Art. XXXIX.—*The Primary Analcite of the Crowsnest Volcanics;* by J. D. MacKenzie.

The writer recently published a description of some analcite-bearing pyroclastics which occur in southwestern Alberta,* and interpreted the nature of the analcite as primary. In the light of the facts of the occurrence as fully described in the publication referred to, it was not thought necessary to consider the hypothesis that the analcite might be secondary.

However, in a recent number of this Journal† a review questions the writer's conclusions and suggests that what is now analcite may have been originally leucite, and that it has become converted to analcite by sodium solutions, through a process the possibility of which is suggested by Lemberg's experiments. The reviewer's questions are principally based on a misinterpretation of the conditions of deposition of the pyroclastics as described, and also to an inferred doubt that primary analcite could form under the conditions of eruption.

It is the intention of the present note to show: (1) that under the conditions described there is no reason to suppose the conversion of the analcite to be probable; (2) that the possibility of conversion is doubtful, even with conditions such as the reviewer imagined; and (3) that it is quite possible for analcite to form under the conditions described.

(1) In the article under consideration‡ the writer, when summarizing the conditions of deposition of the Crowsnest volcanics, stated that:

> " . . . the area they now cover was occupied by a shallow sea probably of fresh water . . . . ,"

the evidence for this conclusion being given elsewhere in the article. It might have been better to have used the term "lake" instead of "sea," and a further ambiguity is introduced two lines below by the word "submarine"; this should be "subaqueous." Despite these inaccuracies of statement, it seems clear from the context that the volcanics were described as having been deposited in fresh water. However, the evidence for the character of the water is not conclusive, and it may have been brackish, or salt; nevertheless it was more probably fresh, and was so described. Thus, the assumption by the reviewer of "solutions of sodium salts" is not justifiable from the writer's description, and the evidence in hand

* Geol. Surv. Canada, Mus. Bull. No. 4, Geol. Series No. 20, Nov. 19, 1914.
† Vol. xxxix, p. 222, February, 1915.
‡ Op. cit., p. 13.

indicates no reason to suppose conditions favorable for the conversion of leucite to analcite to have been present.

(2) Supposing, however, that the pyroclastics were deposited in salt water, we may critically inquire into the possibility that the present analcite represents converted leucite.

Lemberg's experiments* clearly show that finely-powdered leucite is converted into analcite by treatment with solutions of sodium salts. This reaction, it is indicated, may take place even with rather dilute solutions and at relatively low temperatures. While these experiments are significant, the extent to which they may be called upon to explain analcite occurrences in igneous rocks is problematical.

In the case under consideration the analcite phenocrysts are euhedral trapezohedrons up to one inch in diameter, and form 50 per cent of the volume of the rock. Fifty per cent of the remainder are composed of smaller analcite phenocrysts and analcite in the groundmass. The analysis of the phenocrysts shows that the analcite is in a high state of purity.

The large trapezohedrons in thin section are quite homogeneous, with the analcite cubic cleavage well developed, proving that they are single individuals. That this condition resulted from a conversion of leucite to analcite seems inconceivable. Lemberg's experiments, carried out on finely-powdered material, throw no light on the mechanism of the change. Whether it is a molecular exchange, or merely a substitution of sodium for potassium atoms with the taking on of a molecule of water, we can only surmise. In either case, the conversion would proceed from the exterior of the crystals inward, and it is altogether unlikely that the conversion would have been so complete in every case as to leave no trace of the original leucite. Supposing a replacement by equal volumes to have taken place, it is probable that a granular aggregate of analcite would replace the original leucite, a tendency which would be accentuated by the fact that leucite generally is composed of twinned layers.

If, instead of replacement by equal volumes, the molecules of analcite be supposed to take the place and orientation of the original leucite molecules, an increase of volume of about 10 per cent would result, with accompanying distortion, an effect that has not been observed.

The analcite-bearing rocks are, as described,† very slightly altered. This is a strong argument for the primary character of the analcite, and the writer would refer to Pirsson's well-stated argument in maintaining the primary nature of the analcite in some of the basalts from the Highwood mountains.‡

* Zeitschrift der deutschen Geol. Gesellsch, xxviii, pp. 535, et seq., 1876.
† Op. cit., p. 28.
‡ Jour. Geology, vol. iv, p. 686, 1896.

The statements there made are strikingly applicable to the analcite rocks of the Crowsnest volcanics. In particular it is not reasonable to suppose the complete transformation of leucite to analcite could take place in the presence of the easily altered nephelite, and the latter remain unaffected, and the same argument applies to the ægirite and ægirite-augite. Both nephelite and ægirite, in fact, according to Brögger,* may alter to analcite, and if conditions were favorable for the complete transformation of leucite into that mineral, surely the nephelite, ægirite, and ægirite-augite would not remain unaffected.

Washington also, in discussing the primary nature of the analcite† in some basalt flows of Sardinia, presents a similar line of arguments, and in view of these, and the facts and reasons stated above, the possibility that the blairmorites of the Crowsnest volcanics were originally leucite rocks seems to be highly improbable.

(3) Finally, the possibility of primary analcite forming in eruptive lavas remains to be considered. From the character of the analcite-bearing rock (op. cit., p. 20) it is quite apparent that the analcites did not form in lavas "undergoing explosion" as suggested in the review.

Plainly, one-inch analcites could not form in a lava "undergoing explosion" unless we assume a virtually instantaneous growth of the crystals. The obviously intratelluric nature of these phenocrysts meets the objection that the pressure in the magma was not sufficient for their formation.

In order that analcite may form in a magmatic solution, it is necessary, so far as the water is concerned, that when the crystallization temperature of the mineral is reached, the pressure on the magma must be in excess of the partial pressure of the (gaseous) water at that temperature. It may be well to point out that the amount of analcite forming in a given case is not proportional to the *pressure*, but to the *amount* of water present. That the necessary pressure was realized in the magma chambers feeding the Crowsnest volcanoes is made evident by the nature of the blairmorite described. It is not a rock crystallized wholly under surface conditions, and on the face of it, the first generation of analcite phenocrysts formed *before* and not during explosion. This intratelluric nature of these phenocrysts necessitates their formation under pressure—obviously enough for analcite to form.

While it is not necessary in the case of the blairmorite to assume the actual formation of analcite in lavas undergoing eruption, such a thing is by no means impossible. The above

* Zeitschrift Kryst. Min., vol. xvi, pp. 223–333, 1890.

† Jour. Geology, vol. xxii, pp. 749–750, 1914.

postulated conditions of partial pressure of the water vapor might conceivably be realized under surface conditions, so that even there analcite could form.

Some of the Sardinian basalts recently described by Washington* are examples of rocks consolidating at the surface and containing analcite, though it is possible that here, too, the mineral is intratelluric in origin. The shackanite of Daly† may be also mentioned in this connection.

With the facts of the original paper in mind, and their further explanation here given, the primary nature of the analcite of the Crowsnest volcanics can not be open to any reasonable doubt.

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* Jour. Geology, vol. iv, pp. 742–753, 1914.
† Geol. Surv. Canada, Mem. 38, p. 411, 1912.