# The iridescent feldspars

To the physicist interested in the structure and properties of crystalline solids, the feldspars offer themselves as a fascinating field for study and research. Being a most important group of rock-forming substances, they have naturally been the subject of numerous painstaking investigations by mineralogists. A great volume of data concerning them has accumulated, and much of this awaits interpretation in terms of structural theory. Of particular interest is the optical behaviour of the feldspars. This includes a variety of attractive phenomena for which no satisfactory explanation has hitherto been forthcoming. Amongst them may be mentioned particularly the brilliant play of colours exhibited by the species of feldspar known as labradorite, which is found not only in the locality from which its name is derived, but also in various other parts of the world. Another group of feldspars known as the moonstones has found use in jewellery by reason of a beautiful optical effect known to mineralogists as "schiller" which they display. There are also other types of feldspar which display characteristic optical effects, e.g., peristerite, murchisonite and amazonite. Labradorite and the moonstones have been the subject of two recent memoirs* published in the *Proceedings* of the Indian Academy of Sciences. Further papers dealing with other types of iridescent feldspars are scheduled to appear in the same journal in the near future. It is felt, however, that the results so far obtained are of sufficient general interest to justify the publication of a review article in *Current Science*, presenting this field of research in its broadest aspects.

Chemical analysis shows that apart from minor impurities present as inclusions, the commoner feldspars may be regarded as admixtures of three components having a definite composition, namely the potash, soda and lime feldspars. Their mineralogical names and chemical formulae are respectively orthoclase ($KAlSi_3O_8$), albite ($NaAlSi_3O_8$), and anorthite ($CaAl_2Si_2O_8$). In their external aspect as well as in the internal structure revealed by X-ray studies, all the feldspars possess certain features in common. Nevertheless, there are important differences. In particular, we remark that while the chemical formulae of orthoclase and albite are similar, the replacement of the monovalent alkali ion

*"The Structure of Labradorite and the Origin of its Iridescence," by Sir C V Raman and A Jayaraman, *Proc. Indian Acad. Sci. A.*, 1950, **32**, 1–16.
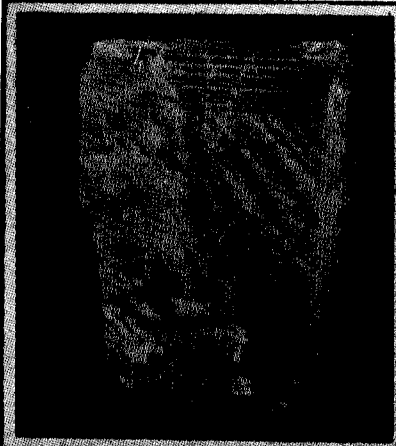†"The Structure and Optical Behaviour of the Ceylon Moonstones," by Sir C V Raman, A Jayaraman and T K Srinivasan, *Ibid.*, 1950, **32**, 123–40.
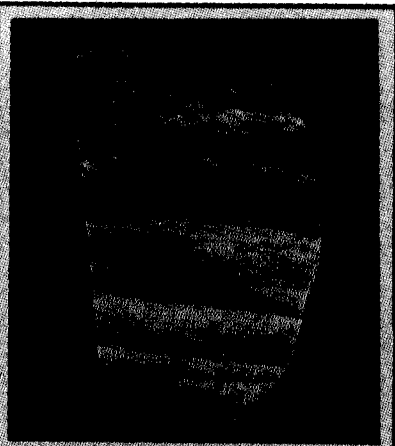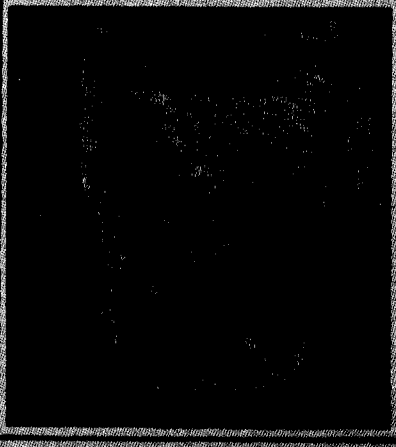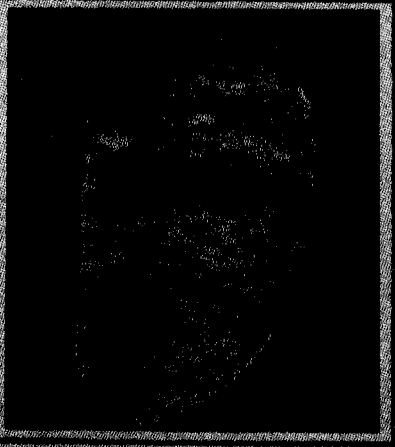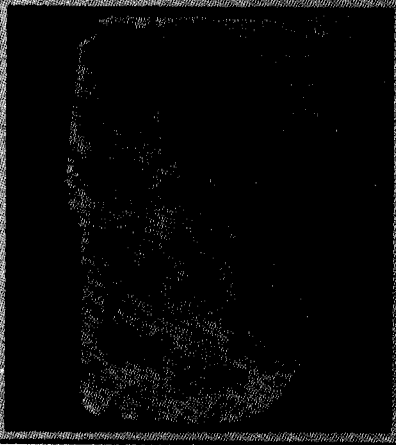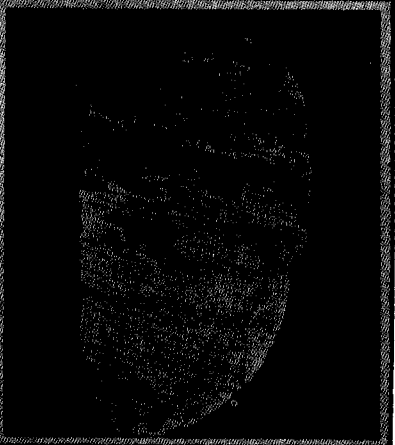
(A)

(B)

(C)

Figure 1

(A)

(B)
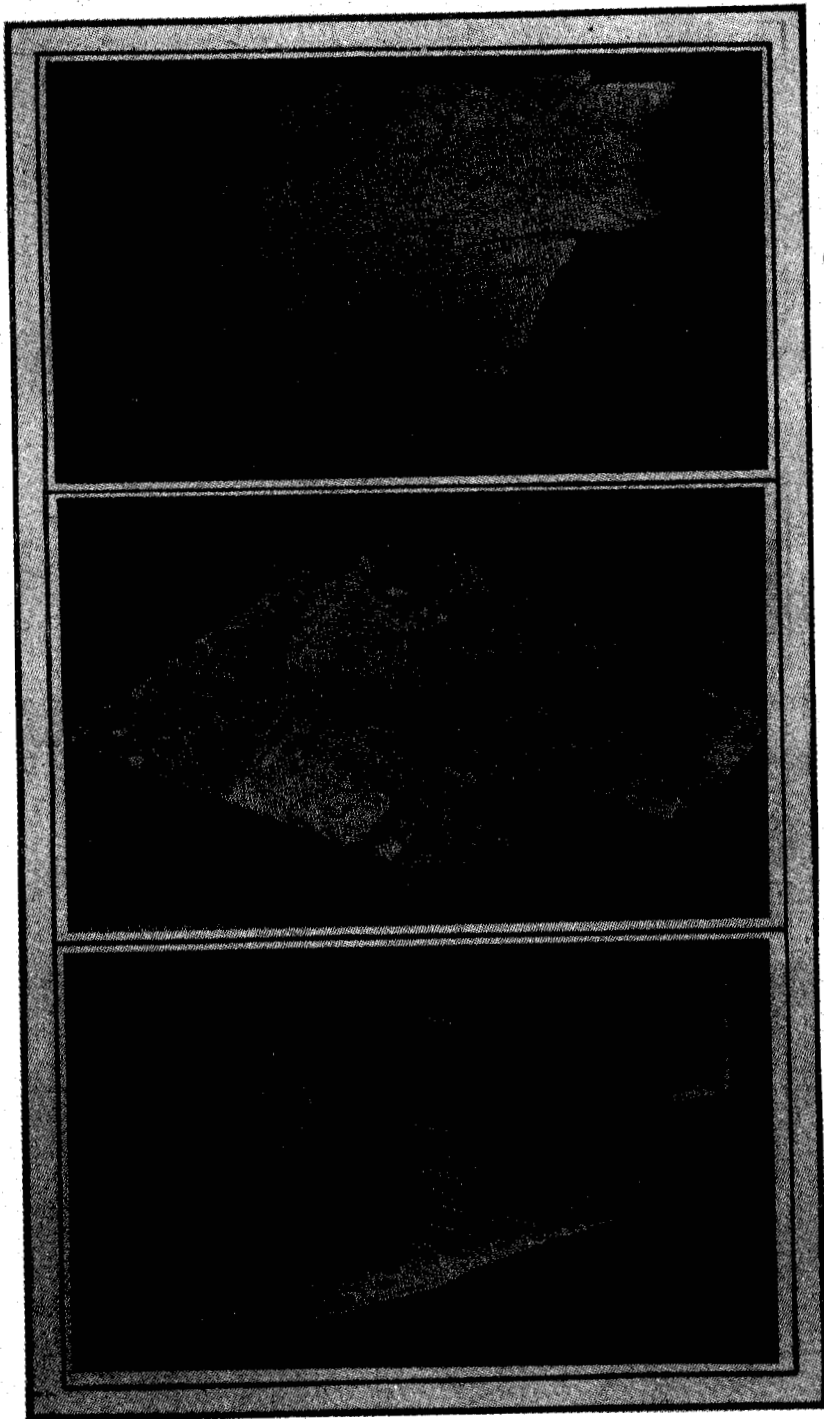
(C)

Figure 2

Figure 3

by the divalent calcium ion in anorthite is accompanied by a simultaneous replacement of a silicon atom by an aluminium atom. In spite of such replacement, albite and anorthite resemble each other in their crystal forms very closely, both being triclinic, while orthoclase is a monoclinic crystal. The explanation which has been given for this remarkable situation is that the replacement of silicon by aluminium does not involve any alteration in crystal structure, while on the other hand, the replacement of the larger potassium ion by the smaller sodium or calcium ion results in a definite change of structure.

It has been stated above that a naturally occurring feldspar usually contains all the three components. Their relative proportions, however, vary considerably. Labradorite, for instance, is principally a mixture of albite and anorthite in roughly equal molecular proportions, but contains in addition an appreciable proportion of orthoclase. The Ceylon moonstones consist principally of ortho-clase, but include also a substantial proportion of albite and a small percentage of anorthite. In view of the differences in chemical composition and crystal structure of the three components in their pure state, the question naturally arises of the precise nature of their admixture in any particular feldspar as found in nature. In the two papers under reference, it has been shown that the answer to this question is furnished by the optical behaviour of the material under study. In other words, the play of colours exhibited by labradorite, and the schiller of moonstones are alike the optical consequences of the manner in which the component feldspars are distributed within the respective minerals. In the common or macroscopic sense, both labradorite and moonstones are monocrystals. But the passage of a beam of light through the mineral and the diffusion of light resulting therefrom reveal the existence of optical heterogeneity, in other words, of local variations of composition and refractive index. The observed characters of the diffused light, viz., its spectral nature, intensity, state of polarisation and distribution in different directions, and their variations with the setting of the crystal and the direction of passage of light through it, furnish us with the data needed to infer the nature of the local heterogeneities within the crystal. The explanation of the optical phenomena presented by these feldspars thereby ceases to be a matter for conjecture or speculation and rests instead on a solid basis of observation and inference.

The optical behaviour of a mixed crystal is, of course, not comparable in all respects with that of a mixture of liquids. Nevertheless, it is useful to indicate the resemblances between the optical phenomena under consideration and the diffusion of light in binary and ternary liquid mixtures. The blue schiller exhibited by the finest moonstones may, indeed, be not inaptly compared in its origin and in its spectral character with the blue opalescence which develops in a binary liquid mixture, e.g., of methanol with carbon disulphide, as its critical solution temperature is approached. The schiller is essentially a diffusion of light within the feldspar. It results from the segregation of the albite from the orthoclase in the form of tiny crystallites which so dispose themselves that the crystalline order and
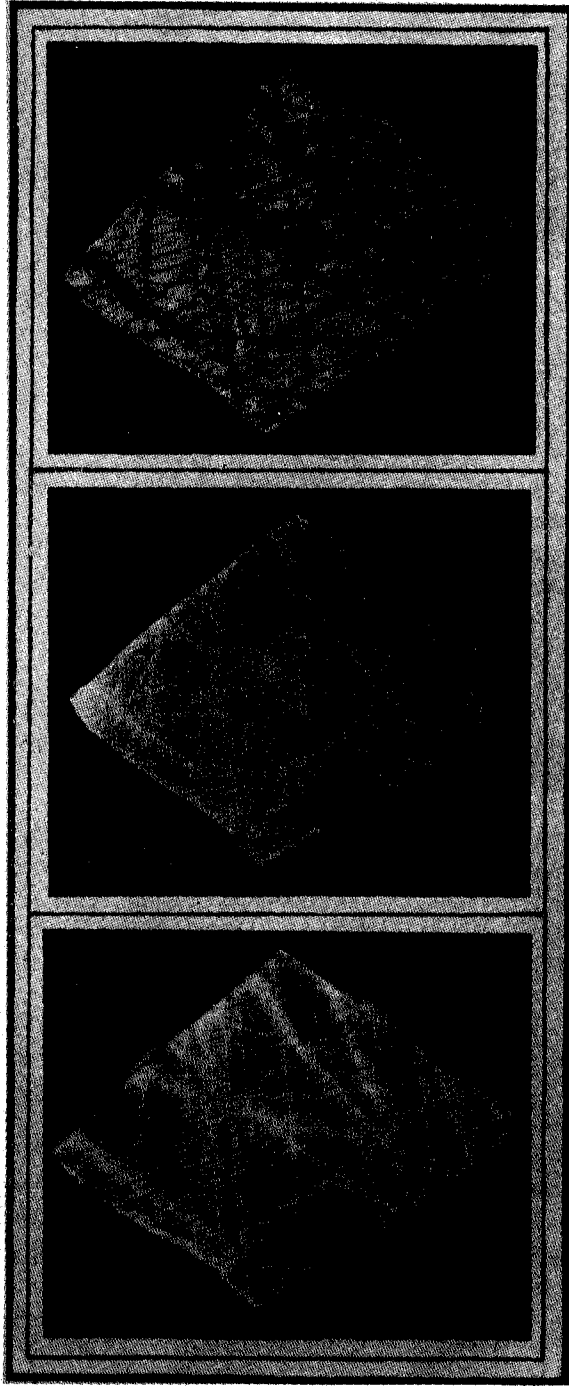
A

B

Figure 4

symmetry of the parent mass is left unimpaired. The blue colour exhibited by many specimens of labradorite may similarly be compared with the blue opalescence which develops when water is added to methanol containing benzene in solution, and the benzene tends to separate out in consequence. The diffusion of light in the labradorite which manifests as its iridescence is due to tiny crystallites of orthoclase which have segregated from the albite-anorthite mixture and set themselves in an appropriate orientation within the crystal lattice.

The interested reader will naturally refer to the original papers for further information regarding the topics dealt with above in their barest outlines. They contain a description and discussion of many facts of interest discovered in the course of the studies and which considerations of space preclude even being mentioned here. The illustrations accompanying the present article are taken from the paper on labradorite and represent four of the numerous specimens studied. As the reproductions are not in colour, they are not very effective as pictures of the beautiful phenomena actually observed. But they demonstrate a most important feature of the optical behaviour of labradorite, namely that it shows its characteristic iridescence in *two* different settings of the crystal with reference to the direction of the incident light. These settings (A and C in each figure) lie one on either side of the setting (B in each figure) at which the aventurinism due to the macroscopic inclusions is most prominently displayed. The parts of the labradorite which exhibit the iridescence in the two settings are different, being respectively the alternate layers of multiple twinning in the mineral. The distribution of these layers as well as the nature of the twinning is very different in the four specimens. This becomes evident in the iridescence displayed by them.

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