RELIABLE AND RAPID METHOD FOR DISTINGUISHING QUARTZ AND UNTWINNED FELDSPAR WITH THE UNIVERSAL STAGE*

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Abstract

A reliable and rapid method is described for the determination of quartz and untwinned feldspar in mineral grains or thin sections by means of the universal stage. The orthoclase-albite and oligoclase-anorthite groups can be determined simultaneously by the Becke-line method.

The determination of a hundred grains can be made in about 30 minutes. Only turbid (altered) feldspar is difficult to determine, but may be counted as a separate group.

1. Introduction

The counting of mineral grains is coming to be more and more generally adopted in sedimentary petrological studies. An accurate and rapid method for determining the light fraction minerals, quartz and feldspar, has however, not yet been described.

The various varieties of feldspar can be easily distinguished by the use of immersion liquids. Distinguishing quartz from untwinned oligoclase-andesine, which has the same refractive indices (1.544–1.553), has caused many difficulties. Staining methods have been suggested by many authors (3, 8, 9). According to Holmquist (9) these methods are not reliable for Ca-free feldspar. CaF_2 seems to be strongly absorptive to dyes, but NaF and KF are less so. The soda and potash fluorides, furthermore, are soluble in water. Albite from geodes and adularia cannot be stained and microline is not, or only partly, colored (9).

The distinction between quartz and feldspar with the universal stage has not received the attention it deserves. In 1931 the main outline for the determination of uniaxial and biaxial minerals by this method was clearly given by Reinhard (11). In most handbooks of mineralogy the determination of uniaxial minerals by means of the universal stage is generally omitted as being useless. Dodge (4) is the first author to call attention to the universal stage for the determination of the quartz content of quartz-feldspar mixtures. His description of the manner in which quartz can be distinguished, however, is inadequate. Ingerson (10) gives a more complete description, but his method is so complicated that it is not likely to be used in actual practice. It is furthermore not always conclusive and cannot be used for mineral grains.

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As the necessary manipulations cannot be understood without a thorough knowledge of the optical properties of uniaxial and biaxial minerals a brief summary of these data is here recorded.

Two groups of feldspar which have refractive indices above and below that of Canada balsam (about 1.535), or some other mounting medium, can be distinguished simultaneously by the Becke method. The determination of turbid grains remains difficult. If many such grains are present a study has to be made of the different stages of alteration which causes the turbidity. If the nature of the turbid grains cannot be determined in this way they may be counted as one group of "turbid" feldspar.

Rock particles are also characteristic components of certain groups of sediments (1) and should be distinguished and counted in the same way as the mineral grains. The time required for counting 100 grains of a quartz-feldspar mixture is about 30 minutes. The counting of 100 grains is more than sufficient as generally less than 5 mineral species with practically the same specific gravity must be distinguished. If a series of rock samples from one formation must be investigated, the determination of only 50 grains per slide will be sufficient. Changing slides on the universal stage takes less than 5 minutes.

The method has been tried out in the sedimentary petrological laboratory of the N. V. De Bataafsche Petroleum Maatschappij in Amsterdam. We wish to express our gratitude to Dr. W. J. Jong for his friendly criticism.

2. The Universal Stage

The universal stage (with 4 axes) provided with a mechanical stage (Fig. 1) which was used in Amsterdam, was manufactured by Leitz and fitted on a Leitz polarizing microscope, model KM. The axes on which the different parts of the universal stage can be rotated have been variously labelled by different authors.

Emmons and Reinhard use letters, which is confusing, as the meaning of these symbols is not universally understood. Numbers are more practical. Berek and Winchell, however, have numbered the axes in different ways. Berek (2) indicates the vertical rotation axis of the inner stage with I. Winchell (12) gives I to the microscope axis and V to the vertical axis of the inner stage. Using the notations of Winchell, the E-W axis of the inner ring of the modified universal stage (Emmons, 5) can be indicated by VI. If it is desirable, for special purposes, to add more rotation axes, these could be labelled with higher figures, always giving odd numbers to vertical and even to horizontal rotation axes.

Winchell (12) uses a different sequence of numbers for the axes of the modified universal stage than for those of the stage with four axes. This

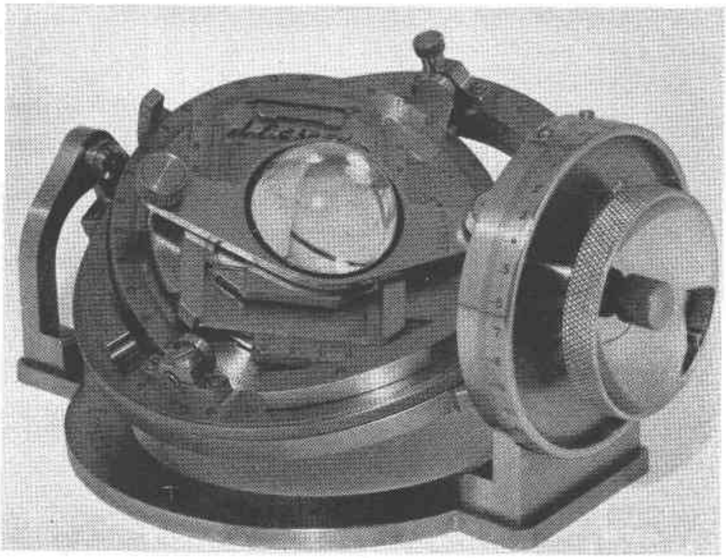


FIG. 1

is confusing. Figure 2 shows a diagram of the stage with the notations of the axes which are used in this paper. For convenience these will be compared with those used by Berek, Reinhard and Emmons (2, 5, 11).

Berek	Reinhard	Emmons	This paper and Winchell
V	M	M	I = vertical rotation axis of the stage of the microscope on which the universal stage is attached.
IV	K	O.E-W	II = horizontal rotation axis of the outer ring of the universal stage. This axis should be in the E-W position.
III	A	O.V.	III = vertical rotation axis of outer ring.
II	H	N-S	IV = horizontal rotation axis of inner stage. This axis must be normal to II in the zero position.
I	N	I.V.	V = vertical axis of inner ring.
		I.E-W	VI = horizontal E-W axis of inner stage of the modified universal stage. This axis should be parallel to II.

The adjustment of the universal stage is described by Berek, Reinhard and Winchell (2, 10, 12). For our purpose careful adjustment is not necessary. The vertical axis of the inner ring should be properly centered and the stage of the microscope should be fixed with the axes II, IV and VI of the universal stage parallel to the vibration directions of the nicols (E-W, N-S and E-W, respectively). This position with the inner and outer stages of the universal stage parallel to the table of the microscope will be called the "zero position" of the universal stage (Fig. 2).

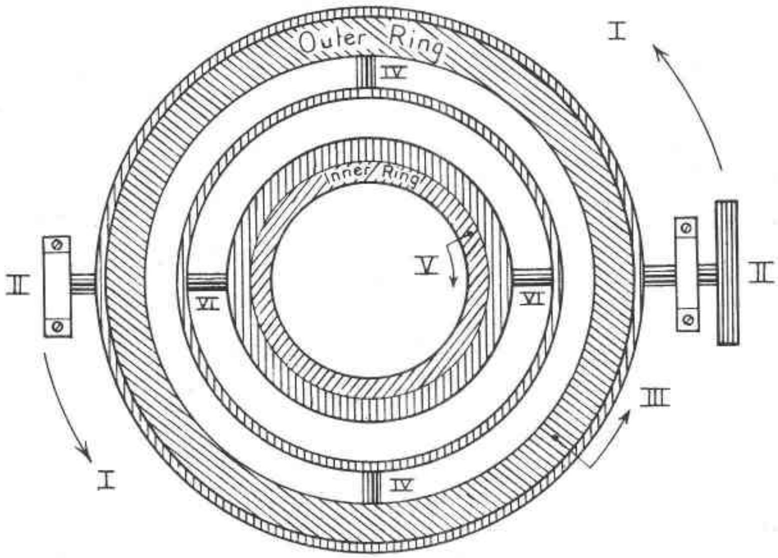


FIG. 2

3. Theory of Distinction Between Uniaxial and Biaxial Minerals

The distinction between quartz and feldspar by means of the universal stage is based on the difference in shape of the indicatrices of uniaxial and biaxial minerals. The indicatrix of a uniaxial mineral is an ellipsoid of rotation and that of a biaxial mineral a triaxial ellipsoid (Figs. 3 A, B; and 4 A, B).

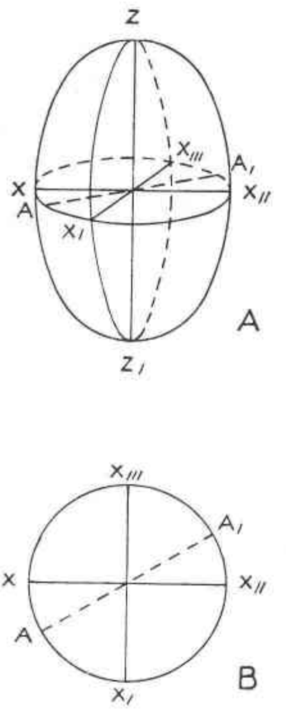
The method is based on three facts:

1. A mineral remains in extinction when rotated on a horizontal axis (II, IV or VI) only when a symmetry plane of the indicatrix is normal to this axis.

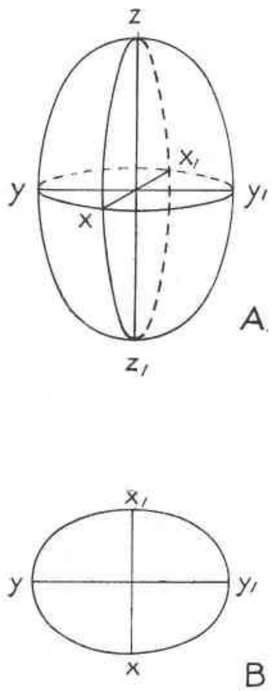
2. Uniaxial minerals have an infinite number of optical symmetry planes parallel to the optic axis and one plane of optical symmetry normal thereto (Figs. 3 A and B).

3. Biaxial minerals have only three planes of optical symmetry which are perpendicular to each other (Figs. 4 A and B).

Those sections through the indicatrix which are important in distinguishing between uniaxial and biaxial minerals will be dealt with separately.



FIGS. 3. A AND B. Indicatrix of uniaxial mineral; $XX_{11}=X_1X_{111}=AA_1$.



FIGS. 4. A AND B. Indicatrix of biaxial mineral; $XX_1 < YY_1$.

A. UNIAXIAL MINERALS

1. *Optic axis perpendicular to the inner stage*

The mineral remains in extinction by rotation of V (vertical axis of inner stage). The mineral also remains in extinction by turning II or IV from "zero position," as one of the many planes of symmetry parallel to the optic axis always remains parallel to the planes of vibration of the nicols.

2. *Optic axis parallel to the inner stage*

If the mineral is brought to extinction by rotating V, the optic axis and the plane of symmetry normal to the optic axis are parallel to the planes of vibration of the nicols. Rotation of II or IV from the zero position does not disturb the extinction, as a plane of symmetry remains parallel to the vibration directions of the nicols. If, in this case, the optic axis is parallel to IV (N-S), the inner stage can be inclined by rotation of IV without changing the extinction. It is important for the distinction between uniaxial and biaxial minerals, however, that subsequent rotation of II does not disturb the extinction. Rotation of IV (optic axis is parallel to IV) only brings another optic plane of symmetry normal to II. If the mineral were biaxial the grains would depart from extinction.

3. *Optic axis inclined towards the inner stage*

If the mineral is brought to extinction by V, the optic axis (and one of the symmetry planes parallel to it) is always parallel to the vibration plane of one of the nicols. If the axis perpendicular to this plane is rotated, extinction remains. The mineral departs from extinction if the other horizontal axis is turned. The optic axis is inclined to this axis and moves out of the vibration direction of the nicols. If the latter rotation axis were IV and were rotated 30°, the extinction of the mineral could be restored by rotation of V (vertical axis of inner ring). The optic axis will again be parallel to the N-S vibration plane of the nicols and subsequent rotation of II does not disturb the extinction (a biaxial mineral would depart from extinction). This holds only if the optic axis is normal to II. If the optic axis is parallel to II, V should be rotated 90° in order to bring it normal to II. This is not necessary when the modified stage is used. The inner table should then be inclined by VI. The extinction should be restored by V, followed by rotation of IV instead of II.

B. Biaxial Minerals

1. *Optic axis normal to the inner stage*

The mineral remains practically at extinction by rotating the vertical axis of the inner stage. The mineral, however, remains at extinction by rotation of II or IV from zero position only if the plane of the optic axes (one of the three planes of symmetry of the triaxial indicatrix) is parallel to the plane of vibration of one of the nicols. (Uniaxial minerals in this position remain at extinction by rotation of either II or IV.)

2. *An axis of symmetry of the triaxial ellipsoid is perpendicular to the inner stage*

Two planes of symmetry (Fig. 5 A, ZXZ_1X_1 and XYX_1Y_1) are perpendicular to the inner stage and will be normal to II and IV, if the mineral is turned to extinction by V. The rotation of II or IV from zero position does not disturb the extinction as the plane of symmetry normal to the axis of rotation remains parallel to the plane of vibration of one of the nicols. After inclination of the inner table by IV, however, rotation of II always disturbs the extinction. This distinguishes uniaxial from biaxial minerals. The reason is explained under 3.

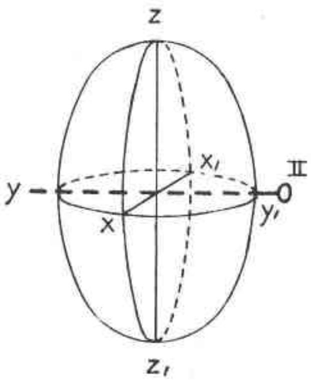


Fig. 5A

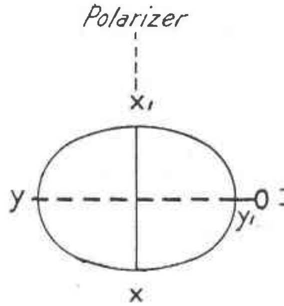


Fig. 5B

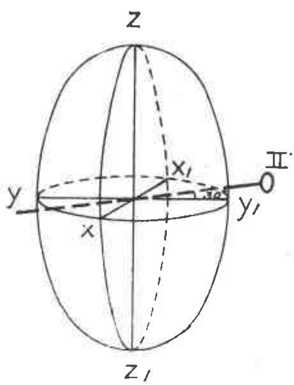


Fig. 6A

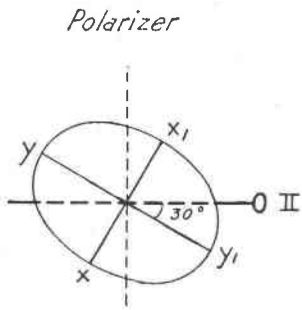


Fig. 6B

3. *Three planes of symmetry of the triaxial indicatrix are inclined towards the inner stage*

If the mineral is brought to extinction by rotation of V, none of the planes of symmetry are parallel to the planes of vibration of the nicols. Only the axes of a sectional ellipse which gives the vibration directions of the ray perpendicular to this section are parallel to the cross-hairs of the microscope. By rotation of II or IV from the zero position the mineral always departs from extinction. This is very difficult to explain and therefore only a simple case will be cited. For instance, if in the zero position of the stage ZZ_1 were parallel to IV (N-S) and YY_1 were inclined 30° to II (Fig. 6A), the mineral would be extinguished as the optical plane of symmetry XYX_1Y (Fig. 6A) is parallel to the E-W vibration plane of the nicols. If II could be rotated 90° (Fig. 6B) the axis YY_1 and XX_1 would make an angle of 30° with the cross-hairs. The mineral would then not be in position of extinction. The rotation from the zero position to the 90° position of II corresponds to a gradual departing from extinction. If II had been rotated only 45° and the mineral then brought to extinction by rotation of V, the mineral would again depart from extinction by rotation of II. This phenomenon can be seen when a small model of a triaxial ellipsoid is placed on the universal stage with none of the axes of optical symmetry parallel to the axes of the stage.

The above data can be summarized as follows:

A. Uniaxial Minerals

If the optic axis is perpendicular to II, rotation of II never disturbs the extinction. By rotation of IV the mineral only remains at extinction if the optic axis is parallel to the inner stage. When the inner table has been inclined 20°–60° by rotation of IV and the mineral is brought to extinction by V, with the shortest interval, rotation of II again does not disturb the extinction.

Mineral sections that are normal to the optic axis (remain dark on rotating V) always remain at extinction on rotating II or IV.

B. Biaxial Minerals

Biaxial minerals remain at extinction only if an axis of the triaxial indicatrix is parallel to a horizontal axis of the stage. If a biaxial mineral, which remains extinguished on rotating II, is inclined 20°–60° by IV and the extinction has been restored by rotating V, it no longer remains at extinction on rotating II.

Mineral sections which are normal to an optic axis remain at extinction by a rotation of horizontal axes only when the plane of the optic axes is normal to this axis.

4. *Manipulations for the determination of the quartz-feldspar ratio with the universal stage*

The determination of each grain generally starts from the zero position of the universal stage. By rotation of V the exact extinction position of minerals which have a low birefringence color (sections nearly normal to an optic axis) is sometimes difficult to find. In such cases it is better to start with the inner table inclined at 40° by rotation of IV.

The distinction between quartz and feldspar is carried out as follows:

1. *Determination of refractive index*

The refractive index of the grain is determined by the Becke-line method. If the refractive index is below that of Canada balsam (about 1.535) the grain is not quartz and is probably feldspar (orthoclase-microcline-albite). If the refractive index is equal to or higher than 1.535, it may be quartz, feldspar (oligoclase-anorthite) or muscovite, etc.

Minerals other than quartz and feldspar can generally be recognized by their shape, refractive index and birefringence.

2. *Determination with the universal stage*

The following manipulations should be applied only for the determination of untwinned feldspar with a refractive index higher than 1.535. If the manipulations are simpler with the modified universal stage (5), the axes which should be used instead are given in brackets following those used for the stage with 4 axes.

MANIPULATION	EXPLANATION
A. MINERAL REMAINS AT EXTINCTION DURING ROTATION OF V.	Optic axis is normal to plane of inner stage.
II is rotated 40° to each side:	
1. If mineral does not remain at extinction it is biaxial.	Unaxial minerals always remain in extinction by rotation of II or IV if optic axis is normal to the stage (page 290, A1).
2. If mineral remains at extinction, II is brought to zero and IV is rotated about 40° to either side. If the mineral again remains at extinction, it is uniaxial, if not, it is biaxial.	Rotation of IV is necessary as the mineral could still be biaxial with the plane of the optic axes normal to II (page 291, B1).
B. THE MINERAL IS BROUGHT TO EXTINCTION BY ROTATING V.	
II is rotated about 40° to both sides and returned to zero position. Afterwards IV is rotated 40° to each side.	
1. If the mineral does not remain at extinction in both cases, it is biaxial.	A uniaxial mineral remains at extinction during at least one of the two rotations (page 291, A3).
2. The mineral remains extinguished only after rotation of IV. II and IV are returned to zero position.	
Inner table is rotated 90° by V. The mineral now remains at extinction only by rotating II. If a modified stage is used this manipulation is not necessary. The notations of the axes	For determination of uniaxial minerals on the stage with 4 axes, the optic axis must be normal to II (page 291, A3).

Manipulation	Explanation
to be used in this case under 3 are placed in brackets following those for the old type of stage.	
3. Mineral remains at extinction only by rotation of II {IV}.	Optic axis of uniaxial mineral is perpendicular to II {IV}, but not parallel to IV {VI}.
Inner ring is inclined about 40° by rotating IV {VI}.	Mineral does not remain at extinction.
Mineral is brought to extinction in this position by rotating V over shortest interval. Now II {IV} is rotated 40° to each side.	If uniaxial: optic axis is again brought normal to II {IV} and a plane of symmetry of the indicatrix will remain parallel during rotation of II {IV} (page 291, A3).
If the mineral remains at extinction it is uniaxial, if not, it is biaxial.	If biaxial: one of the three planes of optic symmetry which has been normal to II now is inclined 40° to II (page 292, B3).
4. Mineral remains dark in both cases.	A plane of symmetry of the indicatrix is parallel to the inner stage (page 290, A2 and page 292, B2).
II is returned to zero position and the inner stage is inclined at 40° by rotating IV. Then II is rotated 40° to each side.	If biaxial, the plane of symmetry which was normal to II, now is inclined 40 to II and the mineral should not remain extinguished during rotation of II.
If mineral remains at extinction it is uniaxial.	A uniaxial mineral remains at extinction by rotation of at least one of the horizontal axes (page 290, A2).
If the mineral does not remain extinguished, II and IV are brought back to zero position. V is rotated 90°. (For modified stage this is not necessary. Use notations in brackets.) Now IV {VI} is inclined 40° and II {IV} is rotated 40° to each side.	Mineral still may be uniaxial if optic axis originally has been parallel to II. Rotation of V over 90° in zero position brings optic axis parallel to IV and normal to II. Further explanation is similar to that of 3.
If mineral remains at extinction, it is uniaxial, if not, it is biaxial.	For uniaxial minerals, see page 290, A2. For biaxial minerals see page 291, B2).

The latter case is the most complicated, but is rare, as it occurs only when a plane of symmetry of the indicatrix is parallel to the inner stage.

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