon the molecular network of the crystals of the detectors concerned.   It was therefore decided, as the simplest convenient way of trying out the idea, to test as many natural crystals as possible to determine whether certain crystallographic faces or series of faces gave better or poorer rendition on the crystal set when the "cat's whisker" was applied to them. Very good results were obtained from crystals of some of the better detectors when they were used without mounting, simply resting on a face parallel to that upon which the "cat's whisker" was brought to bear. Among the galena crystals tried, those from Mineral Point, Wisconsin, gave excellent results, the strength and clearness of rendition being very much better on all the octahedral faces of the natural crystal than on the cubic ones.   The best pyrite crystals that were tried came from near Winkelman, Arizona, showing cube, octahedron, dodecahedron, three pyritohedrons and one or more diploids. These and pyrites from some other localities were tried, with the result that the octahedral faces were found to give strongest and clearest results, the cube faces being next best, and the pyritohedrons and diploids rather inferior. Roughness of the octahedral faces, nevertheless, may play an important part in the results obtained. It is hoped

[1] *Am. Mineral.*, **10,** 28–31 (1925).