

# Contribution to the Mineralogy of the Arthur Point Rhodonite Deposit, Southwestern British Columbia

By Z.D.Hora<sup>1</sup>, A.Langrova<sup>2</sup> and E.Pivec<sup>3</sup>

**KEYWORDS:** *rhodonite, sedimentary manganese minerals, chert, braunite, pyroxmangite, metamorphism, replacement mineralization*

## INTRODUCTION

The Arthur Point rhodonite deposit near Bella Coola has been known since 1982, when discovered by the prospector Tony Karup. The property was later described by Hancock (1992). This paper expands upon the information presented in Hancock's description.

Rhodonite is exposed on the shoreline of a small peninsula in two outcrops some 200 m apart, separated by 150 m of heavy vegetation cover.

The rhodonite occurs as stratabound zones within a unit of chert and argillaceous chert several hundred metres thick. While most of the rhodonite outcrop exhibits massive, fine-grained banding in a yellow-green chert, locally along the footwall of the main zone there is a lenticular band, up to 10 cm thick, containing irregular lenses and bands of a metallic-looking mineral, mostly surrounded by pink-coloured rims of manganese silicates (Fig. 1).

## ANALYTICAL PROCEDURES

Mineralogy was investigated using optical microscopy, X-ray powder diffractometry and electron microprobe techniques at the Institute of Geology Academy of Science of the Czech Republic in Prague.

Mineral analyses were made with a CAMECA SX-100 electron microprobe using the wavelength dispersive technique. The beam diameter was 10  $\mu$ m with an accelerating potential of 15 kV; a beam current of 20 nA was measured on a Faraday cup. A counting time of 10 s was used for all elements. The standards employed were synthetic SiO<sub>2</sub>, TiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub> and MgO, and natural jadeite, leucite, apatite, diopside, spinel (all K) and barite (L). The data were reduced using the X-PHI correction. Total Mn and Fe



Figure 1. Sample of chert with braunite lenses and rhodonite-pyroxmangite rims.

are given as MnO and FeO (Table 1), although small amounts of Mn<sub>2</sub>O<sub>3</sub> and Fe<sub>2</sub>O<sub>3</sub> cannot be excluded.

Mineral phases were also identified by X-ray diffraction, using a Phillips X'Pert APD (automatic powder diffractometer), employing CuK $\alpha$  radiation and graphite monochromator. The following conditions were employed: scanning speed 1  $^{\circ}$ /min, generator voltage 40 kV and current 40 mA.

<sup>1</sup> British Columbia Geological Survey (retired)

<sup>2</sup> Geological Institute, Academy of Sciences of the Czech Republic, Prague, Czech Republic

<sup>3</sup> Geological Institute, Academy of Sciences of the Czech Republic, Prague, Czech Republic (retired)

TABLE 1. REPRESENTATIVE ANALYSIS OF MINERALS FROM THE ZONE RIMMING BRAUNITE LENSES IN  
CHERT, ARTHUR POINT, BRITISH COLUMBIA.

	Braunite			Rhodonite				Pyroxmangite				K-feldspar				Albite
	6	19	18	11	5	12	26	8	4	13	15	9	16	22	17	21
SiO <sub>2</sub>	10.45	10.30	10.12	46.30	46.46	45.97	46.39	48.47	49.48	48.79	49.44	64.12	64.38	63.05	64.67	68.66
TiO <sub>2</sub>	0.04	0.04	0.17	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Al <sub>2</sub> O <sub>3</sub>	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.02	18.33	18.27	18.43	18.36	19.68
Cr <sub>2</sub> O <sub>3</sub>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.05	0.00
V <sub>2</sub> O <sub>3</sub>					0.00	0.00		0.00	0.01			0.01				
FeO	0.03	1.21	1.05	0.02	0.00	0.00	0.00	0.00	0.00	0.08	0.09	0.09	0.04	0.00	0.00	0.03
MgO	0.01	0.00	0.00	0.15	0.29	0.15	0.07	0.38	0.58	0.34	0.13	0.00	0.01	0.00	0.00	0.01
MnO	82.07	78.12	79.22	49.72	48.42	49.79	50.84	45.75	45.22	45.63	45.36	1.08	0.87	0.69	0.63	0.19
CaO	0.05	0.20	0.89	3.39	5.04	3.78	3.77	0.96	1.37	0.97	0.82	0.02	0.00	0.00	0.00	0.00
ZnO	0.00	0.00	0.04	0.00			0.06			0.01	0.04		0.01	0.00	0.07	0.00
BaO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.02	0.57	0.33	1.57	0.15	0.03
Na <sub>2</sub> O	0.01	0.01	0.00	0.00	0.03	0.01	0.04	0.95	1.01	0.93	0.97	0.48	0.54	0.52	0.49	11.42
K <sub>2</sub> O	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	16.14	15.96	15.60	15.89	0.16
Rb <sub>2</sub> O	0.04	0.00	0.00	0.00			0.01	0.00		0.00	0.00		0.02	0.08	0.00	0.00
Total	92.70	89.90	91.50	99.59	100.29	99.71	101.20	96.56	97.68	96.75	96.88	100.84	100.42	99.97	100.33	100.84

Sample descriptions: 6, solid lens; 19, grain in chert; 18, grain in pyroxmangite; 11, rhodonite from the contact with braunite; 5, rhodonite in chert; 12, rhodonite from small veins in braunite; 26, continuous zone on the contact with braunite; 8, prevailing pyroxmangite from the rim between chert and braunite; 4, pyroxmangite grains from the chert; 13, pyroxmangite from the small veins in braunite; 15, zone of pyroxmangite without rhodonite; 9, K-feldspar in braunite; 16, K-feldspar in pyroxmangite; 22, K-feldspar in rhodonite; 17, K-feldspar in chert; 21, albite in chert together with K-feldspar

## SAMPLE DESCRIPTION

The studied sample is a banded metasediment consisting of parallel lenticular bands of dark grey chert up to 1 cm thick. It contains lens-shaped layers of a metallic-looking, dark steel grey mineral up to 5 mm thick. This mineral was identified as braunite (Fig. 1).

Such lenses frequently have pink rims, which were found to be a mixture of rhodonite and pyroxmangite. Locally, these pink bands form independent layers in the chert as well as crosscutting veinlets. In rare cases, the braunite lenses are observed in direct contact with chert.

The rock structure indicates a ductile deformation, during which the braunite lenses behaved as plastic bodies, but occasionally they crosscut the linear texture of cherty layers.

During later brittle deformation, fracture and foliation planes were filled with Mn silicates.

Crosscutting relationships, observed with the aid of a microscope, indicate that braunite and chert are older constituents while the pink Mn silicates result from a younger replacement process.

## CHERT

Dark grey to black, thinly laminated siliceous rock is composed of isometric, xenomorph grains of quartz up to 160 μm in diameter. The rounded shapes indicate that this rock may consist of recrystallized radiolarians (Snyder, 1978). In addition to graphitic particles, the chert contains disseminated xenomorph grains of braunite, in part as interstitial filling and also as inclusions 0.01 to 0.03 μm in size. These particles give the chert an overall grey appearance,

while local accumulations in the form of smears enhance parallel structure (Fig. 6, 7).

Quartz represents 70 to 80% of the chert. Other minerals in the chert are K-feldspar, possibly in two generations, with the dominant one having higher Ba content (>1%). Also identified was relatively high purity, well-crystallized albite. The size of feldspar grains is similar to that of the surrounding quartz grains (Fig. 12, 13).

Under the microscope, the chert seems to be intensively replaced by rhodonite and pyroxmangite. This process took place after the recrystallization of silica and after the braunite was deformed jointly with quartz and feldspars. As a curiosity, one tiny grain of Ca antimonate with a composition similar to romeite (Ca, Fe, Mn, Na)<sub>2</sub>(Sb, Ti)<sub>2</sub>O<sub>6</sub>(O, OH, F) was observed in the chert silica. Due to its small size, and the quality of the polish, the incomplete microprobe analysis gave following results: 4.78% SiO<sub>2</sub>, 15.32% CaO, 2.29% Na<sub>2</sub>O, 6.04% MnO and ~60% Sb<sub>2</sub>O<sub>5</sub>.

## BRAUNITE

Braunite is not known from recently forming submarine Mn minerals, which could be considered as a similar protolith to the Arthur Point occurrence. These are usually poorly crystalline oxide phases such as todorokite and birnessite (Crerar *et al.*, 1982). Studies of Mn deposits in Japan by Choi and Hariya (1992) showed that braunite may form as a result of postdepositional reactions between primary Mn compounds and hydrothermal or biogenic silica. These reactions probably take place during diagenesis and/or low-temperature and high-pressure metamorphism.



Figure 2. Photomicrograph (25x) of braunite lens with Mn-silicate rim in chert.

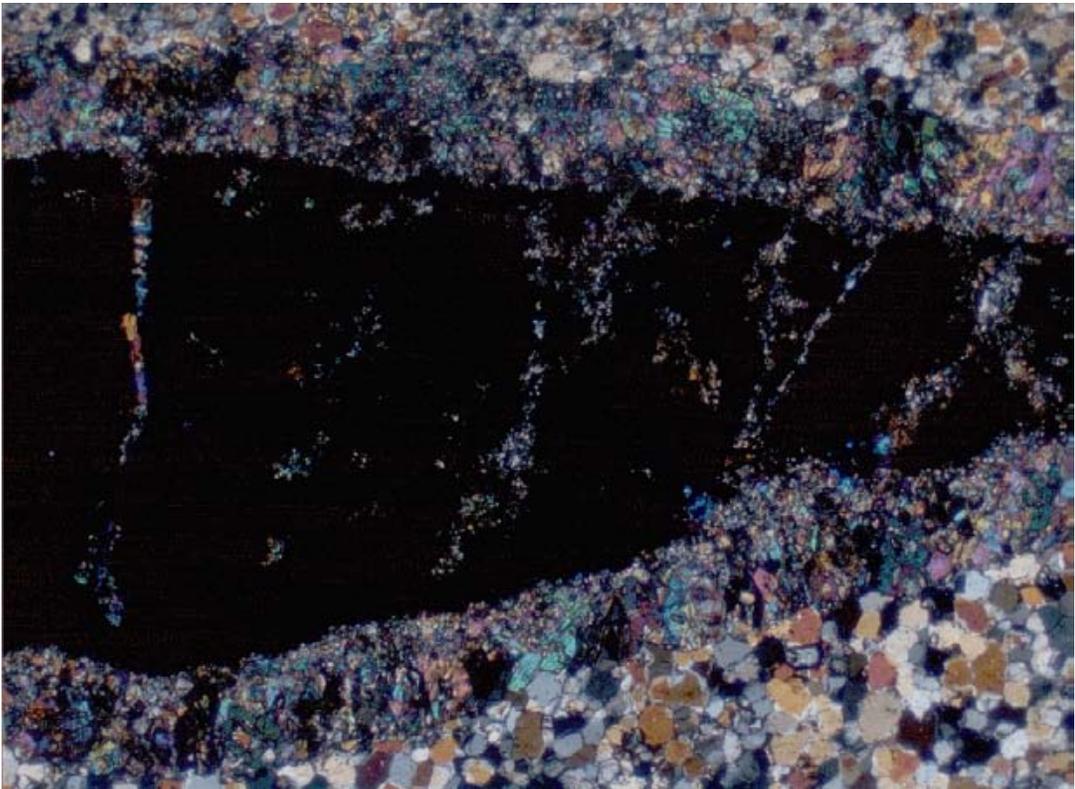


Figure 3. Same view as in Figure 2, in polarized light.

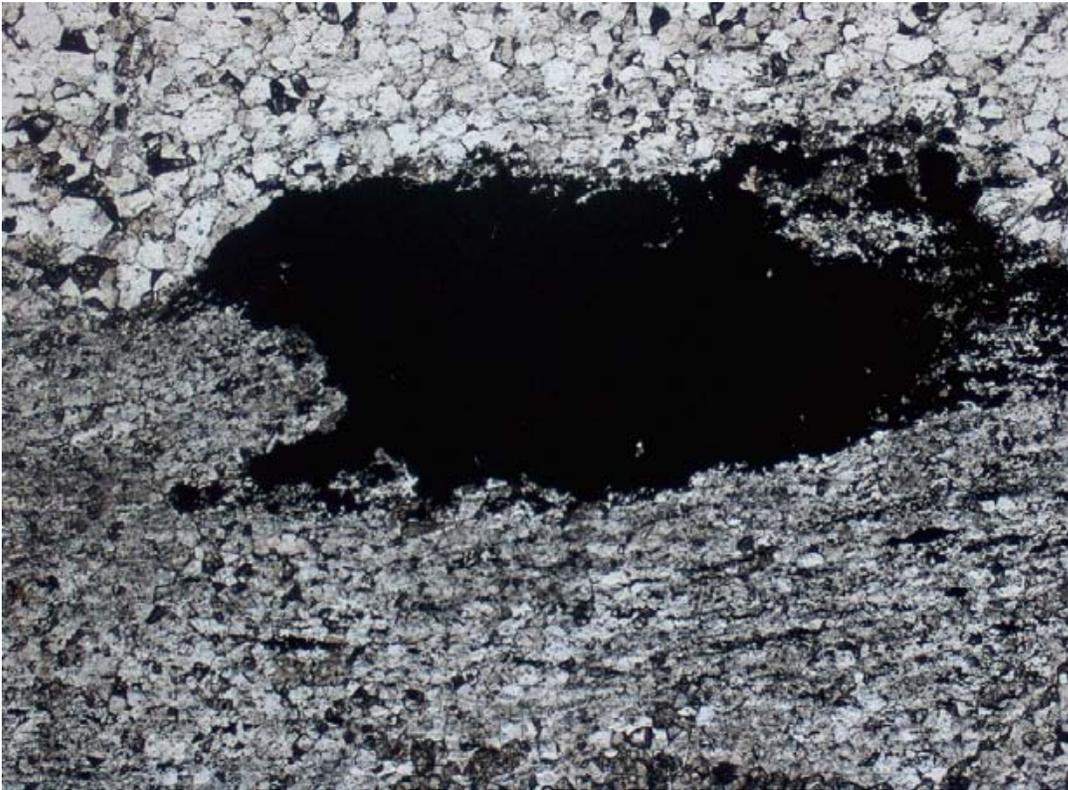


Figure 4. Photomicrograph (25x) of braunite lens in contact with chert on upper rim and with Mn-silicate on bottom rim.

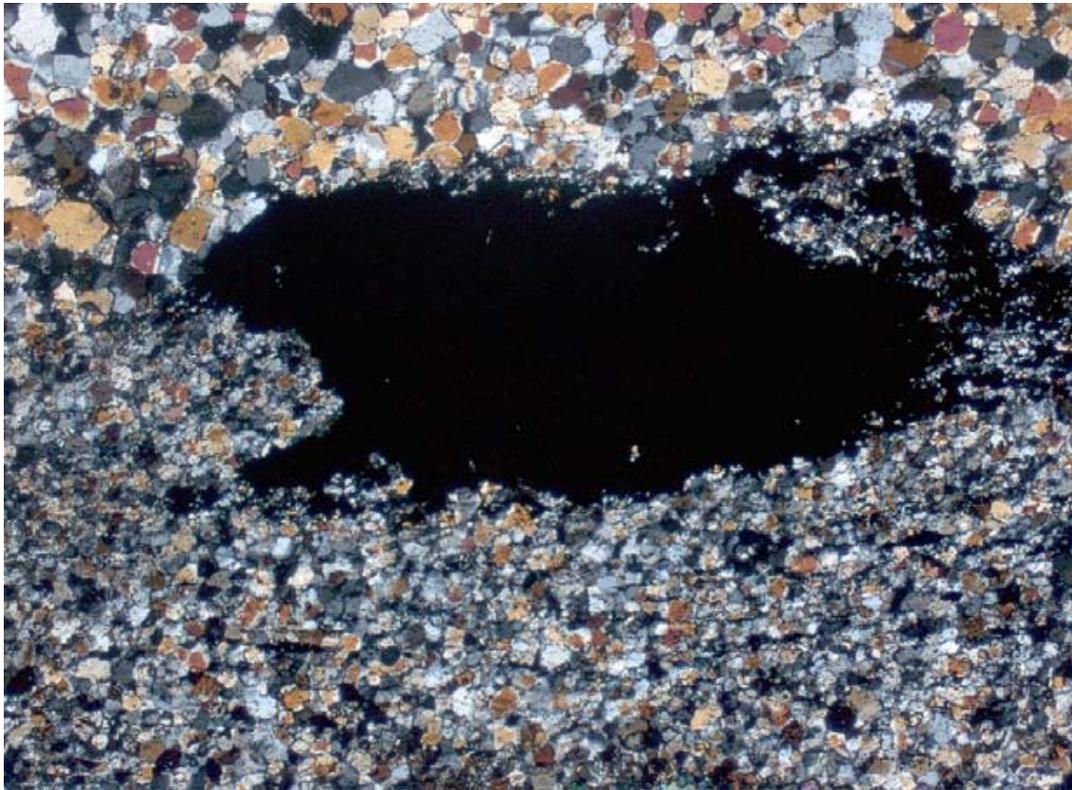


Figure 5. Same view as in Figure 4, in polarized light.



Figure 6. Photomicrograph (25x) of chert with disseminated braunite.



Figure 7. Same view as in Figure 6, in polarized light



Figure 8. Photomicrograph (100x) of chert with disseminated braunite.

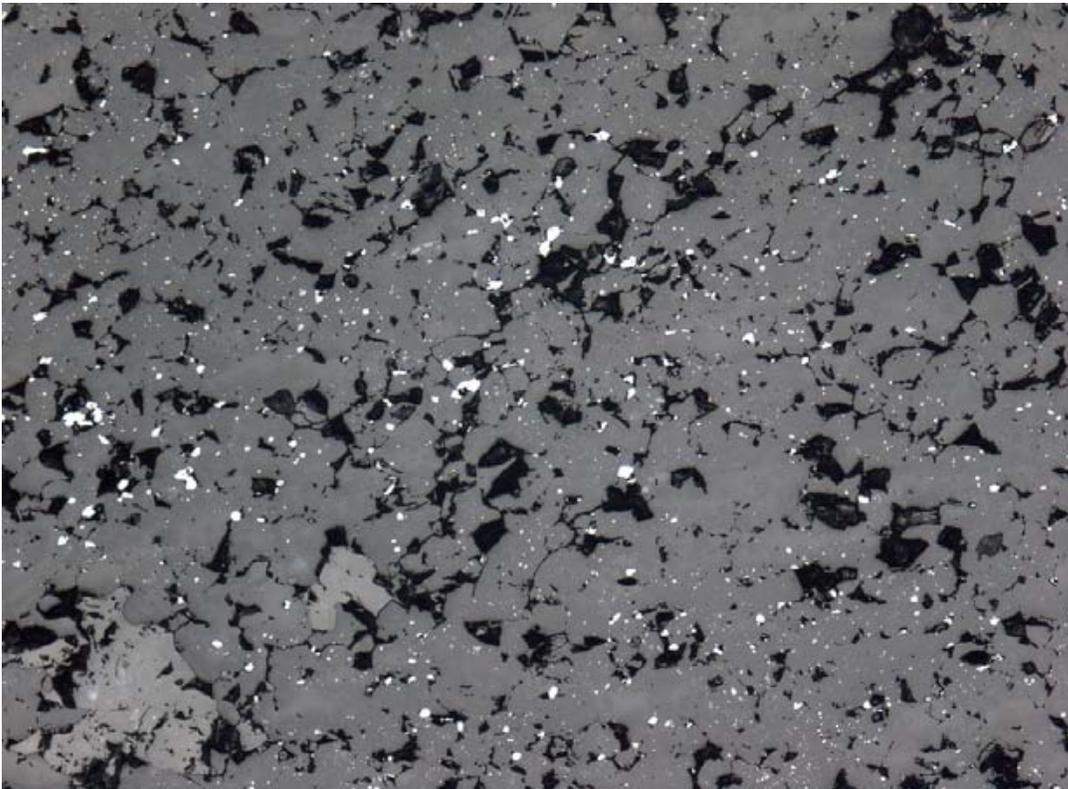


Figure 9. Same view as in Figure 8, in reflected light.

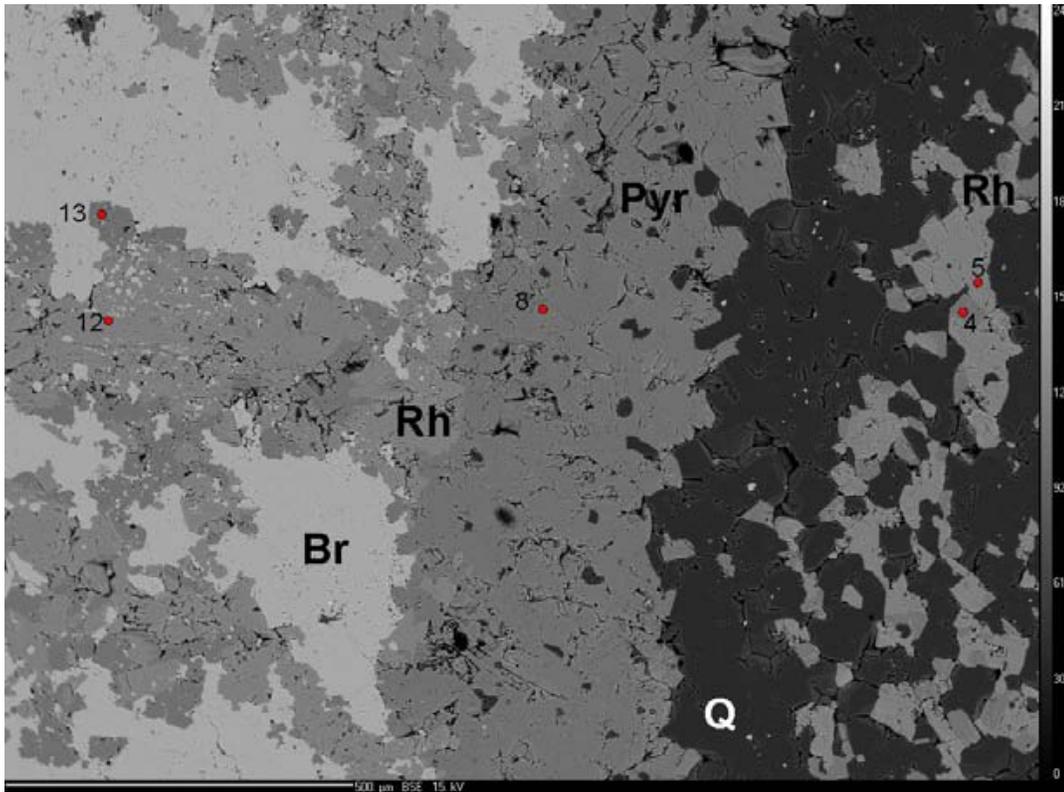


Figure 10. Location of microprobe tests 4, 5, 8, 12 and 13.

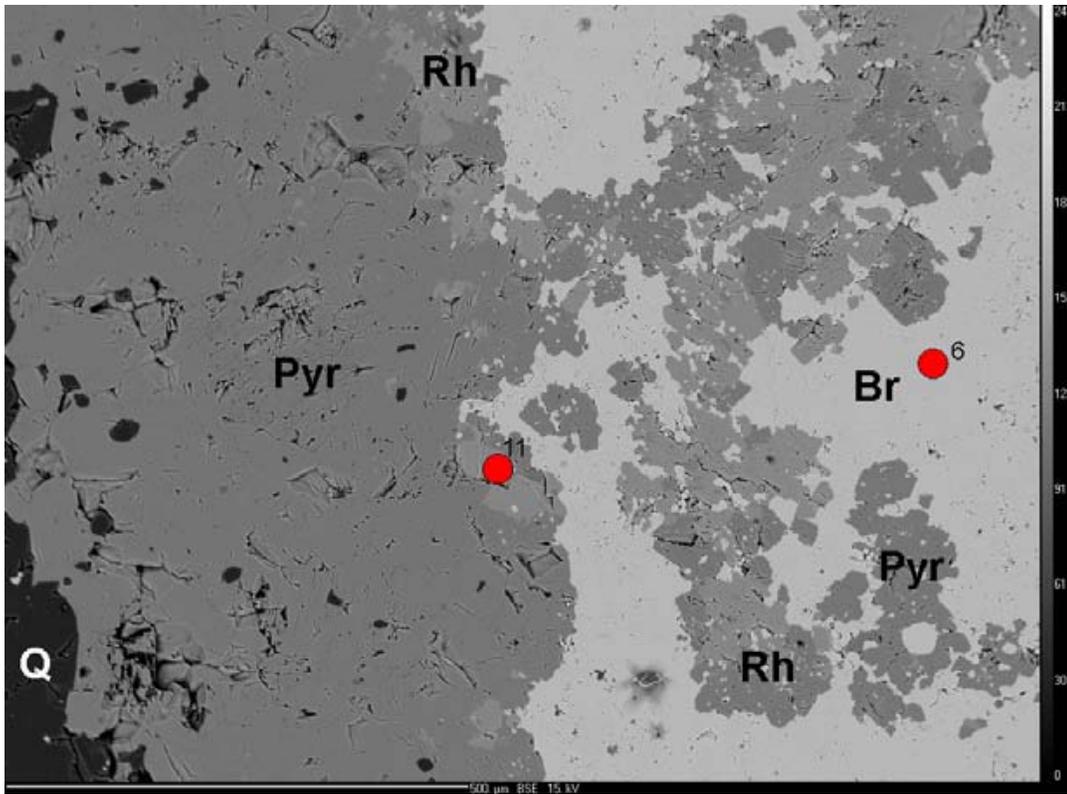


Figure 11. Location of microprobe tests 6 and 11.

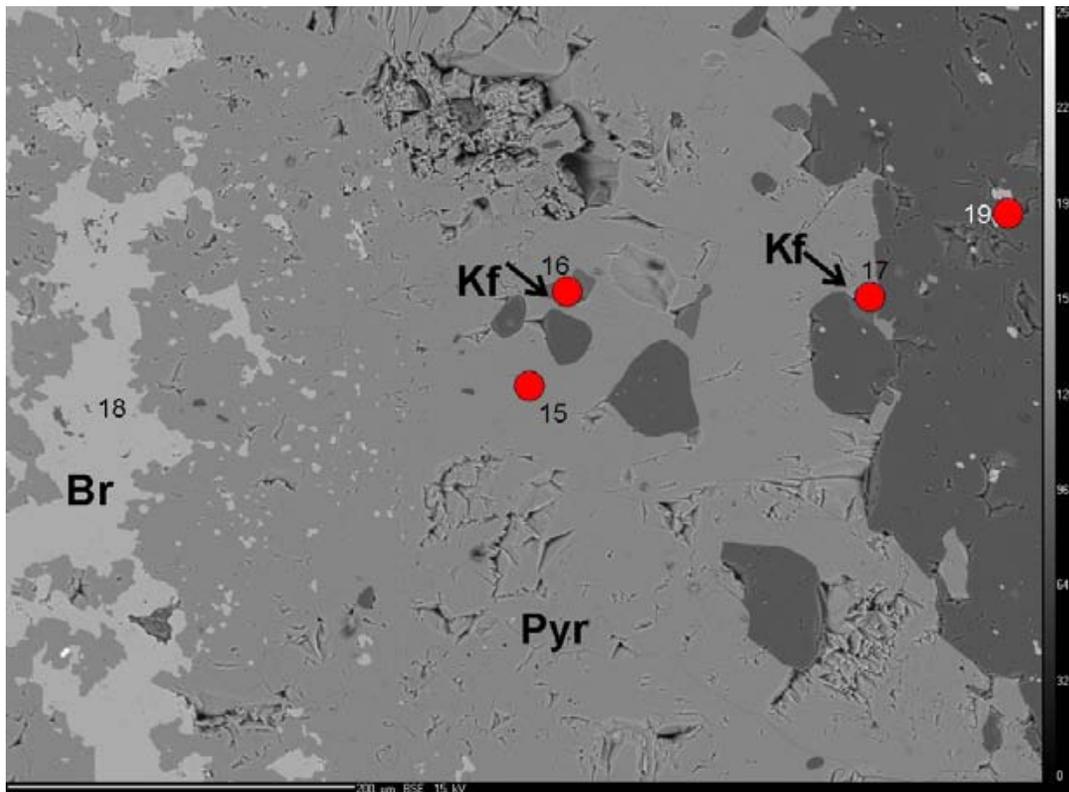


Figure 12. Location of microprobe tests 15, 16, 17, 18 and 19.

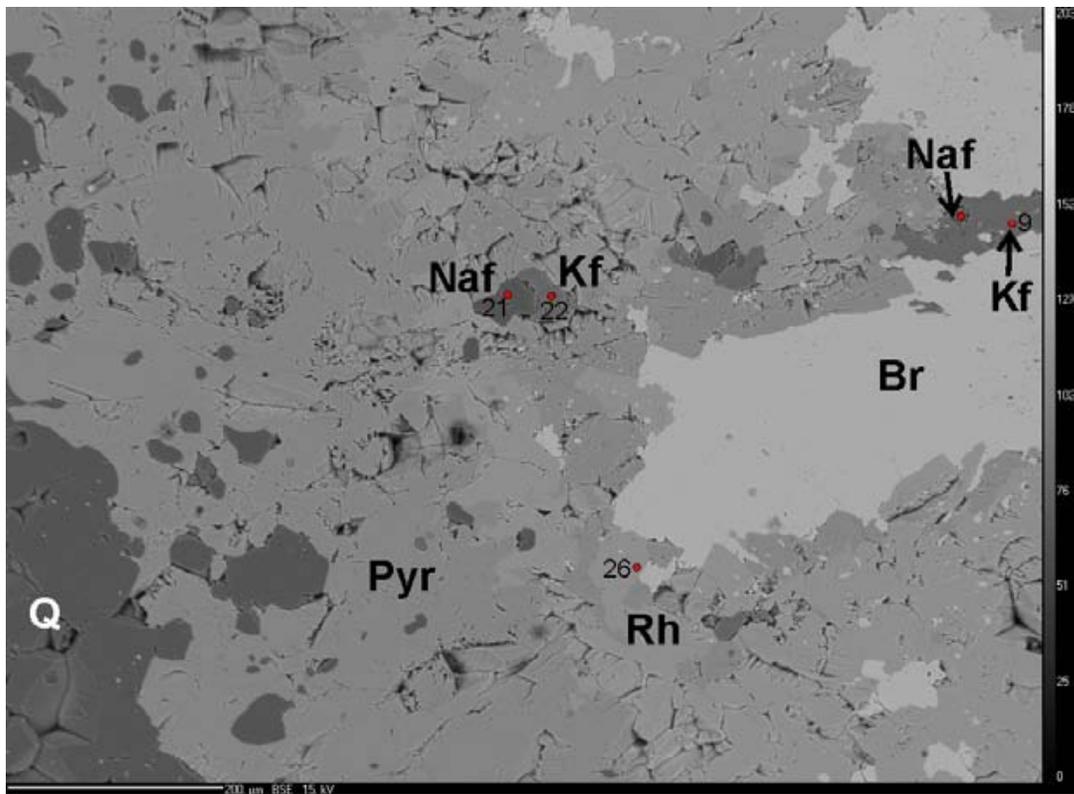


Figure 13. Location of microprobe tests 9, 21, 22 and 26.

The Arthur Point braunite was identified using the combination of reflex and transmission microscopy, XRD and electron microprobe.

In most natural occurrences, braunite contains approximately 10% SiO<sub>2</sub>, while synthetically by substituting Si<sup>+4</sup> for Mn<sup>+4</sup> it can accommodate up to 40% SiO<sub>2</sub> without the lattice constants changing (Huebner, 1967). Our tested sample corresponds to the formula 3Mn<sub>2</sub>O<sub>3</sub>·MnSiO<sub>3</sub>, but this may also be written (Mn,Si)<sub>2</sub>O<sub>3</sub>.

The Arthur Point samples contain both small lenses of massive braunite and disseminated grains within the chert matrix (Fig. 3, 5, 9). Lenses are usually 30 to 50 mm in length and 3 to 5 mm thick. Later fractures were filled with veinlets of rhodonite and pyroxmangite (Fig. 2, 3). Such veinlets are up to 0.01 mm thick and sometimes contain remobilized braunite.

Based on our study, the oldest minerals at Arthur Point site are braunite and quartz. The composition of earlier phases of the Arthur Point sedimentary sequence cannot be established.

### RHODONITE AND PYROXMANGITE

Pinkish coloured lenses, bands and braunite rims within the Arthur Point deposit are not a single mineral. By using a combination of optical and XRD analysis combined with local microprobe analysis, they were identified as a mixture of rhodonite and pyroxmangite.

As is mentioned in Simandl and Church (1996), these two minerals are difficult to distinguish from each other. Considering the optical properties, pyroxmangite exhibits higher birefringence and a smaller angle of optical axis than rhodonite. However, since the size of isometrical grains in the samples is under 40 μm, the difference is so small that the two minerals are optically indistinguishable. Nevertheless, under the electron microprobe, the two minerals exhibit different backscattered electron images (Fig. 10, 11). Also, the interpretation of XRD diagrams confirmed the presence of both minerals. In relationship to braunite lenses, both minerals are younger and form rims to, and fill the fractures within, the braunite lenses (Fig. 2, 3). Rhodonite is dominant and pyroxmangite appears younger in direct contact with massive braunite (Fig. 10, 11).

In chemical composition, the rhodonite is lower in SiO<sub>2</sub> and higher in MnO and CaO compared to pyroxmangite. The Mn content of rhodonite decreases with distance from massive braunite lenses. It appears that the Mn in these rims results from a younger process of hydrothermal replacement. Pyroxmangite replaces rhodonite and its Mn content is independent of where it occurs. The origin of pyroxmangite may be explained by the increase in P-T conditions during the replacement process (Candia *et al.*, 1975).

Microprobe tests on rhodonite from Arthur Point by the British Museum (Natural History) reported MnO content between 42.1 and 48.0% (Hancock, 1992). Since the higher end corresponds to pyroxmangite, it is conceivable that this mineral has escaped attention and its presence in the deposit is more widespread than previously expected.

### SUMMARY

In conclusion, our study led us to believe that the Arthur Point deposit exhibits two separate metamorphic processes. The first, probably a high-pressure – low-temperature process, converted the original sea bottom sedimentary protolith into a braunite-chert assemblage. The second mobilized some manganese and silica and resulted in the formation of Mn silicates, at least in part at the expense of original product. This second phase could be the one described by Hancock (1992) as being between 400 and 500 °C with a pressure range of 500 to 2000 bars.

Also, the so-called deposits of ‘rhodonite’ in British Columbia (Leaming, 1966) are most probably mineralogically more diverse than originally thought.

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