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COLLOFORM AND FRAMBOIDAL PYRITE FROM THE CARIBOU DEPOSIT NEW BRUNSWICK*

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Abstract

Pyrite masses from the Caribou deposit, New Brunswick, commonly exhibit both colloform and framboidal textures which occur as one of the following: (1) colloform bodies containing discrete inclusions of framboids; (2) colloform bodies and framboids occurring in different parts of the same pyrite mass; and (3) framboidal microcrysts which appear to be related to the constituents of colloform bodies by gradational textural variations. These occurrences suggest that the colloform and framboidal textures were formed by similar processes. Textures intermediate between discrete framboids and disseminated euhedral pyrite crystals are also common. The presence of these intermediate textures, and the close association of framboids and euhedral pyrite crystals, suggest that the framboids in this ore were formed as chemical precipitates.

Sommaire

Les amas de pyrite du gisement Caribou (Nouveau Brunswick) présentent habituellement les textures colloforme et framboïdale que l'on retrouve sous l'une ou l'autre des formes suivantes: (1) des amas colloformes contenant des inclusions discontinues de framboïdes; (2) des amas colloformes et framboïdes dans différentes parties de la même masse de pyrite et (3) des microcristaux framboïdaux qui semblent reliés aux éléments constitutifs des amas colloformes grâce à des transitions texturales. Ces exemples nous laissent supposer que les textures colloforme et framboïdale se sont formées de façon semblable. Le développement habituel de textures intermédiaires entre les framboïdes discontinus et les cristaux disséminés idiomorphes de pyrite et l'association étroite de cristaux de pyrite framboïdes et idiomorphes portent à croire que les framboïdes de ce minerai ont été formés par la précipitation chimique.

(Traduit par la Rédaction)

Introduction

Much has been written about pyrite framboids and colloform textures (*e.g.* Love & Amstutz 1966; Roedder 1968; Kalliokoski & Cathles 1969; Rickard 1970; Kalliokoski 1974; Boctor *et al.* 1976). Despite the common coexistence of the two textures, especially in stratiform massive sulfide deposits, the incorporation of framboids into colloform structures (Rust 1935; Ramdohr 1953; Papunen 1966) is apparently rare.

The mineralogy of the Caribou stratiform massive sulfide deposit, New Brunswick, is being studied in detail, with the work directed towards improving metal recoveries from these fine-grained sulfide ores. The Caribou sulfides commonly exhibit colloform and framboidal textures: of 101 polished sections etched with 1:1 HNO_3, 66 were found to contain framboids, mostly in pyrite-rich ores. Inclusions of framboids in micro-colloform structures are common.

Caribou Deposit

The Caribou deposit is about 50 km west of Bathurst in northern New Brunswick. Three major, en-echelon lenses of massive sulfides form an almost continuous, stratigraphically conformable core zone enclosed within a footwall of graphitic schist and argillite, and a hangingwall of metavolcanic, muscovite schist which are part of the Ordovician Tetagouche Group. The sulfide zone has a combined length of more than 1500 m, and much of it is 25 to 30 m thick. Ore reserves are about 45 million tonnes of 4.5% Zn, 1.7% Pb, 0.47% Cu, and 44 g Ag/t.

The sulfide zone is a steeply plunging synform. The hangingwall contact for the most part sharply abuts the massive sulfides, but there is also some interfingering. In marked contrast, the abundance of sulfides decreases gradually toward the footwall graphitic schist. The matrix within this section of less-abundant sulfides has been recognized by Roscoe (1971) to consist predominantly of metamorphosed tuff and argillite.

Sulfide foliations and micro-foldings are common in specimens from this deposit (Davis 1972). However, some sulfides also show original textures, such as colloform and framboidal textures. Framboidal pyrite had been reported previously

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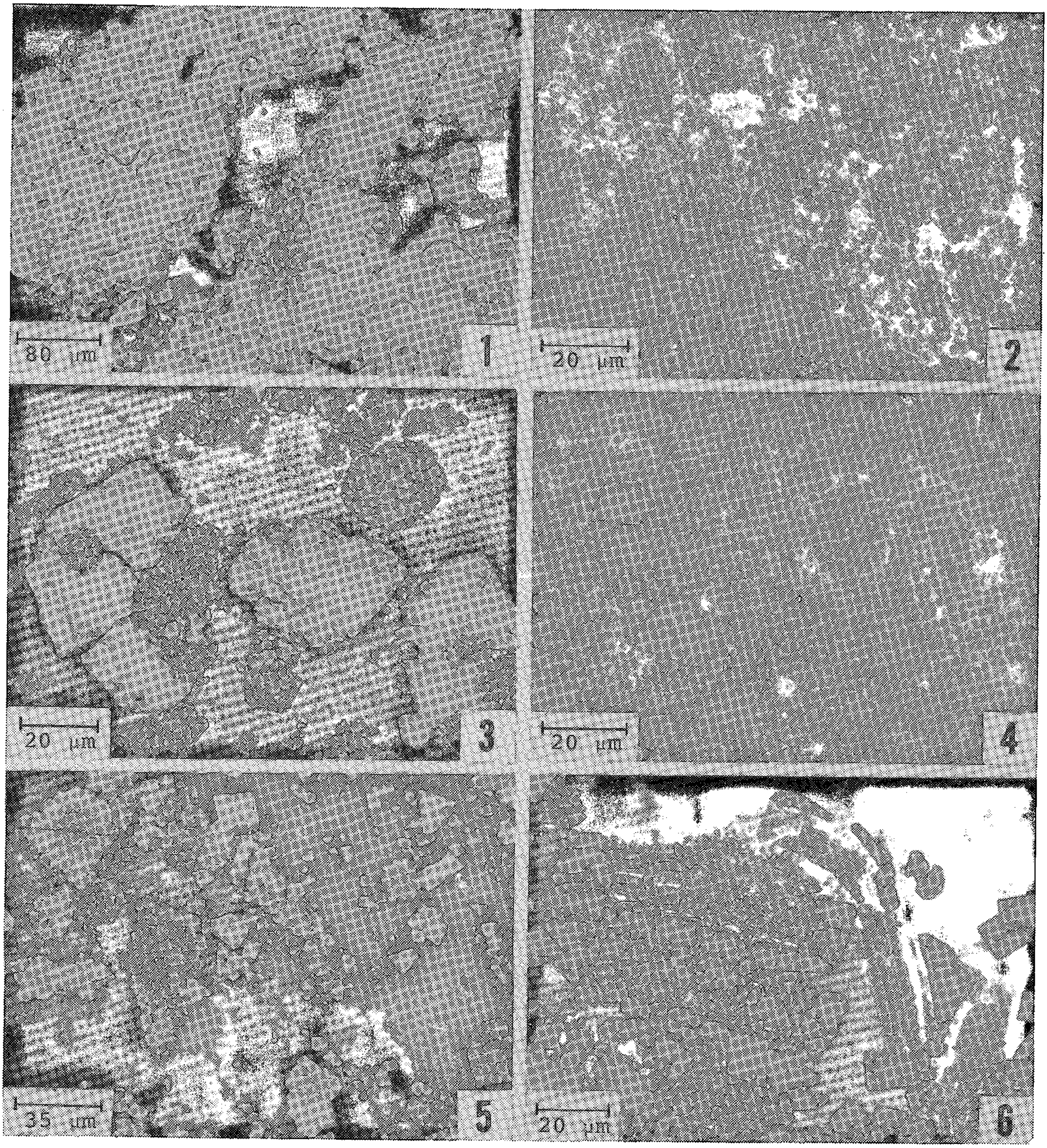

FIG. 1. Colloform pyrite showing rhythmic bands of galena (grey) and chalcopyrite (light grey).

FIG. 2. Pyrite aggregate showing framboidal texture after etching with 1:1 HNO_3. Lower left corner unetched.

FIG. 3. Inclusions of framboids (Chattanooga type) in euhedral pyrite crystals in a chloritic matrix. Etched with 1:1 HNO_3.

FIG. 4. Framboidal aggregate showing overgrowth zones resulting in coarser microcrysts. Etched with 1:1 HNO_3.

FIG. 5. "Euhedral" pyrite crystals showing relict framboidal texture resulting from overgrowth. Matrix is sphalerite (grey) and chlorite (dark). Etched with 1:1 HNO_3.

FIG. 6. Broken fragments of colloform pyrite, with bands of galena and non-sulfides, containing discrete inclusions of framboids in a matrix of sphalerite (grey) and chloritic material (dark). Etched with 1:1 HNO_3.

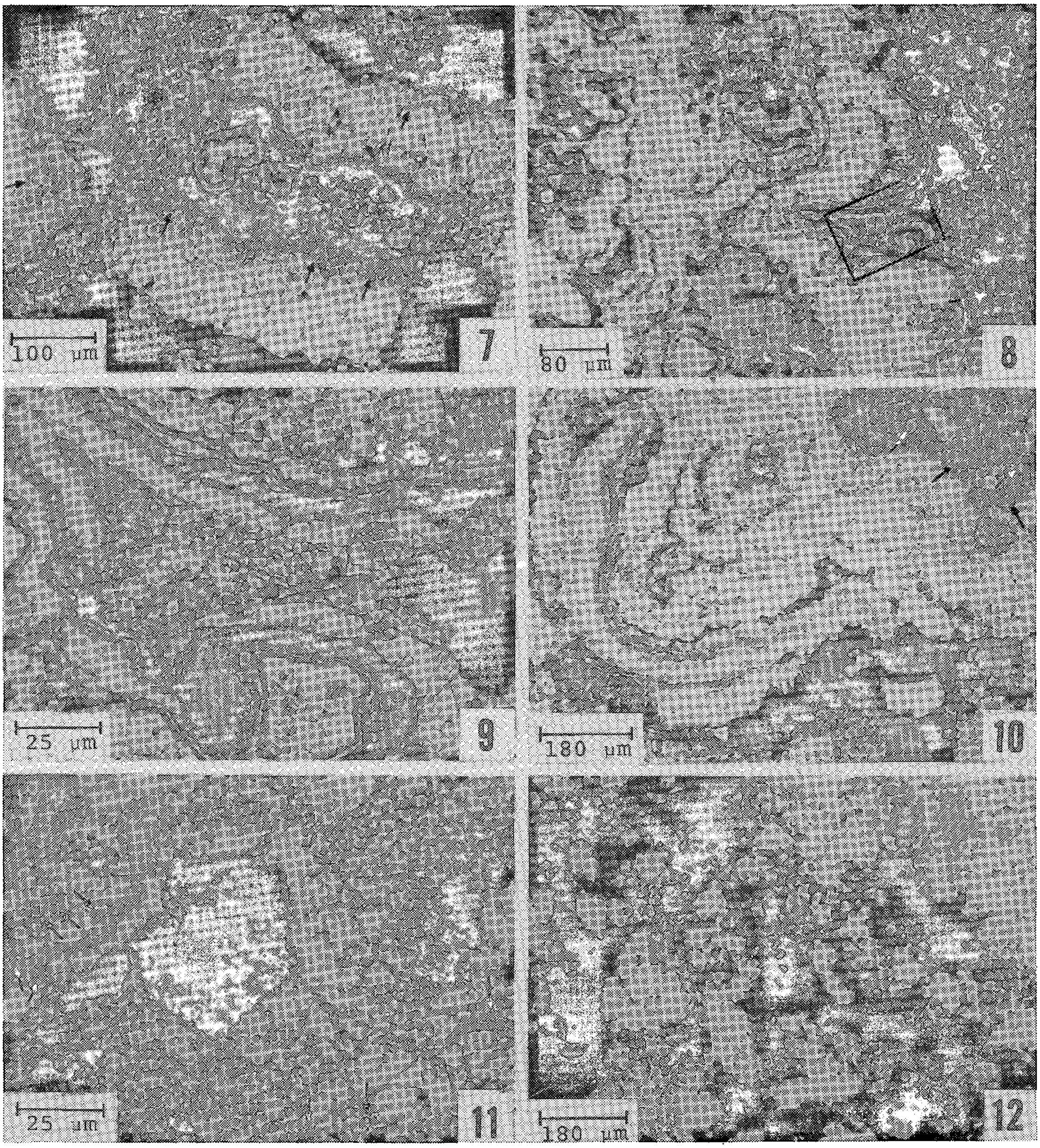

FIG. 7. Reniform pyrite (with zones of galena, chalcopyrite, and a non-sulfide mineral) also showing framboidal texture (marked). Etched with 1:1 HNO_3.

FIG. 8. Colloform and framboidal (marked, the whole zone on the right margin) textures occurring in different parts of the same pyrite mass, possibly implying coeval and closely related formation mechanisms for the two textures. Etched with 1:1 HNO_3.

FIG. 9. Colloform pyrite containing framboids and carbonate mineral (dark zones, dissolved). Enlarged from part of Figure 8.

FIG. 10. Colloform texture showing coarser peripheral euhedral crystals, and also showing framboids (marked, upper right corner) within the colloform body. Etched with 1:1 HNO_3.

FIG. 11. Part of a colloform structure consisting of intergrowth of chalcopyrite (main light grey matrix) and pyrite (microcrystals). Colloform structure contains framboids (marked) and shows gradational textural variations between framboidal microcrysts and the constituents (*i.e.* pyrite microcrystals) of the colloform body. Carbonate (dark, dissolved), sphalerite (grey). Etched with 1:1 HNO_3.

FIG. 12. The non-framboidal, extremely fine-grained pyrite aggregates show subrounded gross outlines and dusty appearances resembling those of framboids. Sphalerite (grey), silicates (dark).

by Roscoe (1971) and Davis (1972). According to Davis, deformed pyrite framboids parallel the foliation. The colloform bodies reported in the present study are usually in brecciated fragments in the ore.

Colloform and Framboidal Textures

Pyrite is the principal constituent of the colloform bodies, but bands of galena, chalcopyrite, sphalerite, and silicates are also common (Fig. 1). Some colloform bodies consist of extremely fine-grained chalcopyrite and pyrite intergrowths which alternate with bands of silicates; other colloform bodies consist of: (a) rhythmic bands of sphalerite and chalcopyrite; (b) magnetite with discontinuous concentric bands of pyrite; (c) translucent gangue minerals with rhythmic zones either of chalcopyrite or of gangue minerals. The colloform texture of some pyrite is evident simply because of systematic variations in pyrite grain sizes. Coarser, euhedral pyrite crystals occur at the peripheries of some colloform bodies. In a few cases, colloform bands are interrupted by euhedral magnetite or arsenopyrite inclusions, but there is no distortion of the enveloping bands.

Much of the pyrite in the ore zone at Caribou consists of microscopically dusty aggregates in which framboids are visible after etching (Fig. 2). Framboids commonly occur as aggregates in matrix of sphalerite, silicates (chlorite?) and, less commonly, in chalcopyrite. Clusters and irregular bands of framboids occur in some massive pyrite. Some disseminated pyrite microcrystals (5-15 μm) have relict framboidal cores; other framboids occur as discrete spheroids in a matrix of chlorite or within euhedral magnetite and pyrite (Fig. 3).

Although framboids up to 90 μm in diameter have been observed, most are 5 to 30 μm. Each consists of numerous approximately equidimensional polyhedral microcrysts, usually less than 1 μm though some framboids have microcrysts up to 4 μm. The arrangement of the microcrysts within framboids varies from random, linear, or polygonal to concentric. The interstices between microcrysts, seen after etching, are filled with pyrite. In the same polished sections, some framboids appear as discrete spheroids and have ordered internal arrangements similar to the Chattanooga type reported by Love & Amstutz (1969), whereas others have an outer zone of coarser, elongate microcrysts, corresponding to the Plotz-Antachajra type (Love & Amstutz 1969). The former type is more abundant. However, gradational textural variation is common between the two types. Some framboids have overgrowths of coarser microcrysts, broader inter-microcryst spaces (Fig. 4), or a brownish rim (seen after etching) around the outermost zone of microcrysts. Other framboids are grossly "euhedral" in outline, with a relict framboidal texture (Fig. 5). The textures observed are, in general, similar to those reported by Love & Amstutz (1966, 1969), Kalliokoski & Cathles (1969), Davis (1972) and Ostwald & England (1977).

The micro-colloform structures and framboids from the Caribou deposit commonly are associated as one of the following: (1) colloform bodies containing discrete inclusions of framboids (Fig. 6); (2) colloform bodies and framboids occurring in different parts of the same pyrite mass (Figs. 7, 8, 9, 10); and (3) framboidal microcrysts which appear to be related to the constituents of colloform bodies by gradational textural variations (Fig. 11). The inference from these occurrences is that the colloform and framboidal textures were formed approximately coevally by similar and closely related processes.

Discussion

Pyrite framboids are common constituents in organic-rich sediments that range from Precambrian to Recent. The possible biogenic origin of framboids has been discussed by many writers; although there is evidence that some framboids may be fossils (Neves & Sullivan 1964; Honjo *et al.* 1965; Javor & Mountjoy 1976), framboidal pyrite has also been formed by purely inorganic synthesis (Berner 1969; Farrand 1970; Sunagawa *et al.* 1971; Sweeney & Kaplan 1973).

Electron probe analyses indicate that framboidal aggregates (Fe 46.7, S 53.5 and As 0.2 wt. %) from the Caribou deposit have the same chemical composition as the adjacent coarser euhedral pyrite crystals. However, the original compositions of framboids were not necessarily FeS_2, and microcryst shapes do not necessarily represent original forms, particularly since some of the ore shows effects of metamorphism (Roscoe 1971; Davis 1972). The presence of framboidal inclusions in pyrite crystals or colloform bodies might suggest that the framboids are fossils (Figs. 3, 6). However, according to Love & Amstutz (1966), the internal arrangement of framboids is usually crystallographic and does not conform with the structure of any known bacterial cell or colony. In addition, the inclusions may indicate only that the framboids formed slightly earlier than the other pyrite tex-

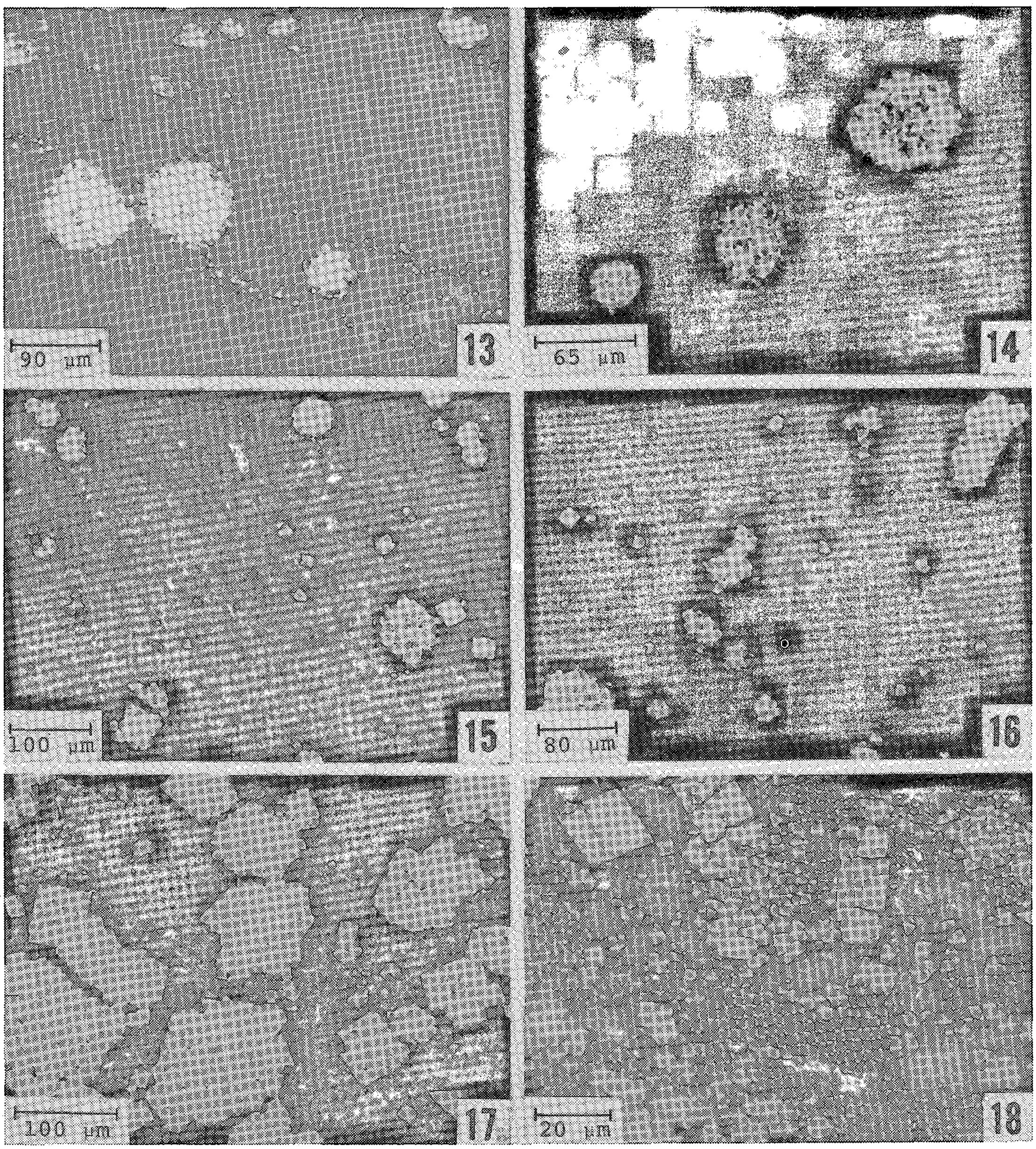

FIG. 13. Framboidal pyrite and disseminated pyrite crystals in a matrix of metasediment. The close association suggests that the framboidal microcrysts and the disseminated pyrite microcrystals were formed by the same process.

FIG. 14. Pyrite microcrystals showing textural variations from framboidal to non-framboidal aggregations in a matrix of metasediment.

FIG. 15. Pyrite microcrystals showing textures from framboid-like aggregates to "euhedral" aggregates, in a matrix of metasediment.

FIG. 16. Pyrite microcrystals showing non-framboidal aggregations in a matrix of metasediment.

FIG. 17. "Euhedral" aggregates of pyrite with numerous sericite(?) "inclusions" in a matrix of metasediment.

FIG. 18. Pyrite showing intermediate texture between framboids and euhedral crystals in a matrix of sphalerite. Etched with 1:1 HNO_3.

tures, a case similar to that reported by Papunen (1966). The following textural relationships imply chemical precipitation: (1) in the ore zones, some extremely fine-grained pyrite aggregates, with subrounded gross outline and dusty appearance, resemble those of framboids; however, etching reveals that the aggregates are non-framboidal, irregular grains (Fig. 12). (2) Nearly all micro-colloform structures in this ore are associated with framboids. In addition, some framboidal microcrysts and the constituents of colloform bodies appear to be related by gradational textural variations (Fig. 11). (3) Disseminated euhedral pyrite crystals usually occur within a few μm from discrete framboids; textures intermediate between these two types are common. The intermediate textures suggest similar formation mechanisms for (a) the framboidal microcrysts and the disseminated pyrite microcrystals (Figs. 13, 14); (b) the framboid-like pyrite microcrystal aggregates and the "euhedral" aggregates of pyrite microcrystals (Figs. 15-17); (c) the framboid-rich layer and the pyrite microcrystal-rich layer, commonly related to each other by gradational textural variation; and (d) the coarser euhedral pyrite crystals and the fine-grained pyrite microcrystals (Fig. 18).

Recrystallization of framboids might result in the formation of single euhedral pyrite crystals (Love & Amstutz 1966). In the Caribou deposit, some disseminated euhedral pyrite microcrystals (5-15 μm), which occur in thin lenses or lamellae, have relict framboidal cores. Other framboids have overgrowths (or recrystallization?) textures distinguishable either by growth zones (seen after etching) around microcrysts (Fig. 4), or by a compact outer zone of coarser elongated microcrysts which form a "euhedral" gross outline (Fig. 5). The original textures (Figs. 15, 16, 18) described above show loosely packed equidimensional microcrystal aggregates with "euhedral" gross outlines, both before and after etching. The close association of disseminated euhedral pyrite crystals and framboids (Figs. 15, 16, 18) indicates that these disseminated euhedral pyrite crystals are original textures. Consequently, textural relationships (1) to (3) above are considered to indicate that the framboids in this ore were formed by chemical precipitation. The framboids in colloform pyrite might be formed by colloidal precipitation (Rust 1935; Ramdohr 1953; Papunen 1966). However, colloform and framboidal textures also crystallize from supersaturated solutions (Roedder 1968; Farrand 1970).

Within a few millimeters of the framboids and pyrite crystals in a chloritic matrix are some marcasite, needle-like rutile and ilmenite crystals. Marcasite is generally considered to be stable, and Ti to be mobile, only in acidic environments, whereas framboidal pyrite is usually synthesized in neutral or slightly alkaline environments. Boctor *et al.* (1976) suggest that the coexistence of marcasite and framboidal pyrite is probably due to non-equilibrium or local heterogeneity of the chemical environment. An indication that this type of environment may have existed for the Caribou ore is that native iron has been found with pyrite, magnetite and ilmenite in a silicate matrix in the ore zone.

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