THE STRONTIUM OCCURRENCE NEAR LA CONNER, WASHINGTON

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A strontium deposit from which celestite and small amounts of strontianite were mined during the latter part of the war is located at the southeast corner of Fidalgo Island in western Skagit County. The nearest town is LaConner, situated about one mile to the northeast and on the mainland. Fidalgo Island lies southeast of the main San Juan group in north Puget Sound and is separated from the mainland by a very narrow pass known as Swinomish Slough, through which the tide moves with considerable velocity. To reach the strontium deposit it is necessary to go by boat from LaConner through the south end of the slough to the open sound and then a short distance westward along the southward facing cliffs of Fidalgo Island. The deposit is marked by an abandoned mine tunnel situated a few feet above tide level.

Fidalgo Island is made up largely of massive rocks and has a very uneven topography. The land lying east of Fidalgo is, on the contrary, very flat, and is a part of the extensive Skagit River delta. Here and there the level surface of the delta is interrupted by rocky and precipitous hills which once were islands, similar to but smaller than Fidalgo and which have become tied to the mainland by the outward extension of the river flood plain.

The geology of Fidalgo Island has never been studied in detail. R. D. McLellan,[1] in the map accompanying his report on the geology of the San Juan Islands, covers only portions of the western side of Fidalgo Island. The country rock in the vicinity of the strontium deposit probably belongs to the Fidalgo formation, referred by McLellan to the Triassic.[2] The following description is quoted from McLellan's report:[3]

"The Fidalgo formation is composed of three distinct rock types which are invariably associated with each other: (1) Large irregular masses of extremely coarse-grained dunite, which weathers to a dark green or dark brown color. (2) Thin irregular off-shoots or fine-grained dunite, injected into the joint-cracks of the coarse-

[1] R. D. McLellan, The geology of the San Juan Islands. *Univ. of Wash. publications in geology*, vol. 2, Nov. 1927.

[2] *Op. cit.*, p. 144.

[3] *Op. cit.*, pp. 142 and 144.

grained variety. These off-shoots weather first to a light brown or buff color, and on further disintegration, to a bright orange-red. (3) Both types of dunite are everywhere cut by thin stringers (rarely exceeding two inches in thickness) of serpentinized pyroxenite. The latter is composed almost entirely of altered diallage, the crystals often being as large as the width of the stringer permits. Of the three rock types the pyroxenite is the least resistant to alteration and erosion."

A specimen collected by the writer from a point 50 feet west of the celestite vein outcrop consisted mainly of olivine and serpentine with subordinate calcite and epidote. Of a later age are large amounts of quartz and pyrite. The quartz occurs both in veins and in scattered but fairly pure masses less than an inch across and sometimes with a vuggy tendency. The pyrite is impregnated through the rock in scattered small grains. It is found with or without the quartz, in fact the latter occurrence is the commoner. The country rock specimens collected immediately adjacent to the deposit were not pyritized, but were calcitized instead.

Although the LaConner strontium deposit has been mentioned a few times in print,[4] no detailed description of it has as yet been published. This locality was visited by the writer in 1921 and again in 1928. The deposit consists mainly of celestite which occupies a shattered zone running north 65 degrees east and dipping 42 degrees to the northwest. The lode width varies between 3 and 4 feet, but only rarely does that entire distance contain vein minerals. The latter occur in stringers and pods which parallel the strike of the shattered zone. Sometimes the country rock predominates in this zone with the celestite and associated minerals subordinate.

The deposit crops out from tide level to the top of the hill and then can be traced northeastward for a short distance until obscured by the vegetation. About eight feet above high tide a 110 foot tunnel has been driven on the vein. At the top of the hill a trench about 100 feet long and 2 to 10 feet deep into the vein has been excavated. The bottom of the trench lies about 80 feet above the tunnel level. The vein at this point is about 30 inches wide and

[4] Hill, J. M., *U. S. Geol. Survey, Mineral Resources*, **1915**, pt. 2, p. 187, and **1916**, pt. 2, p. 194. Patty and Glover, *Wash. Geol. Survey, Mineral Resources of Washington, Bull.* **21**, p. 113, 1919. Shedd, Solon, *Wash. Geol. Survey, Bull.* **30**, pp. 144–145, 1922.

very rich. This development took place during the war. The small tonnage of strontium minerals secured was shipped by barge to Seattle.

Celestite is quantitatively the most important of the vein minerals, but there is also considerable strontianite. Calcite, dolomite, and limonite are present, but the last two named are extremely subordinate. Descriptions of the individual minerals follow:

CELESTITE. The characteristic bluish tinge of this mineral can be discerned in most of the specimens collected. The depth of the blue varies considerably. In some instances the celestite is either milky or clear and colorless. The characteristic basal cleavage is very well developed, but the prismatic cleavage is less apparent in the unaltered mineral. However, most of the celestite is altered in part at least to strontianite and the tendency of the replacing mineral to follow cleavage directions in the form of minute veins causes the prismatic cleavage to show up very plainly on the basal cleavage face. The strontianite is whiter in color and of denser appearance. In some specimens the alteration to strontianite is practically complete, the only evidence of the former presence of celestite being a "ghost" cleavage. No euhedral or even anhedral crystals were found. However, partial dissolution by salt water of celestite-bearing rocks along the beach has brought about the formation of some peculiar shapes. Dissolution proceeded with greatest ease along the planes of the macro and brachydomes, producing an eight-faced form. This is not pseudo-octahedral, however, because the dissolution of one dome is very much greater than the other. These water-worn celestite specimens are milky-white and translucent. The surfaces of the dome faces exhibit a sort of pillow structure on a very fine scale. The dissolving power of salt water on celestite has already been pointed out by Kraus.[5] The Fidalgo Island celestite is the only primary mineral of importance in the vein.

CALCITE. That considerable calcium carbonate was present in the celestite-bearing solutions is evidenced by the extreme calcitization of "horses" of country rock in the shattered zone and by the occasional presence in the deposit of veins of pure calcite. The calcite is white in color and coarsely crystalline. The crystals are arranged normal to the walls of the veins which are rarely over an

[5] Kraus, E. H., The occurrence and distribution of celestite-bearing rocks. *Amer. Jour. of Science*, 4th ser., vol. **19**, pp. 286–293, 1905.

inch in thickness. No specimens were obtained containing both calcite and celestite, so the age relationship between these two minerals could not be determined. A very small amount of dolomite occurs with the calcite.

STRONTIANITE. This mineral is obviously of secondary deposition. It occurs as an alteration product of both celestite and calcite. In the former instance the strontianite coats the surface of the celestite and is also found within the latter mineral in veins along cleavage cracks. These vary in thickness from a size visible only under the microscope to a stage where alteration is virtually complete, and only the celestite cleavage remains as a clue to the identity of the mineral formerly occupying that space. Strontianite coats the surface of the calcite or lines small vugs within, but does not penetrate through the calcite in veins to the degree it does with celestite. The strontianite is white where pure and the crystallization is so fine as to give the material a powdery appearance. The most striking characteristic of the Fidalgo Island strontianite is its habit. On the surface it generally appears in botryoidal or nodular form, while within the specimen the mineral is characteristically cellular or reticulated. At times the strontianite is yellow or brown in color due to the presence of limonite. The obviously later age of the strontianite plus its habit lead the writer to believe that it is a secondary mineral and was formed by the action of carbon dioxide bearing ground water on the vein celestite. Furthermore, it has been noted "that the principal bodies of the carbonate are found within 10 feet of the surface and are more abundant where the vein is capped by trees and moss, which suggests that organic acids may have been responsible for the alteration."[6] Sherzer has noted the alteration of celestite to strontianite in the Plum Creek quarries, Michigan.[7]

LIMONITE. This mineral is found in very minor amounts associated with the strontianite. The iron was undoubtedly derived from the serpentine country rock.

The Fidalgo Island strontium minerals are rather unique in their occurrence. Celestite and strontianite have been described from a number of other localities in the United States such as Cal-

[6] Hill, J. M., *U. S. Geol. Survey, Min. Resources*, **1916**, pt. 2, p. 187.

[7] Sherzer, W. A., *Am. Jour. Sci*, 3rd series, vol. **50**, p. 246, 1895.

ifornia, Arizona, Texas, Ohio, New York and West Virginia.[8] In all of these occurrences, however, the strontium minerals are found in sedimentary rocks, usually limestone and dolomite, but sometimes with salt, gypsum, and clay. The strontium is considered by most investigators to have been deposited simultaneously with the other sedimentary material. Later ground water activity caused a concentration of the strontium (generally in the form of celestite) along water courses. In only one locality was the presence of igneous rock mentioned. That was in Arizona where igneous flows and dikes are numerous through the sedimentary series.[9] The same general associations apply to the foreign deposits of strontium minerals. Celestite in the Bristol district in England occurs in marl, while in Sicily it is associated with sulphur and gypsum. Strontianite occurs in commerical deposits in Westphalia, Prussia. The country rock at this locality is Cretaceous marl and limestone.[10]

However, strontium minerals have also been reported in hydrothermal deposits. Hill notes that celestite is a gangue mineral at the Lead Hill mines, Salina, Utah.[11] Strontianite occurs in England only in mineral veins, as a rarity.[12] In the Fitzroy township, Ontario, considerable celestite occurs in galena-bearing veins.[13] In describing a deposit in Carlton County, Ontario, Spence states: "Vein has . . . . originated upon a line of structural dislocation

[8] Pratt, J. H., Strontium ores: *Mineral Resources*, **1901**, pp. 1905–1958. Phalen, W. C., Celestite deposits of California and Arizona: *U. S. Geol. Survey, Bull.* **540,** pp. 521–533, 1914. Culin, F. L., Celestite and Strontianite: *Ariz. Univ. Bureau of Mines, Bull.* **35,** p. 4, 1916. Kraus, E. H., Occurrence of celestite near Syracuse New York: *Am. Jour. Sci.*, 4th ser., vol. **18,** pp. 30–39, 1904; Occurrence and distribution of celestite-bearing rocks: *Am. Jour. Sci.*, 4th ser., vol. **19,** pp. 286–293, 1905. Kraus and Hunt, The occurrence of sulphur and celestite at Maybee, Mich.: *Am. Jour. Sci.*, 4th ser., vol. **21,** p. 237, 1906. Hawkins, A. C., Notes on pyrite and celestite from Rochester, New York: *Am. Mineralogist*, vol. **11,** p. 165, 1926. Hess, F. L., Texas celestite deposits: *Eng. and Mining Jour.*, vol **88,** p. 117, 1909. Knopf, A., Strontianite deposits near Barstow, Calif., *U. S. Geol. Survey, Bull.* **655,** pp. 267–270, 1918. Hill, J. M., Strontium ores and salts: *U. S. Geol. Survey, Mineral Resources*, **1912,** p. 960.

[9] Culin, F. L., *loc. cit.*

[10] Spence, H. S., Barium deposits of Canada: *Canada Mines Rept.*, **1922,** p. 100.

[11] Hill, J. M.: *U. S. Geol. Survey, Mineral Resources*, **1915,** p. 186.

[12] Sherlock, R. L., Celestine and strontianite: *Mem. Geol. Survey, Special reports on the mineral resources Great Britain*, vol. **3,** p. 51, 1918.

[13] Young, G. A., Geology and economic minerals of Canada: *Canadian Geol. Survey*, vol. **2065,** p. 54, 1926.

in the limestone. . . . . The celestite has probably been deposited by ascending solutions from a deep-seated source, rather than concentrated from the enclosing crystalline limestone."[14] Small amounts of sphalerite and chalcopyrite as minute crystals on calcite are noted associated with this celestite. The same writer describes the occurrence of celestite in irregular masses in brown dolomite in Renfrew County, Ontario.[15] He believes that the dolomite was originally a crystalline limestone (which is the normal country rock) and was altered by the same ascending solutions which introduced the celestite. A diabase dike forms the foot wall to the deposit. The magnesium and strontium bearing solutions are thought by Spence to have been brought in by the diabase.

The writer believes that the Fidalgo Island celestite is of hydrothermal rather than ground water origin. Reasons for this belief follow: (1) The complete absence of limestone or dolomite or other sedimentary rocks in which the primary strontium could have been deposited. (2) The presence in the locality of large amounts of igneous rock. (3) The confinement of the celestite to a very narrow steeply inclined zone in the rock. (4) The presence of impregnated pyrite and quartz veins in the near-by country rock.

The stages involved in the formation of this deposit were thought to have been as follows: (1) The intrusion of the dunite. (2) The intrusion and solidification of a younger magma not yet exposed at the surface in this immediate vicinity. McLellan[16] describes considerable late Jurassic igneous intrusive activity throughout this area. (3) The upward and outward movement of solutions from the consolidated magna which caused first the deposition of quartz and pyrite in the dunite as already described, and later the precipitation of celestite and calcite along a zone of weakness in the dunite. (4) Ground-water activity which caused the alteration of some of the celestite and calcite to strontianite.

[14] *Op. cit.*, p. 78.
[15] *Op. cit.*, p. 81.
[16] *Op. cit.*