TEXTURES OF THE UNGAVA NICKEL ORES

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ABSTRACT

The nickel deposits of the Cape Smith – Wakeham Bay Belt have been formed by the selective replacement of ultrabasic rocks (and to a minor degree sediments). The replacement began soon after the commencement of serpentinization of the ultrabasics. Sulphides of iron, nickel, and copper replaced unaltered portions of the olivine and pyroxene but none of the alteration minerals, such as serpentine and amphibole. The textures exhibited by the sulphides, therefore, are those normally associated with the silicate minerals of basic igneous rocks. The mineralization probably originated from the serpentinization of olivine and pyroxene which contained small amounts of copper and nickel.

The hypothesis of Wager, Vincent, & Smales (1957), which claims that nickeliferous pyrrhotite deposits are the product of basic magma in which the sulphur pressure was high enough during the early stages of crystallization to cause the nickel to form sulphides rather than entering olivine and pyroxene, does not seem to apply to the nickel deposits of the Cape Smith – Wakeham Bay Belt.

INTRODUCTION

The northern part of the Ungava peninsula, frequently referred to as the Cape Smith – Wakeham Bay Belt, was known as early as 1932 to contain copper and nickel mineralization. However, it was not until 1955 that extensive prospecting began, and by 1957, thirty-two companies had obtained mineral exploration licences. The search for ore was carried on throughout the entire length of the belt and many high-grade copper-nickel deposits were found. Unfortunately all of these were too small to be of economic value, and by 1958 the interest in this remote part of Quebec had decreased to such an extent that only three of the thirty-two companies which had been there during the previous year returned to continue their work.

Although these deposits are not of great economic importance at the present, they are extremely interesting to the student of ore deposits since they exhibit a unique case of selective replacement. The textures observed in the "ores" are not those normally associated with sulphides, but rather with the silicate minerals of basic igneous rocks. The reason for this is that the replacement of the original igneous rock by the sulphides was so selective that most of the primary textures have been preserved in the "ore." The object of this paper is to describe these textures found in the Ungava nickel "ore."

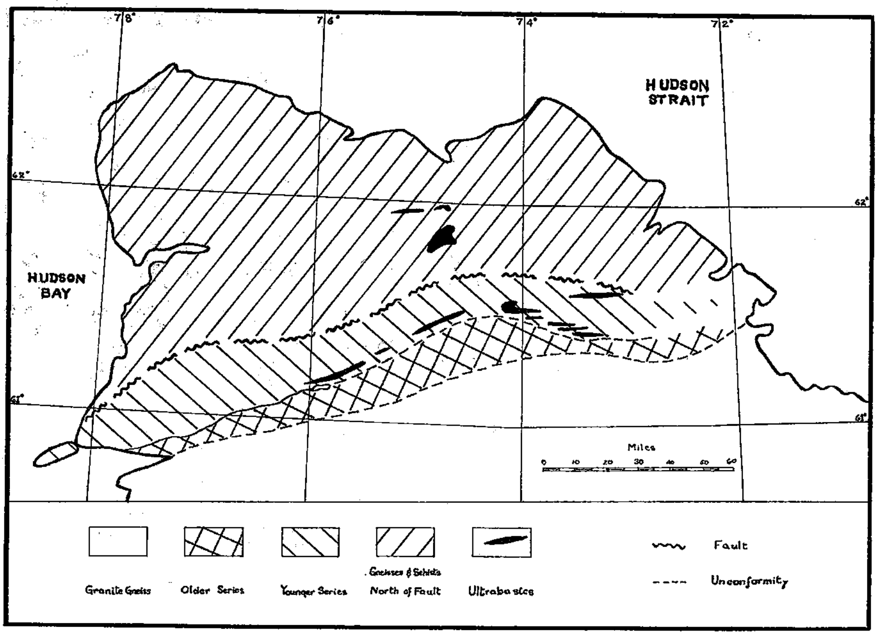
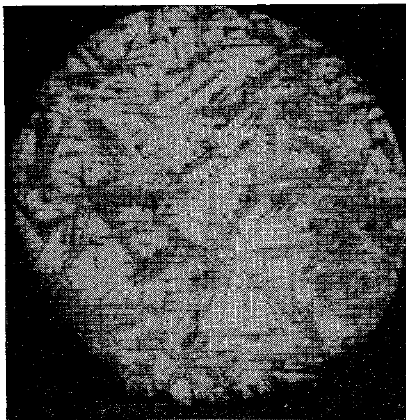


FIG. 1. Cape Smith – Wakeham Bay Belt. After Bergeron 1957.

GENERAL GEOLOGY

The Cape Smith – Wakeham Bay Belt is underlain by a great thickness of rocks which are probably of late Precambrian age. These are divisible into three main groups, each of which forms a broad belt extending from Hudson Bay across the peninsula to Hudson Strait (Fig. 1). The oldest group consists of tightly folded metamorphosed sediments and volcanics, which rest unconformably to the south on the Archean granites. The rocks of this series are unconformably overlain to the north by a younger series which is composed almost entirely of pillowed basalt and a few sill-like bodies of serpentinite. It is with these ultrabasic rocks that the nickel deposits are associated. The rocks of this series are truncated to the north by a thrust fault which extends from Hudson Bay across to Hudson Strait, to form what is probably one of the most prominent "breaks" in the Province of Quebec. To the north of this fault is a great thickness of metamorphic rocks, which grade from chlorite schists near the fault to amphibolites and associated rocks along the coast (Bergeron 1957, 1959; Beall 1959).

The ultrabasic rocks with which the nickel deposits are associated occur at the base of the younger series in large sill-like bodies some of which are many tens of miles long and up to several hundred feet thick.



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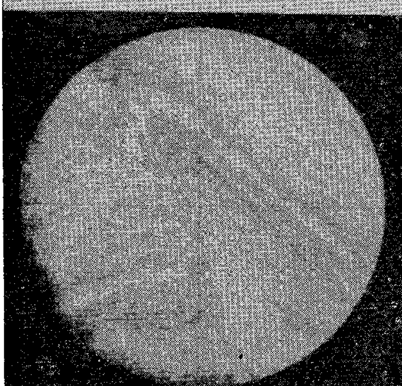

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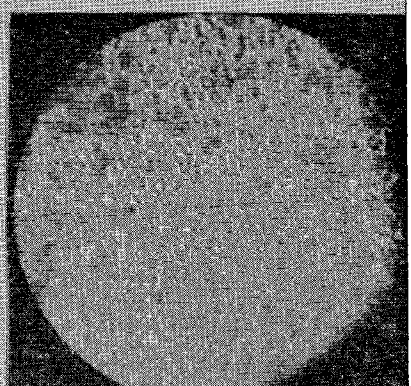

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They are nearly always composed entirely of serpentine and rarely contain any of the primary igneous minerals, such as olivine and pyroxene. These masses of rock are probably extrusive rather than intrusive, simply being extremely basic phases of the normal olivine basalt, which is by far the most abundant rock type of this series.

Nickel Deposits

The nickel deposits are of the replacement type, usually occurring at the base of the serpentinite sheets, where they form small tabular bodies of sulphides. However, a few deposits have been found in sedimentary rocks close to the ultrabasics. The details of these two particular types of occurrence will be discussed later.

The "ore" is composed predominantly of nickeliferous pyrrhotite, pentlandite, and chalcopyrite in a gangue of serpentine, chlorite, magnetite, and amphibole. Pyrrhotite is the most abundant metallic mineral. However, when observed more closely, it can often be seen to contain large amounts of exsolved pentlandite. Chalcopyrite, although not as abundant as the other sulphides, is nearly always present. Magnetite is only a minor constituent, and is actually associated with the original igneous rock and its alteration products rather than with the sulphides. In general, the different minerals occur as separate grains, rarely showing any cross-cutting relationships, which makes it very difficult to determine their paragenesis.

As previously mentioned, the nickel deposits occur in two different rock types. The replacement deposits in the ultrabasic rocks are the most abundant and economically the most important, and will therefore be described first. Of lesser importance, because of their lower copper and nickel content, are those deposits which have been formed by the replacement of sediments close to serpentinite bodies.

Fig. 2. Pyrrhotite (white) containing oriented inclusions of anthophyllite (grey) (x 340, reflected light).

Fig. 3. Pyrrhotite (light grey) containing exsolution lamellae of pentlandite (white) and oriented inclusions of anthophyllite (black) (x 340, reflected light).

Fig. 4. Pyrrhotite and chalcopyrite (white) pseudomorphous after partially serpentinized olivine. Magnetite (light grey) is in the centre of the small veins of serpentine (grey) (x 120, reflected light).

Fig. 5. Sulphides (black) pseudomorphous after grains of olivine and pyroxene. Note the rims of serpentine (white) that surround the replaced olivine grains (x 375, transmitted light).

Fig. 6. Selective replacement of sediments (black) by pyrrhotite (white). Note fault (x 30, reflected light).

Fig. 7. Grains of pyrrhotite (grey) rimmed by pentlandite (white). Unreplaced sediment is black. This exsolution texture was brought out by etching with nitric acid fumes (x 120, reflected light).

Replacement of Ultrabasics

The deposits in the ultrabasics were formed by sulphides of copper, nickel, and iron which replaced pyroxene and olivine, but none of the secondary minerals, such as serpentine and anthophyllite. The evidence suggesting this comes from the textures found in the "ore."

The most common texture observed in these deposits is found where sulphides have replaced pyroxene. Figure 2 is a typical example of this, showing the oriented inclusions of anthophyllite, which are nearly always present in the sulphides which have replaced pyroxene. These inclusions can be oriented in as many as four different directions, none of which appear to bear any relationship to the crystallography of the sulphides in which they occur. This conclusion is drawn from two facts. Firstly, the relationship between the orientation of inclusions and the cleavage of the host sulphide appears to be completely variable; and secondly the directions of oriented inclusions of anthophyllite frequently extend across grains of different sulphides without being changed.

A few samples were examined in which pyroxene was found to be only partially replaced by sulphides. In these particular cases the oriented inclusions of anthophyllite which were present in the sulphides continued right into the pyroxene. Here the directions of orientation could plainly be seen to be related to the crystallography of the pyroxene, with two sets of inclusions being parallel to the cleavage and the other two sets bisecting the angle between the cleavage. The four different sets of anthophyllite inclusions seen in Figure 2, therefore, reflect the crystallography of the pyroxene that was replaced by the sulphides.

It appears from this texture that before the pyroxene was replaced by the sulphides it had already begun to alter to anthophyllite. This alteration took place along certain crystallographic directions in the pyroxene, and had it gone to completion would have resulted in the typical "bastite" structure found in some ultrabasic rocks. However, before this could take place, sulphides replaced the remaining pyroxene, but at the same time retained the oriented inclusions of anthophyllite. Where no sulphides were introduced the pyroxene was entirely converted to secondary minerals. This is suggested by the fact that fresh pyroxene and olivine are rarely found in the ultrabasic rocks of the Cape Smith – Wakeham Bay Belt.

Sulphides that have replaced pyroxene usually have the highest content of pentlandite of all the "ores," sometimes containing as much as 50%. The pentlandite occurs as exsolution lamellae within pyrrhotite and particularly against the inclusions of anthophyllite (Fig. 3).

Sulphides also occur as replacements of olivine in the Ungava nickel "ore." The textures indicating this are a little easier to interpret than those formed by the replacement of pyroxene. Figure 4 shows a typical example of a partially altered olivine crystal which has been replaced by sulphides. Sulphides which have replaced olivine occur as small irregular masses, which are usually separated from one another by veins of serpentine containing magnetite in their centres. Frequently the sulphides still retain the shape of the original olivine crystal as is shown in Fig. 4.

In all the cases where sulphides were found to have replaced olivine the veins of serpentine were always present. It therefore appears, just as in the case of the pyroxene, that alteration of the olivine had already commenced before the replacement by sulphides began. The alteration took place along fractures in the olivine grains, with the formation of veins of serpentine containing shreds of magnetite along their centres. These veins would normally have become wider until they finally consumed the entire grain, leaving behind a mass of serpentine and magnetite which may or may not have retained the shape of the original grain. However, before this took place, sulphides replaced the remaining olivine, producing textures such as those shown in Fig. 4. In places the olivine was completely serpentinized and no sulphides were introduced.

In this type of "ore" pyrrhotite and chalcopyrite usually occur as individual grains replacing different parts of the olivine crystal; and therefore, are usually separated by a band of serpentine. This makes the determination of their paragenesis difficult. However, it appears that the pyrrhotite might be slightly older than the chalcopyrite. The nickel values for this type of rock are due mainly to pentlandite, which occurs as grains having a similar habit to pyrrhotite and chalcopyrite. It was not possible to determine whether the pentlandite replaced the original olivine, or some other sulphide which had previously replaced the olivine. A small amount of pentlandite occurs as flame-like borders around the pyrrhotite.

An interesting texture is found where both olivine and pyroxene have been replaced in the same rock by sulphides. This is shown in Fig. 5. The replaced olivine is outlined by a rim of serpentine, which radiates out into the surrounding sulphides, which are pseudomorphous after pyroxene. The sulphides which replaced pyroxene contain the oriented inclusions of anthophyllite. The reason the serpentine forms rims around the replaced olivine grains is probably that the grains were not fractured and therefore the alteration took place from the grain boundaries inwards.

Replacement of Sediments

As mentioned previously, some nickel deposits occur in sedimentary rocks close to ultrabasic rocks. This particular type of mineralization can usually be found to be related to shear zones that cut the ultrabasic rocks. This has produced channelways along which the sulphides could travel. The replacement of the sediments took place selectively, preserving the original stratification of the sediments. Figure 6 shows the selective nature of the replacement and the association of this type of mineralization with faults.

Pyrrhotite is the most abundant sulphide in this type of deposit, and with minor amounts of exsolved pentlandite makes up the bulk of the "ore." Chalcopyrite is present only in very minor quantities. The pyrrhotite occurs as small anhedral grains which are frequently rimmed with pentlandite (see Fig. 7). The borders of pentlandite usually extend a short distance into the grains of pyrrhotite in a flame-like fashion. Where chalcopyrite is present it is found to have replaced pyrrhotite along grain boundaries. Since the pentlandite was exsolved against the chalcopyrite, the paragenesis must be pyrrhotite replaced by chalcopyrite, followed by the exsolution of pentlandite.

Summary and Conclusions

The nickel deposits of the Cape Smith – Wakeham Bay Belt are associated with ultrabasic rocks which occur in a narrow belt extending across the Ungava peninsula from Hudson Bay to Hudson Strait. The deposits are of the replacement type, usually occuring within the ultrabasic rocks where they form small tabular bodies of sulphides. In a few cases mineralization has taken place in sedimentary rocks close to the ultrabasics. The "ore" is composed predominantly of nickeliferous pyrrhotite, pentlandite, and chalcopyrite in a gangue of serpentine, chlorite, magnetite, and amphibole.

Within the ultrabasic rocks the sulphides replaced only olivine and pyroxene, and the alteration minerals such as serpentine and amphibole remained unchanged. Because of the selective nature of the replacement, nearly all of the textures observed in the sulphides are those normally found with silicate minerals. Since both the olivine and pyroxene had been partially altered before mineralization took place, the sulphides contain the alteration products characteristic of the silicate they replaced. Hence, sulphides which have replaced pyroxene contain sets of anthophyllite inclusions, which correspond to crystallographic directions in the pyroxene along which alteration took place. Those sulphides which have replaced olivine contain the irregular veins of serpentine which are so characteristic of partially altered olivine crystals.

The deposits in sedimentary rocks can usually be found to be related to shear zones which connect them with bodies of ultrabasic rock. The replacement took place selectively and by so doing preserved the original stratification of the sediment. The type of "ore" usually found in these deposits is composed of pyrrhotite rimmed with exsolved pentlandite.

There can be no doubt, from the textures exhibited by the ores, that alteration of the primary igneous minerals had already begun before mineralization took place. Also, since fresh olivine and pyroxene are rarely found in the Cape Smith – Wakeham Bay Belt, it is reasonable to assume that the alteration of the ultrabasic rocks went to completion. Therefore, mineralization must have begun soon after the onset of serpentinization and might have continued as long as there was fresh olivine and pyroxene available for replacement.

It is not possible to say whether or not the sulphides were introduced as hydrothermal solutions. However, the close association in time of the mineralization and the serpentinization suggests that water may have played an important role in the transportation of the mineralizers. The fact that the anhydrous silicates were the only ones to be replaced also supports this hypothesis.

The source of the sulphides was probably the ultrabasic rock in which the nickel deposits occur. There are no signs in this rock of any primary sulphides from which the mineralization could have come. However, copper, nickel, and iron might originally have been present in the olivine and pyroxene, and then with the beginning of serpentinization these elements could have been liberated and made available to form sulphides. This would agree with the observation that the alteration of the olivine and the pyroxene had already begun before the mineralization took place.

The fact that the copper, nickel, and iron did not originally combine with sulphur might possibly have been due to a low sulphur pressure during the early stages of crystallization. By the end of crystallization the sulphur pressure might have become high. However, by this time the copper, nickel, and iron would have been incorporated in the silicates, and would not have become available to form sulphides until serpentinization began.

Wager, Vincent, & Smales (1957, p. 891) have used similar reasoning in explaining the low nickel content of the sulphides of the Skaergaard intrusion in east Greenland. Here apparently the sulphur pressure was sufficiently low during the early stages of crystallization to cause the nickel to enter the olivine and pyroxene instead of forming sulphides.

As a corollary of this hypothesis, Wager *et al.* make the statement that "nickeliferous pyrrhotite ore deposits are the product of basic magma initially richer in sulphur than the Skaergaard magma." This statement is only true when applied to ore bodies which are magmatic. The Ungava nickel deposits are composed of nickeliferous pyrrhotite, but they show no evidence whatsoever that they formed before the crystallization of the silicates under the effect of a high sulphur pressure. Instead it appears that sulphur and sulphides were not in any great abundance until at least the end of the crystallization of the ultrabasic rock.

In conclusion it can be said that the general veracity of the statement made by Wager *et al.*, concerning nickeliferous pyrrhotite deposits, will depend on whether most occurrences of this kind are magmatic or not. Those of northern Ungava are definitely not magmatic.

There are undoubtedly other nickel deposits in ultrabasic rocks that have had a similar origin to those of the Cape Smith – Wakeham Bay Belt. However, if the replacement was not quite as selective it might have been more difficult and perhaps impossible to interpret the textures exhibited in the ore. It is hoped therefore, that these Ungava nickel "ores" will serve as an example of a type of replacement to be expected in ultrabasic rocks.

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