

- (1966b) Interpretation of the shape of mineral grains in metamorphic rocks. *J. Petrology* **7**, 68–94.
- ROGERS, J. J. W. (1961) Origin of albite in granitic rocks. *Amer. J. Sci.* **259**, 186–193.
- AND D. B. BOGY (1958) A study of grain contacts in granitic rocks. *Science* **127**, 470–471.
- VANCE, J. A. AND J. P. GILREATH (1967) The effect of synneusis on phenocryst distribution patterns in some porphyritic igneous rocks. *Amer. Mineral.* **52**, 529–536.
- WHITFIELD, J. M., J. J. W. ROGERS, AND M. C. MCEWEN (1959) Relationships among textural properties and modal compositions of some granitic rocks. *Geochim. Cosmochim. Acta* **17**, 272–285.

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STAINING FOR CORDIERITE AND FELDSPARS IN THIN SECTION¹

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INTRODUCTION

Often in the course of studying cordierite-bearing rocks it is desirable to know where cordierite is concentrated with regard to relict bedding, gneissic layering, or granitic veins or pods. Even within a thin section, different areas may represent different sub-systems; it is therefore critical, in determining phase equilibrium and variance, to observe without ambiguity the bounding relations of cordierite against other pertinent phases.

Cordierite characteristically lacks *diagnostic* habit, color, pleochroism, distinctive relief, radioactively induced halos, and cleavage. Lamellar twinning (Deer, Howie, and Zussman, 1962, p. 268) superficially resembling that of plagioclase is commonly present. These features make staining a desirable petrographic procedure where the presence of cordierite is suspected. Though the stains and relevant procedures described here have been applied with varying success and should be further refined, we hope the methods will aid those who are studying the metamorphism of aluminous rocks.

Wheeler has experimented with amaranth stain described by Laniz, Stevens, and Norman (1964). Boone has been concerned with a more Mg-specific stain, trypan blue, which Professor M. B. Bayly of Rensselaer Polytechnic Institute had successfully applied to rock slabs and

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which he suggested might be extended to thin section staining as well. Trypan blue was mentioned by Friedman (1959) as a stain for Mg-bearing carbonates. The chief modification reported here involves decreased NaOH concentration for staining thin sections and the use of epoxy cement to insure inertness during immersion in the NaOH solution.

COBALTINITRITE-AMARANTH STAIN

The method of Laniz, Stevens, and Norman (1964) for differentially staining K-rich feldspar and plagioclase in rock slabs has been entirely successful in the Cornell Petrology Laboratory, but has had only limited success as applied to staining thin sections. Apparently the several immersions, required between the HF vapor etch and the final treatment with amaranth, result in destruction of the etched film on plagioclase. Subsequent staining is thus ineffective. This fault can be corrected by an additional brief etch before immersion in BaCl₂ solution.

Laniz, Stevens, and Norman (1964) describe the stain they produce on cordierite as darker than that on plagioclase. The technique described below produces a lighter stain on cordierite than that on plagioclase. There is sufficient difference so that the minerals are readily distinguishable for studies of textural relations and point counts. Therefore this method may be preferable when both plagioclase and cordierite should be stained, especially since one of us (EPW) has found that re-etching after staining plagioclase with amaranth can bleach the plagioclase. Another advantage of the technique of Laniz, Stevens, and Norman is that it requires no special mounting of the thin section. The trypan blue stain may be preferable when only K-rich feldspar and cordierite should be stained, because of the striking contrast between the blue cordierite and the yellow feldspar.

Reagents.

HF, concentrated as received.

Sodium cobaltinitrite saturated solution.

Barium chloride 5% by weight solution in distilled water.

Amaranth, Biological Stain C.I. 16185, 14.2 gm per liter of distilled water.

Perhaps the principal cause of failure when using this technique is weak HF. Acid which has deteriorated to a point at which plagioclase fails to stain is still strong enough to produce a satisfactory stain on K-rich feldspar, thereby causing the operator to believe the acid is satisfactory, and some other part of the procedure is at fault. Even freshly-shipped acid may not be reliable.

If 20 gm sodium cobaltinitrite is added to 60 ml distilled water, there will be a residue of undissolved reagent. The solution remains effective as long as this residue is present, and more reagent may be added as it is used up by decomposition in the solution. It need not be discarded after use; capped tightly, the solution remains fresh. The amaranth solution need not be discarded after use, and appears to be unchanged after more than a year of use.

Apparatus:

Plastic box (for HF) slightly larger than thin section, with plastic cover for the opening when etching is not in progress.

Plastic cover with platinum wire hooks to support thin section over HF.

Hot plates with sensitive control in lower temperature range.

Flexible tubing attached to a source of compressed air.

1 100 ml beaker	Teflon-coated forceps	Petri dish
1 250 ml beaker	3 30 ml beakers	Stop watch

Procedure:

1. Wash thin section surface with detergent solution.
2. Dry on hot plate at a temperature of $\sim 56^{\circ}\text{C}$, in a current of air (from a small fan or compressed air source).
3. Fume 20 seconds in close proximity over HF.
4. Immerse 15 seconds in a 30 ml beaker of sodium cobaltinitrite.
5. Wash briefly with tap water followed by distilled water from wash bottle. Total time should not exceed 15 seconds.
6. Dry thoroughly on hot plate as in step 2.
7. Fume 7 seconds over HF as in step 3.
8. Immerse with agitation in 30 ml beaker of barium chloride solution.
9. Dip twice briefly in 100ml beaker of fresh distilled water.
10. Press section face-down on folded Kimwipe backed by paper towel to absorb free moisture.
11. Dry on hot plate as in step 2.
12. Immerse section in 30 ml beaker of amaranth solution for 15 seconds.
13. Dip briefly 4 times in 250 ml beaker of fresh tap water, removing most of the amaranth solution.
14. Blow off remaining liquid with compressed air, resting edge of thin section on paper towel to absorb liquid driven to this edge by air stream.

The following comments are numbered to correspond with the steps of the procedure to which they apply.

1. A freshly-prepared, clean thin section needs no washing.
2. A sheet of paper toweling on the hot plate helps to prevent excessive heating of the thin section and absorbs moisture from the back of the thin section.
3. Mild heating of the acid will counteract the effect of reduced HF content. Tentatively, the temperature of the acid should be increased as many degrees above 20°C as the HF percentage is decreased below 50%. If a series of sections is treated in close succession, a blank slide may be run first, to decrease the initially high fume concentration with regard to the subsequent working range.
5. Water should be streamed over the thin section from the edge to avoid damaging etch films on mineral surfaces. Washing time in this and subsequent steps should be kept to a minimum to avoid leaching of films.
10. Pools of moisture that remain on the thin section can cause a concentration of BaCl_2 where they dry, and resultant excessively dense amaranth stain.
13. Since amaranth is water-soluble, excessive washing will unduly reduce the stain density. On the other hand, if the stain is too dense it can be thinned by additional washing, and the density of spots where BaCl_2 solution has dried can be reduced by judicious application of a stream of water from the wash bottle.

TRYPAN BLUE STAIN

Materials: only thin sections in which epoxy adhesive is the bonding agent are suitable for this method.

- HF, concentrated as received.
- Trypan blue (Diamine blue 3B).
- Methyl alcohol (methanol).
- 10 wt. percent aqueous solution NaOH.

Preparation of staining solution (cf. Friedman, 1959).

1. Dissolve 0.2 gm trypan blue powder in 25 ml methanol. Mild heating and stirring are necessary to disperse the powder effectively, as it tends to form small polygranular clumps. Add methanol if necessary to maintain volume of solution.
2. Add 15 ml of 10 percent NaOH solution to the trypan blue-methanol mixture and heat to approximately 50°C, for staining.

Procedure: make certain that the section has been mounted with epoxy adhesive, as Canada balsam and Lakeside are rapidly attacked by NaOH.

1. Etch the surface of the thin section as for cobaltinitrite stain. Stain for K-rich feldspar, or for plagioclase first, if desired, then re-etch the surface for 7 seconds at room temperature (22°C) over HF fumes. Do not rinse or otherwise disturb the re-etched surface.
2. Immerse the etched section in warm trypan blue basic solution. Effective immersion time varies from 30 seconds to a minute. Withdrawing and rinsing the section for inspection followed by re-immersion is not recommended.

Discussion: It is recommended that crushed grains of the rock in question be tested first, to determine the best immersion time in the trypan blue solution. Grain size of the rock will determine what sieve fraction is best to spread lightly on glass slides which have been freshly coated with 'rubber cement.' Staining time cannot be indefinitely long, as plagioclase will begin to pick up the stain after cordierite. How soon after appears to be directly related to the An-content of the associated plagioclase. Hornblende, chlorite (and probably other Mg-rich phases) will also accept the stain, but this is not detrimental to further optical studies of any of the associated phases. Once stained, slides may be covered at room temperature with Permunt or a similar mounting medium to secure cover slips to the slides. No deterioration of the stain is evident on uncovered or covered slides which were stained over 14 months previous to this writing.

As yet limits cannot be placed on the variation of stain acceptability with variation of cordierite distortion index (Miyashiro, 1957) less than 0.08 or greater than 0.29 or with compositions more Fe-rich than 34 mole percent. It is doubtful that distortion index, small amounts of alkalis or ferric iron, or H₂O content (Schreyer and Yoder, 1964) will affect the applicability of the stain, although it is predictable that unusually Fe-rich cordierites may not take the trypan blue stain. Cordierites strongly pinitized and exhibiting a yellowish color (presence of cryptocrystalline

ferric oxide(?) admixed with muscovite \pm chlorite) will not accept staining.

Several attempts were made to test the compatibility of the cobaltinitrite and amaranth stains with the trypan blue stain on sections of fine-grained microperthite-cordierite-oligoclase-bearing granofelsels from western Maine. The chief difficulty seems to be in the K-rich feldspar retaining its cobaltinitrite stain through two successive short re-etchings over HF fumes. Judicious overstaining with cobaltinitrite followed by amaranth and trypan staining has so far yielded promising, but far from consistent results. However, no difficulty has been experienced in dual staining of K-rich feldspar and cordierite with cobaltinitrite and trypan blue.

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REFERENCES

- DEER, W. A., R. A. HOWIE, AND J. ZUSSMAN (1962) *Rock-forming minerals*, 1, *Ortho- and ring silicates*, John Wiley and Sons, New York.
- FRIEDMAN, G. M. (1959) Identification of carbonate minerals by staining methods: *J. Sediment. Petrology*, 29, 87-97.
- LANIZ, R. V., R. E. STEVENS, AND M. B. NORMAN (1964) Staining of plagioclase feldspar and other minerals with F. D. and C. Red No. 2: *U. S. Geol. Surv. Prof. Pap.* 501B, B152-B153.
- MIYASHIRO, A. (1957) Cordierite—indialite relations: *Amer. J. Sci.*, 255, 43-62.
- SCHREYER, W., AND H. S. YODER, JR. (1964) The system Mg-cordierite-H₂O and related rocks: *Neues Jahrb. Mineral., Abhandl.*, 101, 271-342.

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ON THE STAINING OF ANORTHOCLASE¹

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Various staining procedures have been used to distinguish feldspar. Literature on the subject has been recently reviewed by D. Laduron

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