A possible explanation of these discontinuities is seen in the *lineage structure* of a crystal as described by Buerger.[4,5] This *lineage structure* is present in quartz crystals but just how the grinding of the lens would produce this irregularity is not clearly apparent to the writer although the zone of weakness caused by this structure would produce a location for these discontinuities. Measurements of the dimensions of the spacings of the steps show them to be of the order of magnitude of 0.1 mm. both between adjacent lines and between zig-zags along separate lines. These measurements agree somewhat with the dimensions of "Lineages."[5]

A combination of causes is the probable reason for these steps. It is probable that the blank lens was cut from an improper position, and perhaps from a physically imperfect crystal. It is possible also that the grinding of the lens might have been imperfect by performed in that instead of the proper random directions of stroking, the strokes might have been at least approximately unidirectional in character. Such a condition of grinding acting on the zones of weakness produced by "lineage boundaries" might result in action similar to that performed by glaciers passing over firmly anchored boulders or projecting rock masses, resulting in a smooth curve on the side of approach and a sharp step downward on the lee side.

Before concluding the author wishes to acknowledge the generous help given him by Prof. M. J. Buerger in supplying crystallographic data and information.

## DISCUSSION OF THE PAPER "HEAVY MINERALS IN THE SYENITES OF PLEASANT MOUNTAIN, MAINE"[1]

RALPH W. MARSDEN, *University of Wisconsin.*

During the course of a study of a syenite stock W. F. Jenks examined the heavy minerals for the purpose of determining the characteristic heavy minerals of each syenite type, the variations in heavy minerals, the degree of constancy within a rock type, and the usefulness of this method of work in the correlation of

[4] Buerger, M. J., The Significance of "Block Structure" in Crystals: *Am. Mineral.*, vol. **17**, pp. 177–191, 1932.

[5] Buerger, M. J., The Lineage Structure of Crystals: *Zeit. Krist.*, vol. **89**, pp. 195–220, 1934.

[1] Jenks, W. F., Heavy Minerals in the Syenites of Pleasant Mountain, Maine: *Am. Mineral.*, vol. **19**, pp. 476–479, 1934.

doubtful members. In conclusion he states, "As indexes of rock types the heavy accessories are practically useless. Not only do the relative and absolute proportions of the minerals vary almost as much within a rock type as within the stock as a whole, but the crystal habit and color are in addition practically invariant." In other words Jenks finds that he is unable to distinguish the seven phases of the Pleasant Mountain syenite by heavy mineral methods, hence the methods are useless.

The results obtained by Jenks are in accordance with the underlying principle of heavy mineral work, for the data point to a constancy of the heavy accessory minerals within the syenite stock, even though there is a marked macroscopic change in rock type. The general presentation of results and the lack of detailed study of the various rock types prevent the statement of this as an established fact.

The problem which Jenks attempts to solve by heavy accessory mineral methods is the distinction of phases of the same stock, not the recognition of masses of different ages, or even isolated bodies derived from the same magma. This problem is, to some extent, comparable to the distinction of the assemblages of the Dartmoor and Falmouth granites of England,[2,3] where the assemblages of the two rocks are very similar even though these masses are separated by 55 miles. In order to distinguish the assemblages of these bodies a detailed study was necessary, which entailed large separations in order to obtain the rare species present. Even then the diagnostic characteristics used included variations in color and crystal habit. Only a slight difference in the accessory minerals would be anticipated in the case of a single stock. The work of Jenks indicates that the accessory mineral variation within the Pleasant Mountain syenite is too slight to be recognized by the methods used.

Jenks states that there are variations in the relative and absolute amounts of the accessory minerals, both within a rock type and the stock as a whole, but no change in color or crystal habit of the minerals. In his investigation he includes the mafic minerals, augite, hornblende, and biotite, with the heavy accessories and makes

[2] Ghosh, P. K., The Mineral Assemblage of the Falmouth Granite (Cornwall): *Proc. Geol. Assoc.*, vol. **39**, pp. 332–338, 1928.

[3] Brammall, A., Dartmoor Detritals; A Study in Provenance: *Proc. Geol. Assoc.*, vol. **39**, pp. 27–48, 1928.

comparisons of relative and absolute amounts of accessory minerals present with augite, hornblende, and biotite included in the computations. In general usage they are not included with the heavy accessories even though they are heavy minerals.[4,5] The mafic minerals should be excluded from consideration in the study and correlation of igneous rocks by heavy accessory mineral methods, because of their known variations within a rock type[6,7] and their abundance in most cases, as compared to the amounts of minor accessories. These mafic minerals comprise as much as 95 per cent of the heavy minerals in the Pleasant Mountain syenite, and a variation in the amount present was recognized within the stock. The inclusion of these minerals with the heavy accessories would and does obliterate the true accessory minerals to such an extent that the variation in percentage recognized might well be confined to the variation of augite, hornblende, and biotite.

Jenks brings out clearly, that in so far as studied, the true accessory minerals are constant throughout the stock. He states, "Magnetite, apatite, titanite, and zircon were accessories in every sample examined. The only additional accessory is rare allanite, . . . from the analcite syenite. In every rock but the analcite syenite the relative and absolute percentages of apatite, titanite and zircon remain fairly constant." In the analcite syenite where a variation in the relative and absolute amounts of accessories was found, the apatite-zircon ratio was the same as in the other rock types; about three to one, and with no change in color or crystal habit, but there was a variation in the amount of titanite. Whether this latter variation is a result of the mafic minerals or inherent in the rock is not made clear. These results are shown in his Table I in which the accessory minerals are given as abundant, very common, common, scarce, and rare; such statements make comparison practically impossible, particularly so since there are no other indications of relative abundance. In several rock types three out of four species present are listed as abundant, with the

[4] Johannsen, A., *Petrography*, vol. **1**, p. 28.

[5] Wells, A. K., The Heavy Mineral Correlation of Intrusive Igneous Rocks: *Geol. Mag.*, vol. **68**, pp. 258–259, 1931.

[6] Lund, R. J., Differentiation in the Cape Spencer Flow: *Am. Mineral.*, vol. **15**, pp. 245–248, 1930.

[7] Groves, A. W., The Heavy Mineral Suites and Correlation of the Granites of Northern Brittany, the Channel Islands, and the Cotentin: *Geol. Mag.*, vol. **67**, Table p. 232, 1930.

remaining one very common. The apatite-zircon ratio is not shown. The presentation of mineral frequency as percentages, now in general use, is far more satisfactory than methods based on estimation. There are errors even when accurate mineral counts are used, but the mineral frequency is presented in a form where the relationship can be readily seen and interpreted.[8]

The Pleasant Mountain syenite, in so far as studied, is another example of the constancy of accessory minerals within a single igneous mass, and a detailed study should give additional support to this basic principle of accessory mineral work. The variations indicated are not in the heavy accessories, but in the mafic minerals, which were included with the heavy accessory minerals. The problem attempted by Jenks was the distinction of types of the same mass, where only a slight difference in accessory minerals would be expected, and a detailed study would be necessary to determine these differences.

[8] Dryden, A. L., Accuracy in Percentage Representation of Heavy Mineral Frequencies: *Proc. Nat. Acad. Sci.*, vol. **17**, pp. 233–238, 1931.