p. 564) pointed out that the range can vary from 0 ° to 90 °, if the quartz grains were oriented at random. The author would suggest that in future work the range should be measured at a special orientation, e.g. with the *c* axis of quartz parallel to the microscope stage.

Conclusions

There are wide variations of the undulatory range of quartz, as well as crystal size in the rocks studied. The range of undulatory extinction in quartz increases with increase in grain size, because quartz volumes happen to increase with increase in surface area.

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AN IMPROVEMENT OF THE PLAGIOCLASE GLASS FUSION METHOD

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Introduction

The correlation between refractive index of plagioclase glass and An content, for both synthetic and natural specimens, is well established (Larsen, 1909, Foster, 1955, Dawson & Maxwell, 1958, Schairer, Smith, & Chayes, 1956). The fusion method for producing plagioclase glass is rapid and simple; the index of the glass giving estimates of An content that are equal to or exceed those obtained by normal optical and powder *x*-ray procedures (2 mole per cent An).

For the fusion process, Foster (1955) heated powdered plagioclase, wrapped in platinum foil, with an oxygen-gas blowpipe. After several minutes in the hottest part of the flame the platinum-wrapped sample

was plunged into water, thereby quenching the sample to glass. Measurement of the refractive index of the glasses, with standarized immersion oils, produced An values of within 1.5 mole per cent on chemically analyzed samples. Disadvantages of this procedure include the preparation of the sample in the platinum wrap and subsequent quenching and the cost of the platinum envelopes.

Dawson & Maxwell (1958) tested an acetylene-air flame and a high temperature electrical furnace for fusion, but both were rejected as being unsatisfactory. They found, however, that an electro-welder produced a plagioclase glass that was suitable for estimating An content. Index of refraction determinations on the plagioclase glasses, fused with the electro-welder, gave An values well within 2 mole per cent on analyzed samples. These determinations were made chiefly on plagioclase fragments cut from thin sections of coarse- to medium-grained rocks.

The portable electro-welder employed by Dawson & Maxwell (1958) was equipped with a twin electrode carbon torch. A small pit was cut in the end of one of the electrodes and the plagioclase sample placed in the pit and fused for a few seconds at 40 amperes. After fusion, the resultant glass beads were collected, crushed, and their index of refraction determined with standard index oils. The individual electrodes were used several times by sawing off the used pit portion of the electrode and boring new pits, thus avoiding contamination of the glasses. Analysis of the alkali content of fused and unfused plagioclase, by flame photometer, indicated no significant chemical change during the fusion process.

Technique

The procedure employed by this author for the determination of the An content of plagioclase was modified from the glass fusion method of Kittleman (1963). With this method the wrapping of the sample in platinum foil or placing it in bored pits in the electrodes is eliminated.

The equipment utilized for fusion include a Craftsman AC arc welder (Sears, Roebuck and Co., Model No. 113.203050) with a Craftsman 220 volt arc torch (Model No. 190.20073) and copper electrodes of 5/16 inch diameter.

A sample of 20 to 30 mg of powdered plagioclase is "piled" on a machined steel block and fused by passing the electrodes on either side of the pile at an amperage of 40. In 1 to 2 seconds five to ten glass beads about 1 mm in diameter are formed. The glass beads are then crushed and their index of refraction determined with standard index oils and a petrographic microscope using a sodium light source. The index of the "matching" oil is read directly with an Abbe refractometer. The An content is then estimated, to the nearest 0.5 mole per cent, from the

refractive index-composition graph constructed from chemically analyzed specimens (Foster, 1955).

With this method there is no contamination of the glass beads from the steel block as the beads rest directly on unfused sample. Unfused areas at the base of the glass beads are easily recognized by their anisotropic character under the microscope and thus can be avoided when estimating the index of the glass. In a few cases inclusions were noted in the glass fragments, probably representing pieces of carbon from the electrodes, however, only the clear glass fragments are utilized for index determination.

In most samples the range of index of the clear glass fragments was less than 0.001; if a greater divergence was encountered the sample was rejected and a new sample fused.

Results

In Table 1 the experimently determined An content of four analyzed plagioclase samples is compared with the calculated An content. The An content, as determined by the fusion method, is within 0.6 mole per cent of that calculated from chemical analysis. Index values of duplicate

TABLE 1. DETERMINATION OF MOLE PER CENT AN CONTENT OF ANALYZED PLAGIOCLASE BY THE GLASS FUSION METHOD

Sample	Locality	Source	Mole Per Cent An (calculated)	Index of Fused Plagioclase Glass	Mole Per Cent An from Index of Glass
Albite	U.S. Bureau of Standards	C. E. Harvey Wash. State University	1.6	1.4898	1.0
				1.4899	1.0
Anorthite (Synthetic)	———	C. E. Harvey Wash. State University	100.0	1.5753	99.5
				1.5757	99.8
Labradorite	Stillwater Complex, Montana	E. D. Jackson USGS	60.5	1.5403	60.9
				1.5403	60.9
Labradorite	Stillwater Complex, Montana	E. D. Jackson USGS	70.9	1.5496	71.3
				1.5493	71.0

samples show agreement within 0.5 mole per cent. The reliability and accuracy of the An content, as determined by the index of the plagioclase glass, is more than adequate for routine investigations. The fusion procedure was utilized, by this author, for the determination of the An content for approximately 110 plagioclase samples from a porphyritic basalt flow (Hoffer, 1966).

There remains the possibility of selective melting of the plagioclase during fusion, thus leaving unmelted more calcium-rich fragments. However, the high temperature of the arc, over 2000 °C, would immediately melt, upon contact, plagioclase of any composition and thus prevent any large-scale selective melting. The results, as shown in Table 1, indicate that if selective melting did occur during the fusion process it is of insignificant value in estimating the An content of the plagioclase sample.

Conclusions and discussion

The plagioclase fusion method, as outlined above, has the advantage of convenience and speed over the techniques employed by Foster (1955) and Dawson & Maxwell (1958). The need for a bored pit in the end of one of the electrodes and packing it with the sample or wrapping it in platinum foil is eliminated. In addition, complete fusion of the entire sample is not necessary in this method as the fragments of incomplete fusion can be identified and eliminated in determining the matching index of the plagioclase glass. In addition, the fusion time for the platinum-wrapped sample is much longer than that required with the arc method; several minutes are required for fusion compared to 1 to 2 seconds with an arc electro-welder. Preliminary results indicate an accuracy of ± 1 mole per cent An.

As indicated by Foster (1955), the glass fusion method has many advantages over normal methods of An determination. These include simplicity, speed (the determination of only one index for the glass compared to three for the crystalline fragments), inexpensive equipment, and the An content of the plagioclase can be determined regardless of its structural state (high or low temperature state). In addition, only a small amount of sample is required for fusion (20 to 30 mg) and the accuracy of the method, ± 1 mole per cent An, is equal or superior to results obtained by most optical and *x*-ray diffraction methods.

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ADDITIONAL DATA ON THE COMPOSITION OF SPENCITE

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ABSTRACT

Quantitative analysis of the rare earth fraction of spencite indicates that the stoichiometry reported by Frondel on the basis of an incomplete analysis must be revised.

Frondel (1961), in his report on the new mineral spencite, gives an analysis by one of us (C. O. Ingamells) in which the essential rare earth constituents are only partly differentiated. At the time the analysis was performed, facilities for resolving the individual lanthanons were lacking, and they were reported as follows:

Y_2O_3 group	28.20 wt. per cent
La_2O_3 group	4.16 wt. per cent
Ce_2O_3	1.44 wt. per cent
ThO_2	2.44 wt. per cent

A more complete analysis of spencite, in which quantitative spectrographic values for all the rare earths are included (Table 1) can now be reported.

The rare earths and thorium were separated from the sample by successive precipitation as fluoride, oxalate, and hydroxide. The weight of oxides so obtained amounted to 36.07% of the sample, as compared to 36.24% obtained originally. The sample was not identically the same as that used for the original analysis, and the new values have been adjusted to yield the same total as previously.

Spectrographic analysis was accomplished with a Bausch & Lomb dual grating spectrograph, using a method developed especially for rare earth minerals. The sample (of chemically separated rare earths plus thorium oxide) was mixed 1:1:5 with internal standard-radiation buffer mixture (Sc_2O_3 in $SrCO_3$) and graphite and burnt to completion in the

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