

An intergrowth of calcic labradorite in a plagioclase-quartz-biotite gneiss from Broken Hill, New South Wales

EVAN R. PHILLIPS, BRYAN E. CHENHALL, IAN J. STONE, AND J. W. PEMBERTON

Department of Geology, University of Wollongong, Wollongong, N.S.W. 2500, Australia

SUMMARY. Compositions of An_{61} and $An_{69.5}$ have been determined for two domains in plagioclase from a gneiss. Optical properties indicate that the same compositions apply respectively for an intergrowth of 'matrix' and lamellae found in zones between the domains. The intergrowth appears to span the composition range between the Bøggild and Huttenlocher intergrowths.

THE plagioclase feldspar intergrowth described in this paper was obtained from a plagioclase-quartz-biotite gneiss containing minor amounts of garnet, muscovite, and opaque minerals. This rock belongs to a series of gneisses outcropping as elongate layers on both the eastern and western sides of the Broken Hill orebody in New South Wales.¹

Descriptions of the intergrowth. Under relatively low magnification the plagioclase shows an irregular, patchy, almost undulatory extinction with no regular zonation (fig. 1). Near extinction, in sections normal to $[100]$, two domains with slightly different birefringence are clearly indicated by an extinction angle difference of 6° . The light-grey areas in fig. 1 are the more calcic and have an extinction angle of 41° and the darker areas are more sodic with an extinction angle of 35° .

Under higher power an irregularly distributed, extremely fine system of slightly undulatory lamellae can be seen (light-grey lines in fig. 1). Towards the darker areas these lamellae taper and probably grade into the suboptical range, whereas they coalesce towards the more calcic light-grey domains. Outlines of the lamellae are also visible in plane-polarized light due to differences in refringence. The darker domains pass, either abruptly or gradually, into an intermediate zone of light-grey lamellae set in a dark 'matrix'. The ratio of 'matrix' to lamellae decreases towards the lighter-coloured more calcic areas. (Locally these calcic areas appear to be essentially tightly packed light-grey lamellae giving the impression of a virtually homogeneous domain.) The light-grey lamellae extinguish with the light-grey domains and the dark 'matrix' extinguishes with the dark domains, indicating optically corresponding compositions for the light and dark parts of the crystal. The intergrowth is seen most clearly down $[100]$ and the lamellae make an angle of 16° to 20° against (010) . This intergrowth pattern reflects across albite twin planes (cf. Vernon, 1965, fig. 9).

An electron microprobe was used to determine the composition of various points throughout one plagioclase crystal. The analyses listed in Table I were obtained at the Australian National University with a Delft electron probe, incorporating a Leitz microscope and an Ortec energy dispersive detection and analysis system (Reed and Ware, 1973). Each site selected for analysis was accurately positioned using transmitted and reflected light photomicrographs of the crystal.

¹ An account of some of these gneisses appears in the Miniprint section of this volume, p. M20.

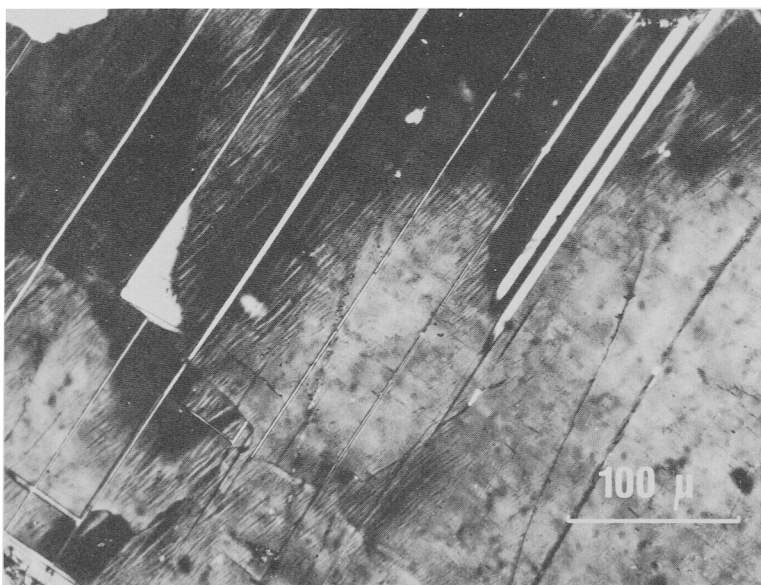


FIG. 1. Photomicrograph of plagioclase crystal. The dark domains are relatively sodic (An_{61}) and the light-grey domains are relatively calcic ($An_{69.5}$). Between the two, intergrowths of light-grey lamellae (rather than spindles) set in a dark 'matrix' may be seen. These lamellae make an angle of 16° to 20° against (010) (set approximately NE. to SW.). The basal cleavage runs approximately WNW. to ESE. parallel to twins at the bottom left of the photograph.

The analyses listed in Table I are representative compositions of the more calcic light-grey domains (1 and 2), the more sodic dark domains (3 and 4), and zones comprising intergrowths of both light and dark areas between these two domains (5 and 6). The results indicate that the more calcic domains have a composition close to $An_{69.5}$ (mole %), the more sodic domains are close to An_{61} , with intermediate zones, where the electron beam impinged upon a mixture of lamellae and matrix, ranging from about An_{64} to An_{67} . Twenty-four random point analyses within the plagioclase gave an average composition of $An_{67.7}$. Fifteen analyses selected to show compositional differences between light domains (5 analyses), darker domains (7), and intermediate zones (3) gave an average of $An_{64.6}$. We suggest that the bulk composition of the feldspar lies near these values. This compares with the $An/(Ab + An)$ value of 69.13 wt % from the norm calculation derived from a chemical analysis of the rock. Measurements from X-ray diffraction patterns of $\gamma = 2\theta(1\bar{3}1) + 2\theta(220) - 4\theta(1\bar{3}1)$ plotted against wt % $An/(An + Ab)$ (Smith, 1974a, figs. 7-42) show that the plagioclase has an intermediate structural state.

We have proposed that the compositions An_{61} and $An_{69.5}$ indicate the An content of apparently homogeneous dark and light-grey domains respectively. However, the notion that each may represent an 'average' composition of suboptical intergrowths cannot be completely discounted.

Discussion. Smith (1974a and b, p. 519) recognized two types of fine intergrowths in calcic plagioclases: the Bøggild intergrowth (Laves, Nissen, and Bollman, 1965) and the Huttenlocher intergrowth (Huttenlocher, 1942; Jäger and Huttenlocher, 1955). The Bøggild intergrowth may occur where the bulk composition ranges from about An_{48} to An_{59} ; the lamellae are a sodic phase about An_{45} and a calcic phase about An_{60} (Smith 1974b, p. 519). The Huttenlocher intergrowth is found in plagioclases with bulk compositions between An_{67} and An_{90} ; the compositions of the two sets of lamellae here are about An_{67} and An_{95} .

TABLE I. *Electron-microprobe analyses of points in calcic labradorite*

	1	2	3	4	5	6		1'	2'	3'	4'	5'	6'
SiO ₂	49.39	49.89	52.45	52.55	51.98	50.05	Or	0.86	1.03	0.63	0.79	0.56	0.86
Al ₂ O ₃	32.14	32.17	30.94	31.22	31.96	31.88	Ab	29.42	29.86	38.43	38.40	34.99	32.29
CaO	14.46	14.41	12.77	12.78	13.63	13.90	An	69.72	69.11	60.94	60.81	64.45	66.85
Na ₂ O	3.37	3.44	4.45	4.46	4.09	3.71							
K ₂ O	0.15	0.18	0.11	0.14	0.10	0.15							
	99.50	100.09	100.72	101.15	101.76	99.69							

1 and 2 From light-grey areas as shown in fig. 1.

3 and 4. From dark areas as shown in fig. 1.

5 and 6. From intermediate zones between dark and light-grey domains.

1' to 6'. Molecular per cent.

Analysts: B. E. Chenhall and I. J. Stone.

We have assumed that the end-member compositions obtained in our work are given by the compositions of the two domains, that is An₆₁ (for 'matrix') and An_{69.5} (for lamellae). These compositions cannot be correlated with the Bøggild intergrowth and only just correspond for a small part of the range with the Huttenlocher intergrowth (Smith, 1974*b*). However, differences may occur. For example, the unzoned patchy development that we have described may not be present in the other intergrowths, cf. Nissen (1974, fig. 2, where his data indicate reverse zoning). In addition, the presence of relatively sodic domains free from lamellae may be unusual. We believe that the intergrowth described here is a phase transformation resulting from the solid-state dissociation of a homogeneous calcic plagioclase. We note that the end-member compositions for the Broken Hill plagioclase described above virtually span the difference between the calcic phase of the Bøggild intergrowth and the sodic part of the Huttenlocher intergrowth. It is thus quite conceivable that the Broken Hill example is a third type of intergrowth of calcic plagioclase situated in the compositional gap between the Bøggild and Huttenlocher intergrowths.

Acknowledgements. We would like to thank the following people for help in the preparation of this note: at the Australian National University, Mr. N. G. Ware; at the University of Wollongong, Mr. A. J. Kantsler, Mrs. S. Greenwood, Mrs. P. Taafe, and Dr. R. A. Facer. Financial assistance from the Broken Hill Mining Managers' Association and a University of Wollongong Special Research Grant is also gratefully acknowledged. A brief discussion of the problem with Professor J. V. Smith and a critical appraisal of the paper by Professor W. Scott MacKenzie are much appreciated.

REFERENCES

- Huttenlocher (H. F.), 1942. *Schweiz. Mineral. Petrogr. Mitt.* **22**, 366.
 Jäger (E.) and Huttenlocher (H. F.), 1955. *Ibid.* **35**, 199.
 Laves (F.), Nissen (H.-U.), and Bollman (W.), 1965. *Naturwiss.* **14**, 427.
 Nissen (H.-U.), 1974. In MacKenzie (W. S.) and Zussman (J.), eds., *The Feldspars*, 491. Manchester University Press.
 Reed (S. J. B.) and Ware (N.), 1973. *X-ray Spectrosc.* **2**, 69.
 Smith (J. V.), 1974*a*. *Feldspar Minerals*, **1**. Berlin (Springer Verlag).
 ——— 1974*b*. *Ibid.* **2**.
 Vernon (R. H.), 1965. *Mineral. Mag.* **35**, 488.

[Manuscript received 29 November 1976, revised 4 January 1977]