"If $a_{ij}$ be the number of elements common to the $i$th and $j$th sets of an incomplete block design, each element occurring in $r$ blocks and each pair of elements in $\lambda$ blocks, then the square matrix of $b$ rows formed of the elements, $a_{ij}$, is the product of the marix (pq) of $b$ rows and $v$ columns and its transpose (qp) of $v$ rows and $b$ columns where we write 0 in the empty spaces of the matrices and 1 in the occupied spaces."

Consider the determinants derived from the matrices, where the necessary number of zero rows or zero columns are added if $b \neq v$ to make it square. Hence, $|a_{ij}| = 0$ if $b \neq v$ and $a_{ij}$ is a perfect square if $b = v$.

In the case of the symmetrical block design, $a_{ij} = \lambda$ $(i \neq j)$ and $a_{ii} = k = r$ and in the other case, at least two $a_{ij}$'s are unequal. The proof of this and also of the relation $v \leqslant b$, is obvious from the following identity proved by the author,[1]

$$\Sigma (a_{ij} - a_{ik})^2 = (k-1)(r-k)(r-\lambda)^2 \leqslant$$

where $i$ is fixed and $j$, $k$ run over all values except $i$ not exceeding $b$. The value of the determinant $|a_{ij}|$ in the symmetrical case is a particular case of that given by Salmon[6] and can be shown to be equal to $r^2 (r - \lambda)^{v-1}$.

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Waltair,
*January* 14, 1951.

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## RAMAN SPECTRUM OF APOPHYLLITE

APOPHYLLITE (KF Ca$_4$ Si$_8$ O$_{20}$·8H$_2$O) is unique among the silicates in that it bears a close resemblance to the micas in its structural characteristics, while like the Zeolites it is capable of giving off its water-content on heating and reabsorbing it on cooling. Only a study of the dehydration curve and the optical anomalies exhibited by apophyllite are on record. If Pauling's rule is to be obeyed, the water content in this crystal has to be incorporated as HO-H-O groups rather than in the customary way. This seems to be corroborated by the appearance of only one high frequency shift Raman line in its spectrum.

The Raman spectrum of a natural specimen of apophyllite was photographed using the $\lambda$ 2537 radiation of a quartz mercury arc as exciter. The incident light was normal to the (001) cleavage face, while the scattered light was gathered edgewise along [100] direction. Its spectrum consists of 19 lines with frequency shifts 90 (1), 108 (3), 138 (2), 166 (1), 187 (1), 209 (2), 232 (1), 280 (1), 307 (2), 344 (2), 355 (1), 433 (1), 488 (2), 541 (2), 586 (2), 820 (1), 1080 (5) and 3520 (10), the first 18 of which are reproduced in the accompanying figure. It is found that while the lines 90, 166, 209, 232 are depolarised, lines 108, 138, 187, 1080 and 3520 are strongly polarised when unpolarised light is incident along the optic axis and the scattered light is taken normal to the (100) cleavage face.
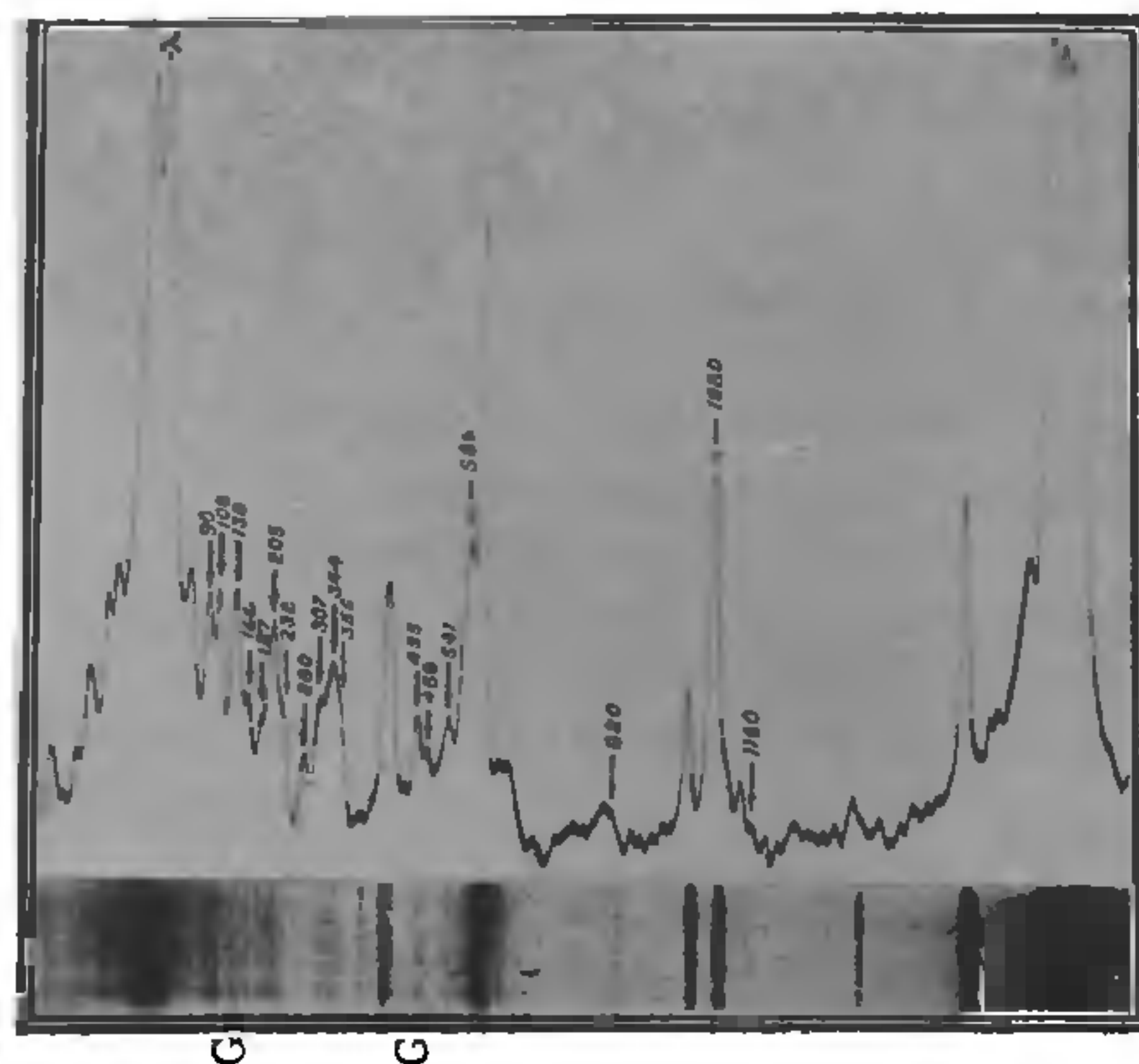


FIG. 1

(*a*) Raman Spectrum of apophyllite taken with $\lambda$ 2537 excitation.

(*b*) Its Microphotometer record.

The structure of apophyllite is based on linked silicon oxygen sheets of a tetragonal type, the adjacent sheets being linked by cations (Ca, F and K) on reflection planes. A calculation of the possible number of vibrations of the different symmetry types of the two molecules contained in the unit cell show that as many as 103 frequencies may be expected to appear in Raman effect. Also in the particular orientation studied, all except the 41 frequencies of the degenerate class E should be fully polarised and as such a tentative assignment can be made as given below.

| Symmetry type | $A_{1g}$ | B | $E_g$ |
|---|---|---|---|
| Frequency observed | 3520 | 108, 138 | 90, 166, 209 |
| | 1080 | 187 | 232 |

The author is grateful to Prof. R. S. Krishnan for suggesting the problem.

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*March* 14, 1951.

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## SCHILLER IN MOONSTONE

I HAVE read with interest the article on the above subject in the October 1950 issue of *Current Science* and also the original paper referred to therein.[1] Some of their references are to earlier work carried out by me, and as I cannot fully subscribe to the interpretations or the conclusions arrived at, I would welcome this opportunity to discuss these in your journal.

I. *Schiller Plane or Schiller Axis.*—The schiller plane of the potash-soda moonstone felspars has been measured by a number of workers[2] (and see reference therein pp. 309-10). The values obtained by them vary between the angles of 72° and 75°·5 as measured on the trace of 001, the plane cutting the c-axis negatively and being perpendicular to 010. The mean value obtained by me for Ambalangoda moonstone was 73°·53' and with $\beta = 63°·57'$ the plane thus makes an angle of 9°·56' with the c-axis. Raman, Jayaraman and Srinivasan prefer to make use of the schiller axis, *i.e.*, the normal to the schiller plane. They give the direction of this schiller axis as 81° to the c-axis and state that the schiller plane makes an angle of 9° with 100 that is with the c-axis. In view of their cursory reference to other determinations of this schiller plane, it is surprising that no information is supplied as to how their own measurements were made. Moreover, without qualification their figure of 81° to the c-axis is ambiguous as it includes two arbitrary directions. However, it is fairly certain that the direction obtained by them is in the same sense as that of previous workers, *i.e.*, that the schiller plane cuts the c-axis negatively. If this is the case, their value of 9° is very close to the figure of 9°·56' obtained by me. The difference is probably well within the limits of their experimental error. Again, within the limits of experimental error, *this plane is identical with the mean plane in which the micro- and crypto-perthitic structures lie in these potash-soda moonstone felspars*, as measured by various workers.

II. *Micro- and Crypto-Perthitic Structure and Schiller.*—Raman, Jayaram and Srinivasan discount the suggestion that the schiller of these blue and white moonstones is connected with the perthitic structure, stating "the coarse structure of which indications are observed under low powers of the microscope in certain other cases is *prima facie* incapable of giving rise to the optical phenomena under consideration". But is this the case? The micro- or crypto-perthitic structures described and photographed by me[2] (pp. 302-12 and plates) in the blue-white Ambalangoda moonstones show lamellæ ranging in thickness from ·001 millimetre downwards the majority lying between ·001 and ·0005 millimetre. Now ·0005 millimetre is below the wave-length of the middle part of the visible spectrum, and it will be evident from the description referred to above that this value cannot represent the lower limit of thickness of these lenses or films. These lamallæ are not flat plates as the writers apparently assume them to be, but are in reality flattened cigar or pencil-shaped bodies tapering away at the edges. Their length—in the plane of 010—is roughly 50 times and the breadth—along the b-axis—is about 10 times the mean thickness. They tend to finger off in the b-axis direction along prism planes.

I submit that these dimensions are of a much lower order than that indicated by the above quotation and that they lie within the limits required for producing the blue to white schiller by the scattering and reflection of light by these bodies.

The writers make a strong point of their observation that the schiller range is several times greater when measured on the c-axis of rotation than when b is the rotating axis. I submit that this is precisely what one would expect if the schiller is due to the minute lenticular bodies described above, with a length much greater in a direction perpendicular to the b-axis than is their breadth parallel to this direction.

The fact that moonstones with white schiller show relatively coarser and more sharply defined micro- and crypto-perthitic structures would also follow from the increasing proportion of the visible spectrum scattered and reflected by these minute bodies.

It may be said that of the many hundreds of transparent or semi-transparent micro- and