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MINERALOGY OF A ZONED REPLACEMENT BODY FROM THE  
BLUE MOUNTAIN LITCHFIELDITE, PETERBOROUGH  
COUNTY, ONTARIO

A. D. EDGAR, *Department of Geology, University of Western  
Ontario, London, Canada.*

This note describes the mineralogy of a zoned, approximately spherical replacement body, about 16 inches in diameter from the Blue Mountain litchfieldite of Methuen Township, Peterborough County, Ontario. Hewitt (1960) has described the geology of this area. Although the prin-

cipal rock type of the area is litchfieldite, it is by no means homogeneous (*cf.* Keith, 1939). Roughly spherical bodies, generally less than 12 inches in diameter, and pods of "secondary" minerals principally cancrinite and "hydronephelite"<sup>1</sup> are fairly common, particularly in freshly blasted quarry faces of the litchfieldite. These bodies are easily recognizable by their pink color, distinguishing them from the white litchfieldite.

The sample described in this report was submitted to this department for mineral identification by Mr. James Gibson of Bancroft, Ontario; and, because of its size and distinctive zoning, provided a good opportunity to make a detailed study of the mineralogy and possible origin of these bodies.

Zones, numbered 1-5 from the core outwards, are easily recognizable on the basis of their milky-white, pink and lilac colors:

*Zone 1*—approximately  $5\frac{1}{2}$  inches in diameter, light pink, coarse-grained ( $\frac{1}{2}$ -1 inch long crystals), the principal megascopically identifiable mineral is cancrinite with very minor flakes (1 mm) of biotite.

*Zone 2*—uniformly  $\frac{1}{2}$  inch in width, very light pink, finer-grained than zone 1, contains cancrinite, calcite and minor magnetite.

*Zone 3*— $\frac{3}{4}$  to  $1\frac{1}{4}$  inch in width, deep pink to lilac-colored, grain-size similar to zone 2, minerals megascopically identifiable are cancrinite, calcite and a few grains of biotite.

*Zone 4*—approximately  $\frac{3}{4}$  inch wide, milky white in color, fine-grained ( $\frac{1}{8}$  inch or less) contains calcite, analcite and natrolite.

*Zone 5*—approximately  $1\frac{1}{2}$  inch wide, greyish white in color, very coarse-grained ( $1$ - $1\frac{1}{4}$  inches) contains microcline, calcite and minor biotite books ( $\frac{1}{2}$ - $\frac{3}{4}$  inch in diameter).

*Host rock*—coarse-grained, grey-colored litchfieldite containing as essential minerals microcline, nepheline, albite ( $An_{0-5}$  as determined by refractive index). Nepheline shows partial to complete replacement by sericite (?) or a clay mineral, and calcite, with the degree of replacement increasing toward zone 5. Accessory constituents are biotite, ferrohastingsite, magnetite, analcite, and possibly cancrinite.

Megascopically contacts between zones 1 to 4 are sharp, whereas the contacts between zones 4 and 5, and 5 and host rock are less sharp.

Thin sections showed inhomogeneity both between and within zones. Many of the minerals appeared "cloudy" indicating alteration. Identifi-

<sup>1</sup> The "hydronephelite" in this locality is mainly a mixture of white mica and analcite (Edgar, 1965).

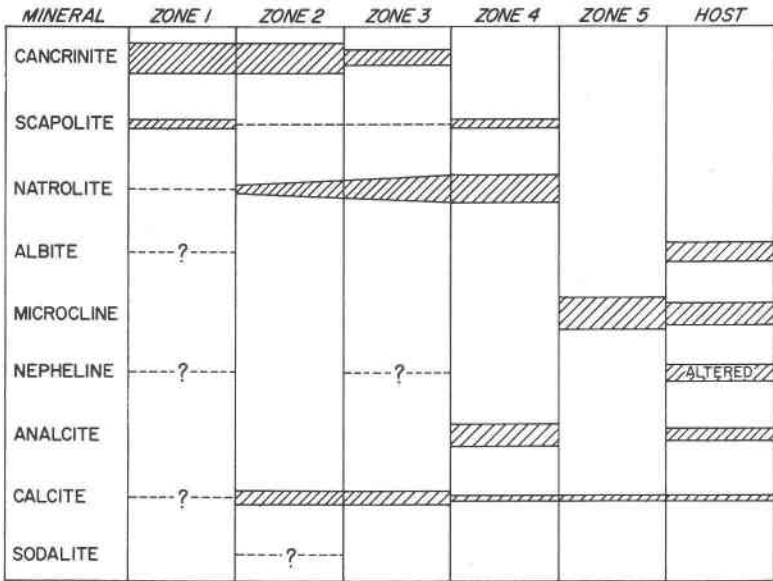


FIG. 1. Diagrammatic representation of mineralogy of inclusion and host rock. Only minerals involved in formation of the inclusion are shown.

cation was by X-ray powder diffractometer of mixtures of hand-picked material from several areas within each zone. For some zones, containing a large number of minerals, X-ray methods could not identify minor phases.

The mineralogy of each zone and of the host rock is shown in Figure 1. Compositions of the minerals, as determined by comparing their diffraction spacings, are fairly uniform in all zones in which they occur.

The abundance of cancrinite, of composition close to  $3\text{NaAlSiO}_4 \cdot \text{CaCO}_3$  (Edgar, 1964), in the pink-colored zones suggests that this mineral is the principal cause of the overall pink-color of the zoned-body.

The cell size and refractive index of analcite gives a composition close to  $\text{NaAlSi}_2\text{O}_6 \cdot \text{H}_2\text{O}$  using the method of Saha (1959). This "normal" analcite may suggest that it has not formed as a result of the breakdown of natrolite. From hydrothermal experiments, Saha showed that natural natrolite breaks down to analcite with less silica than the "normal" composition.

All spacings of natrolite correspond to those of the natrolite called "anhydrous" Peng (1955), although Fang (1963) has shown that completely dehydrated natrolite has a smaller cell volume than the "an-

hydrous" variety described by Peng. Edgar (1965) has shown that most natrolites found in undersaturated alkaline rocks are of the "anhydrous" type.

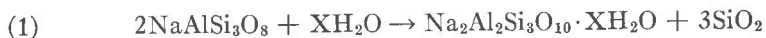
The most noticeable feature of the litchfieldite host-rock is the lack of unaltered nepheline, even at a distance of roughly 12 inches from the outer zone of the replacement body. (This is the greatest distance away from the replacement body that a sample could be taken on the specimen.) Modally determined ratios of feldspar and altered nepheline agree well with the average proportions of feldspar and nepheline for 112 litchfieldites at Blue Mountain (Keith, 1939), suggesting that the nepheline represents originally fresh material. Insofar as can be optically determined, the alteration appears to be a very fine-grained mixture of calcite and possibly sericite or a clay mineral. Small amounts, and difficulties in separation did not permit X-ray identification of these minerals. Hewitt (1960) describes the alteration of nepheline to sericite and zeolites in rocks of this region.

The relative proportions and compositions of the various minerals of the replacement body (Fig. 1) suggest that the specimen has formed by metasomatic replacement of the host litchfieldite by fluids rich in  $\text{CO}_3^{2-}$  and  $\text{Cl}^-$ . The reason for localized concentrations of fluids rich in these ions is not known, although their passage through the litchfieldite may be structurally controlled. Inspection of Figure 1 shows that the minerals of the two innermost zones are rich in Na, and poorer in silica than the host rock whereas minerals in the zone (5) adjacent to the inclusion are K-rich, suggesting that there has been migration of  $\text{Na}^+$  and  $\text{K}^+$  from the host rock to the replacement body with a concomitant removal of silica from the replacement body toward the host rock. The inner zones of the replacement body also contain minerals richest in volatiles ( $\text{CO}_2$ , Cl,  $\text{H}_2\text{O}$ ), indicating that metasomatic replacement proceeded inwards from the host litchfieldite.

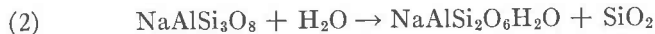
Nepheline in the host rock is the first mineral to be affected by the aqueous solutions. Increasing replacement of the nepheline by sericite and calcite toward the contact with zone 5 indicates that the fluids at this stage contained  $\text{CO}_3^{2-}$  and  $\text{K}^+$ . Zone 5 (microcline-calcite) represents an abrupt change in mineralogy in comparison to the replacement body and the host rock. In addition the contact between this zone and the host rock is less abrupt than between the other zones. The  $\text{K}^+$  for this assemblage may be provided by the breakdown of biotite of the host rock and its transport by the inward migrating solutions. The excess silica required for this assemblage, is much higher than that of the other zones and may have been introduced by reactions involved in the formation of

the minerals of zones 1–4 as outlined below. Thus in zone 5 the  $K^+$  from solutions migrating from the litchfieldite and the excess silica carried in solution from the reactions producing minerals of the inner zones has been trapped.

Zone 4 represents the maximum development of hydrous minerals (natrolite and analcite) suggesting that the activity of water was highest in this zone. Both natrolite and analcite may represent original albite which has been altered according to the reactions:

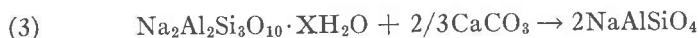


(where  $X < 2.0$  – producing “anhydrous” natrolite)



Minor calcite and scapolite in this zone suggest moderate activity of  $CO_2$  and minor activity of chlorine.

Zone 3 marks the appearance of cancrinite, the disappearance of analcite, a decrease in natrolite, and an increase in calcite with respect to zone 4. These assemblages may indicate decreasing activity of  $H_2O$  and increasing  $CO_2$  activity in this zone, the latter reaching a maximum in zone 1. The antipathetic relationship of cancrinite and natrolite in zones 1–3 suggests that with increasing  $CO_2$  activity cancrinite formed at the expense of natrolite according to the reaction:



$\cdot 2/3CaCO_3 + SiO_2 + XH_2O$  (where  $X < 2.0$ )

The formation of cancrinite is probably unrelated to the disappearance of analcite, unless temperatures were less than  $250^\circ C$  at a pressure of 1,000 bars  $P_{H_2O}$ , since Edgar (1964) has shown that analcite, nepheline and calcite react to produce cancrinite at temperatures above  $250^\circ C$ . Scarcity of nepheline in zone 3 lends support to this conclusion.

The solubility data of Kennedy (1950) shows that the large amounts of silica produced in the reactions outlined above could be removed by the aqueous solutions. Although this removal will be enhanced at higher temperatures, the solubility of silica is probably sufficiently high even at low temperatures, provided high density conditions are maintained, to remove most of this silica.

The mineralogy of zone 2 is similar to that of zone 3 except for increase in the cancrinite and decrease in the natrolite contents. Very minor amounts (5–10%) of sodalite and scapolite suggest that the chlorine ac-

tivity may have reached a maximum in this zone. The source of this chlorine is not known.

In the innermost zone (1) natrolite and calcite have almost disappeared and the zone consists principally of cancrinite (80–85%), scapolite (10%) and very minor albite and nepheline. The reappearance of the more silica-rich minerals, albite and scapolite, may indicate lowering of temperature in this zone to the point where the solutions are saturated in silica and have formed these “secondary” silica-rich minerals.

The very minor biotite and magnetite in some zones is not believed to have been involved in any of the reactions producing the minerals of these zones.

#### CONCLUSIONS

The specimen described in this note is believed to have formed metasomatically from original litchfieldite by aqueous solutions rich in  $\text{CO}_3^-$  and  $\text{Cl}^-$  ions. Changes proceeded from the outside inwards and involved transport of  $\text{K}^+$  and  $\text{Na}^+$  ions with a concomitant removal of silica.

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