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Siderite and Siderostone from the Sangdong Mine, Yeongweol-gun, Korea.

江原道 上東鑛山에서 發見된 菱鐵石 및 菱鐵石岩

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ABSTRACT: The sedimentary siderite rock or siderostone has been firstly found from the upper part of the Cambrian Myobong Slate in the Sangdong Tungsten Mine area. It occurs as layers between slate and calc-silicate rock (originally siliceous ankerite rock and ferroan dolostone) or within calc-silicate rock. Some parts of the siderostone bed, however, are considerably skarnized to iron-rich skarns, leaving only small-scaled relics.

Siderostone consists mainly of siderite and quartz with minor amount of berthierine and fluorite or apatite and is commonly microcrystalline granular in texture. Stratification is well developed in some siderostone. The siderostone and its skarnized rocks occasionally contain scheelite grains. Siderite also occurs in sandstone and slate. Mineralogy and textures of the siderostone suggest that it might be formed in the shallow marine basin where enough organic matter was present to maintain a low Eh and iron was supplied, and that siderite might be formed largely by diagenesis from iron-rich berthierine mud.

要約 : 江原道 寧越郡 上東鑛山의 猫峯粘板岩層上部에서 堆積起源의 菱鐵石岩이 처음으로 發見되었는 바 이 岩石은 粘板岩과 石灰硅酸鹽岩 (원래 硅質앵커라이트 및 硅質含鐵白雲岩)사이 및 石灰硅酸岩內에서 層狀으로 產出된다.

菱鐵石은 菱鐵石岩, 菱鐵石質 砂岩 및 菱鐵石質 粘板岩으로 產出된다. 菱鐵石岩은 主로 菱鐵石과 石英으로 構成되어 있고 버씨어린, 螢石 또는 燐灰石이 小量含有하며 微晶質組織을 가지고 있다. 菱鐵石岩에는 層理가 잘 發達하여 있는 境遇와 그렇지 않은 境遇가 있고 少量의 灰重石을 含有한다.

菱鐵石岩의 鑛物組成과 組織으로 보아 이 岩石이 Eh가 낮게 유지될 수 있을 정도로 有機物이 充分이 存在한 淺海에서 形成되었으며 상당한 部分의 菱鐵石은 鐵分이 높은 버씨어린質泥로부터 續成作用에 依하여 생성되었다.

INTRODUCTION

The Sangdong Mine has been one of the leading tungsten producers in the world since its opening in 1925. Many workers (Han, 1978; John, 1963; Kim and Park, 1970; Kim, 1976; Moon, 1983, 1984; So, 1968) have studied the geology and ore deposits of the mine. So (1968) reported the occurrence of siderite, but he did not mention the occurrence of siderite rock. And the occurrence of siderite rock or siderostone (the sedimentary rock which consists mainly of siderite) (Chang, 1988) has not been reported from the Sangdong mining area.

In the course of the mineralogical invertigation of the Sangdong tungsten deposits, the authors could firstly recognized the occurrence of a siderostone bed ranging up to 9 m in thickness from the tungsten mineralized zones in the upper part of the Myobong Slate. The sidero-

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stone tends to be oxidized readily to brown to dark brown color on the surface, even in the underground, preventing from its easy recognition.

The occurrence of the siderostone beds in the Sangdong tungsten deposits is significant, because it might be the source of iron for the formation of iron-rich clinopyroxene and amphiboles. This paper aims to report the occurrence and characteristics of the sedimentary siderostones from the Sangdong tungsten deposits.

STRATIGRAPHY

The Sangdong Mine area consists of the Precambrian Taebaegsan Series and the Cambro-Ordovician Joseon Supergroup. The Taebaegsan Series consists of slate, phyllite, schist and quartzite of the green-schist to epidote-amphibolite facies (Lee and Kim, 1984). The Joseon Supergroup consists of the Jangsan Quartzite, Myobong Slate and Great Limestone Group.

The Myobong Slate in the region consists mainly of slates with minor amounts of quartzitic sandstone, siltstone, sandy slate, calcareous slate and limestone. It, however, is characteristic that the iron-rich rocks occur within the Myobong Slate in the Sangdong Mine area. They occur as thick siderostone, iron-rich calc-silicate rocks (originally siliceous ankerite rock and siliceous ferroan dolomite rock) or claystone (berthierine-nontronite rock) in the profile of the Myobong Slate in the Sangdong Mine area. They occur as thick siderostone, iron-rich calc-silicate rocks (originally siliceous ankerite rock and siliceous ferroan dolomite rock) or claystone (berthierine-nontronite rock) in the profile of the Myobong Slate in the Sangdong Mine area. Scheelite mineralization is generally found in the horizon rich in iron content.

The general stratigraphy of the Myobong Slate in the Sangdong Mine area is shown in Fig. 1. The calc-silicate rocks might be the meta-morphic products of iron-rich calcareous sediments as mentioned above. The general features of the siderostone bed is shown in Fig. 2 and is apparently lenticular in shape. The siderostone occupies the lower part of the so-called "Hanging Wall" ore bed as shown in the cross sect\on (5th and 6th levels in Fig. 2). It lies on the pelitic

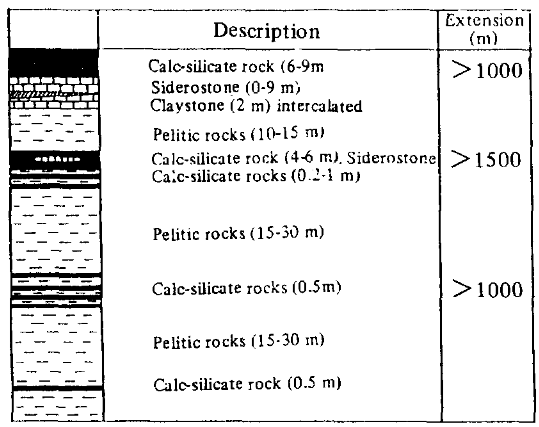


Fig. 1. Stratigraphy of the Myobong Slate in the Sangdong Tungsten Mine area.

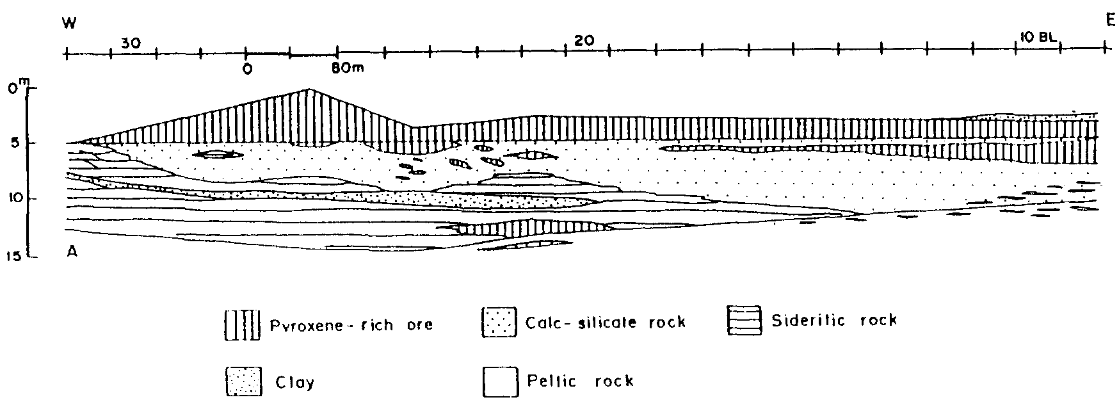


Fig. 2. Geological cross section of the Hangingwall ore bed from −6 and −5 levels in the Sangdong mine.

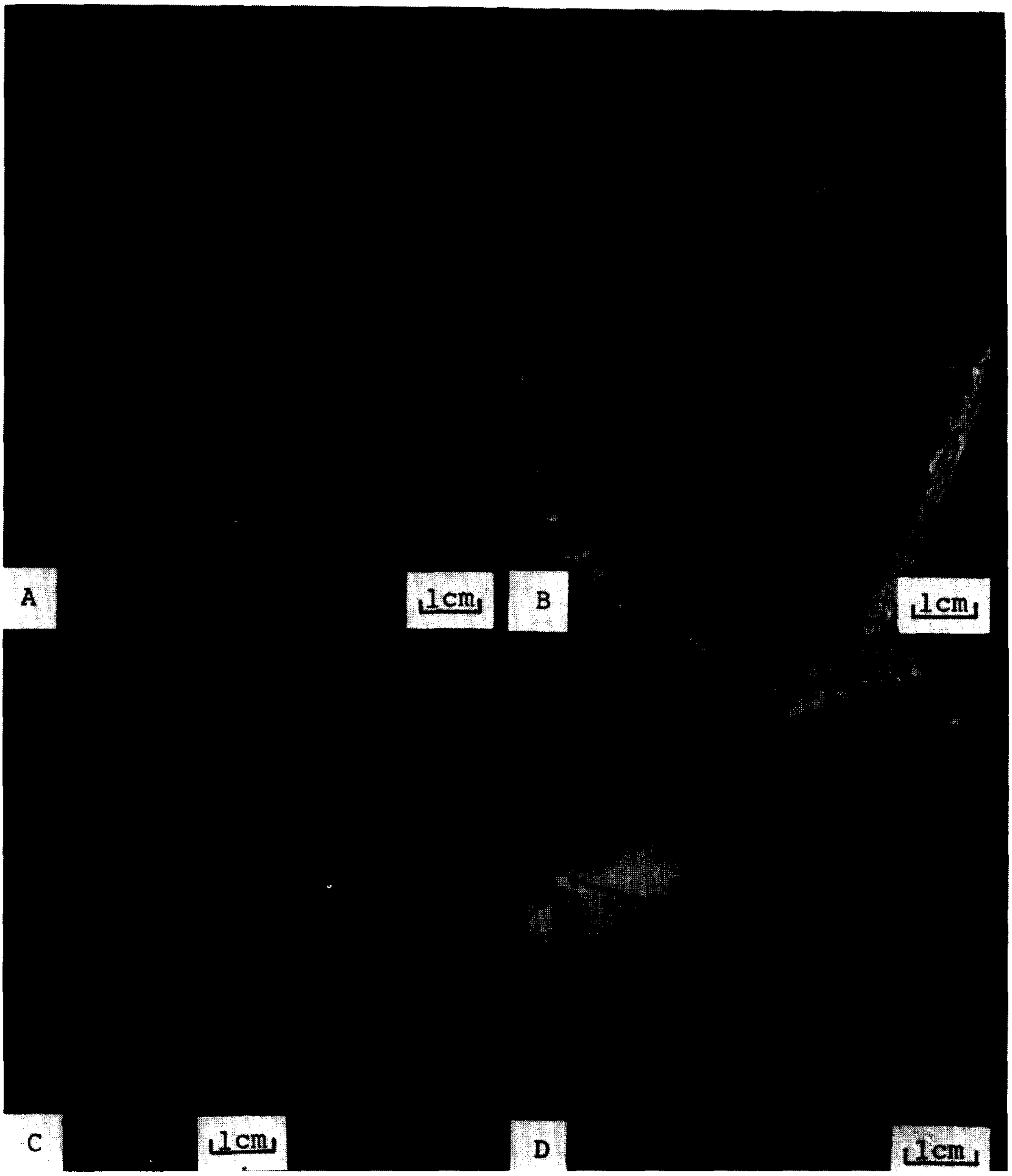


Fig. 3. Photomicrographs of sideritic rocks. A: Siderostone with stratification. Light grey layers are sideritic sandstone, B: Massive siderostone, C: Siderostone with berthierine oolites, D: Sideritic slate.

rocks without tungsten mineralization. Another siderostone bed is found in the "Main" ore bed in a small scale as relics which escaped skarnization. Calc-silicate rock and siderostone in the "Main" ore bed suggest that the "Main" ore bed was also originally iron-rich calcareous sediments in large part. The coarse-grained amphibole aggregates in contact with siderostone might have been resulted from skarnization.

The siderostone is developed only in the Sangdong Mine area. The main siderostone bed in the "Hanging Wall" bed ranges up to 9 meters in thickness. The claystone bed consisting of iron-rich clay minerals (berthierine and nontronite) is intercalated in the siderostone bed. It is inferred that some slip took place along the claystone bed.

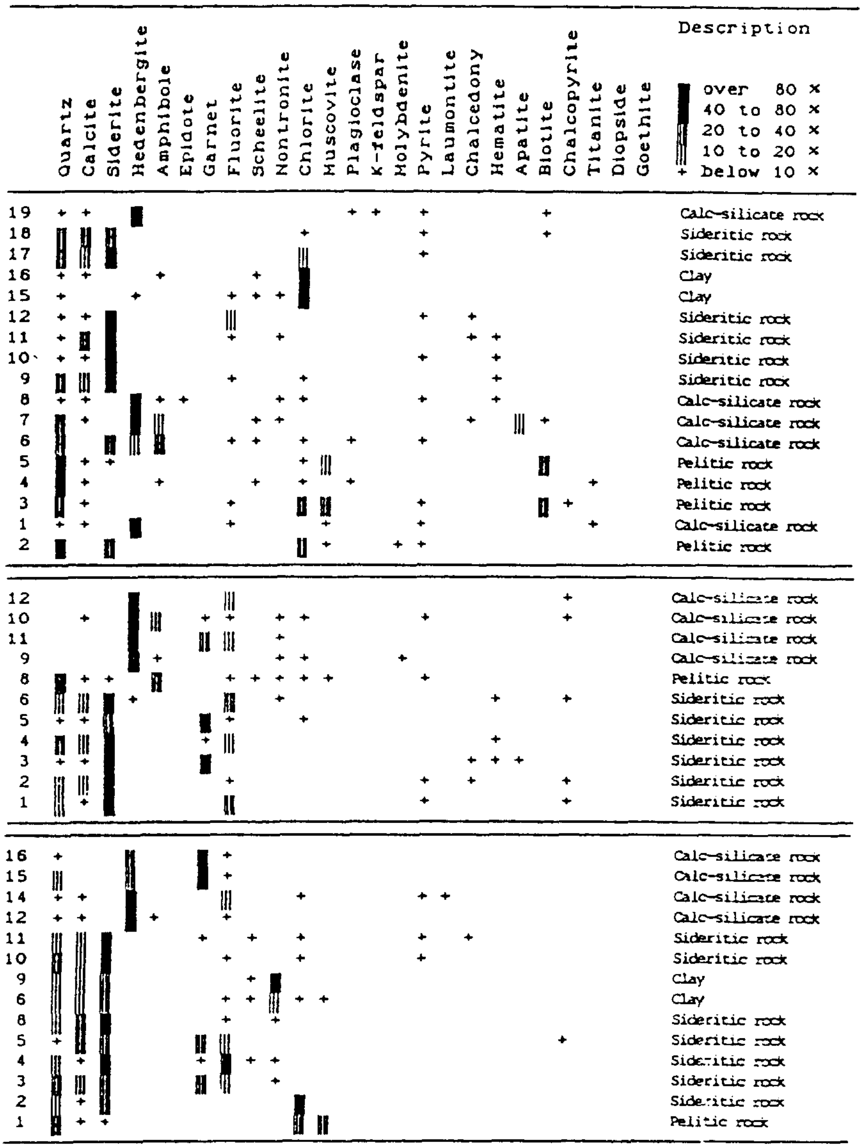
PETROGRAPHY AND MINERALOGY

Siderite occurs in siderostone, sideritic slate and sideritic sandstone. There are two types of siderostones in the area: (1) the siderostone with well-developed stratification (Fig. 3A) and (2) the massive siderostone (Fig. 3B).

The well-stratified siderostone does not occur abundantly, but is easily found in the middle level of the "Main" ore bed (calc-silicate rock) as skarnized relics in a small scale. It consists mainly of siderite and quartz with minor amount of berthierine and fluorite. Berthierine occurs as disseminated oolites or irregular aggregates in the siderostone (Fig. 3D). It is usually microcrystalline.

Fig. 4. Photomicrographs of siderostone. A: Diagenetic transformation of berthierine (BE) into siderite (S) and quartz (Q). F is fluorite. Thin section., B: Recrystallized siderite (RS) in the matrix of cryptocrystalline siderite. SEM photo.

Table 1. Mineralogical compositions of the Hangingwall ore bed of the Sangdong mine, Korea.



A) 6HE36C, B) 5H24B, C) 6W19C

The massive siderostone is found mainly in the "Hanging Wall" ore bed and consists of siderite and quartz with minor amount of berthierine, calcite, apatite and scheelite. Siderite grains are very fine-grained, and partly recrystallized to form rather larger grains (Fig. 4B). Under the microscope, berthierine is replaced by siderite suggesting the diagenetic origin of siderite from berthierine. The rock contains garnet grains in places which were formed by metamorphism. It is usually cut by numerous quartz, calcite and chalcedony veinlets. The mineral compositions of the siderostone and adjacent rocks shown in Table 1.

The massive siderostone of the Hanging wall ore bed shows pseudo-breccia structure, which

Table 2. Electron-microprobe analyses of siderite from the Sangdong mine, Korea.

	407	314-1	314-2
FeO	46.63	50.41	50.65
MnO	3.45	2.44	2.42
MgO	6.52	4.35	4.11
CaO	3.13	3.16	3.25
CO_2	40.28	39.63	39.57
Total	100.00	100.00	100.00

CO_2: by calculation

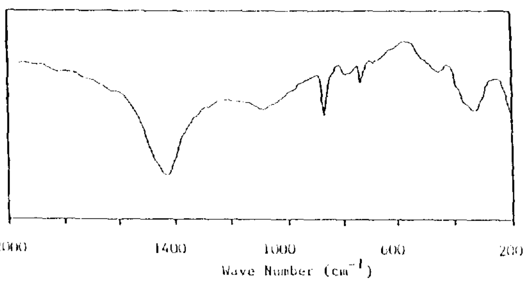


Fig. 5. Infrared absorption spectra of siderite in siderostone from the Sangdong mine, Korea.

was resulted from the filling and partial replace-mobilized neighbouring claystone materials. Similar structure in also found in the neighboring calc-silicate rocks.

Sideritic sandstone is intercalated as thin layers in siderostone (Fig. 3A). Sideritic slate occurs at the contact between slate and siderostone. Siderite occurs usually as tiny crystals. Chemical analyses (for three samples) show that siderite has FeO 46.6 – 50.7 wt. %, MgO 4.1 – 6.5%, CaO 3.1 – 3.3 %, MnO 2.4 – 3.5%, CO_2 39.6 – 40.3 % (Table 2). X-ray diffraction data of siderite are given in Table 3. Unit cell parameters are a = 4.692, c = 15.368 Å. It shows infrared absorption spectral bands at 1419, 868, 735, 455 and 327 cm^{-1} (Fig. 5).

Table 3. X-ray diffraction data of siderite in siderostone from the Sangdong mine, Korea.

I	h	k	l	dcal	dobs
w	0	1	2	3.592	3.605
vs	1	0	4	2.792	2.792
vvw	0	0	6	2.561	2.545
w	1	1	0	2.346	2.332
m	1	1	3	2.133	2.119
m	2	0	2	1.964	1.952
w	0	2	4	1.796	1.787
s	0	1	8	1.737	1.727
	1	1	6	1.730	1.727
vvw	2	1	1	1.528	1.524
w	1	2	2	1.506	1.503
w	2	1	4	1.426	1.422
vvw	2	0	8	1.396	1.393
vw	1	1	9	1.381	1.381
w	3	0	0	1.354	1.352
vw	0	0	12	1.281	1.280
vw	1	2	7	1.258	1.255
vw	0	2	10	1.226	1.227
w	1	2	8	1.200	1.199
	3	0	6	1.197	1.199
vvw	2	2	0	1.173	1.173
vvw	1	1	12	1.124	1.126
vvw	3	1	2	1.115	1.116
w	1	3	4	1.081	1.082
vw	2	2	6	1.066	1.067
vw	4	0	4	0.982	0.983
vw	1	3	8	0.972	0.983
vw	3	2	1	0.930	0.931
vvw	2	3	2	0.925	0.925
a				4.692	
c				15.368	
v				292.97	
c/a				3.28	

DISCUSSION FOR ORIGIN

The nature of chemically precipitated iron minerals within sediments is dependent principally on the pH and Eh condition which are the chief controlling factors for kind and amount of the precipitate (Krumbein and Garrels, 1952). James (1954) and Gross (1965) emphesized that

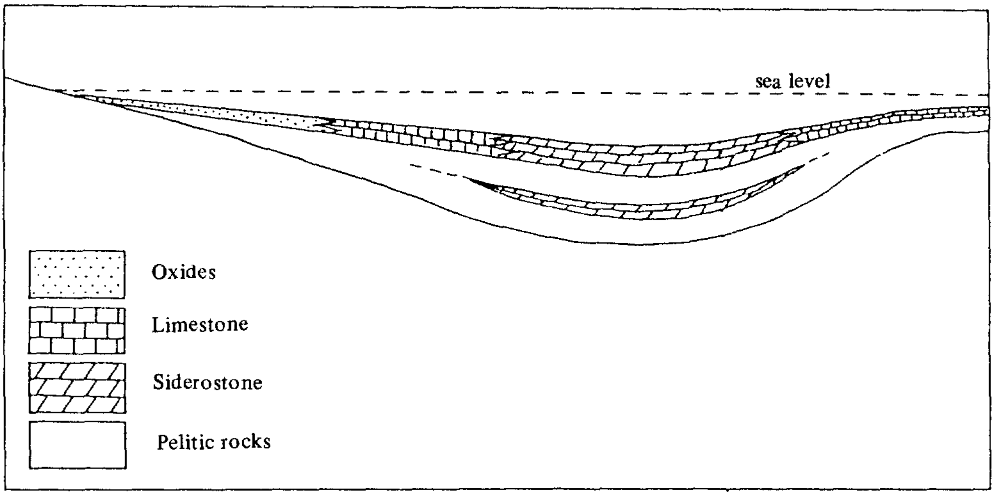


Fig. 6. A schematic drawing showing a probable condition of deposition of the precursor sediments of siderostone and associated rocks of the Myobong Formation in a shallow marine basin.

the composition and mineralogy are closely related to the oxidation state and the depositional environment of the sediment during chemical precipitation. James (1954) separated four distinctive facies of iron formation, namely, oxide, silicate, carbonate and sulfide facies, which were deposited in the perspective order from shallow to deep water within the basin.

Siderostone is bedded in the upper part of the Myobong Slate. It is lenticular in shape, and accompanies claystone and calc-silicate rocks (originally Fe-rich carbonates; i.e., ankerite and dolomite) and limestone. The occurrence supports the sedimentary origin for the formation of siderostone. Evidences supporting a sedimentary origin of the siderostone include :

1. The concordant, stratabound occurrence of siderostone.
2. The well-developed stratified siderostone showing graded bedding.
3. The close association of siderostone with rocks of originally iron-rich claystone, siliceous ankerite, and siliceous ferroan dolomite in the profile.
4. The association of berthierine with siderostone.
5. The presence of low-temperature ore textures such as framboidal texture in pyrite.
6. The absence of epigenetic features.

The localized occurrence of various iron-rich sedimentary rocks including siderostone, siliceous ankerite rock, siliceous ferroan dolostone, and claystone (berthierine-nontronite rock) in association with the tungsten mineralization, suggests that the area was kept in a special environment different from the surrounding areas.

The vast supply of iron coupled with the precipitation of silicate and carbonate phases are the characteristics of the sediments in the Sangdong Mine area. Such an environment is expected in a shallow marine basin where enough organic matter is present to maintain a low Eh. A possible condition of deposition of iron carbonates including siderite and ferroan dolomite in the restricted shallow marine basin is shown in Fig. 6.

It is now widely accepted that iron-formations were deposited as chemical precipitate from silica- and iron-rich gels and small amounts of synsedimentary clay minerals. The original iron formation in the Sangdong Mine area might be composed of iron carbonate, iron silicates and silica. During diagenesis,the iron carbonate and silica recrystallized to microcrystalline carbonate and quartz, and iron silicate mud changed to siderite and quartz. During metamorphism iron carbonate and quartz might have reacted to form clinopyroxene (hedenbergite) if the CO_2 fugacity is reduced. Calcic amphibole might form from ferroan dolomite if the H_2O pressure is high enough and CO_2 fugacity is low during metamorphism

(Klein, 1973). Siderite recrystallized to coarser grained rocks.

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