is linear in the shear stress, then, by comparison with the data at 147 kb, the shear stress above the HEL must be less than about 20 kb. Thus these experiments confirm, by a completely different method, the conclusion of *Graham and Brooks* [1971] that sapphire loses most of its shear strength when it is shocked above the HEL. This experimental technique, with improved accuracy, has potential as an internal strain gage for detecting anisotropic strains in shock studies.

The measured value of Dq can be compared with that predicted by a point charge model [*McClure*, 1959], if it is assumed that the local compressibility about the Cr^{3+} ion is equal to the bulk compressibility of its host Al_2O_3. For a perfect octahedron such a model predicts that Dq should be proportional to $V^{-5/3}$, where V is the molar volume of sapphire. *Stephens and Drickamer* [1961] found that this model worked very well for hydrostatic compression up to 150 kb (3.5% compression) for Cr^{3+} in
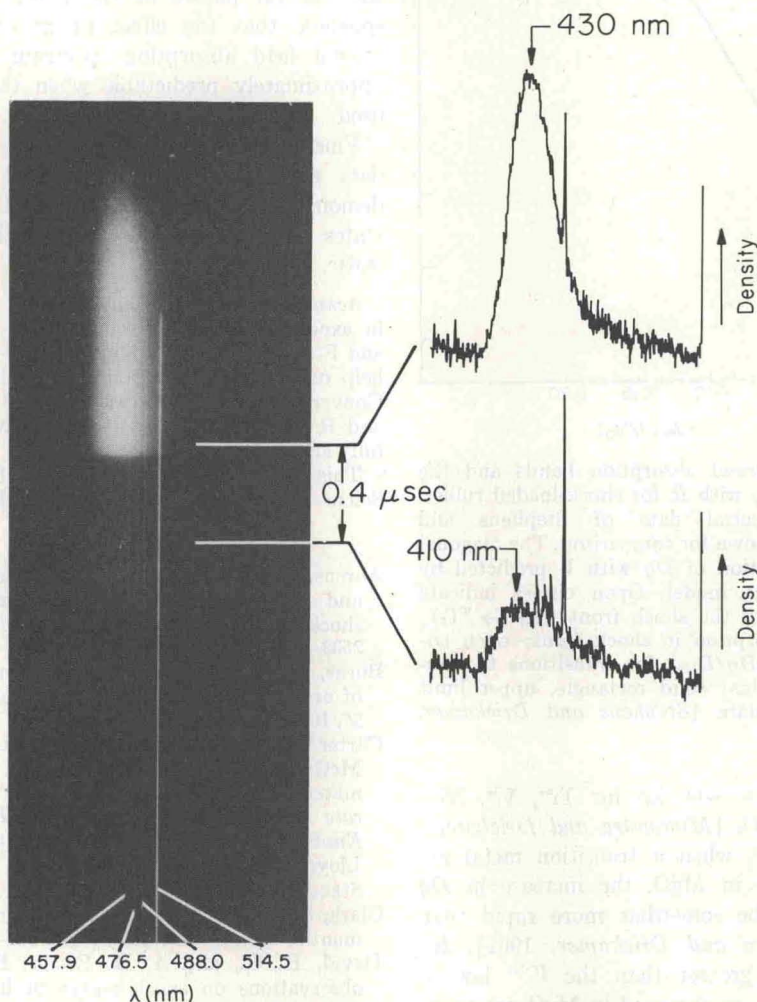

Fig. 10. Spectrum of pink ruby shocked to 430 kb. This is essentially a transmission spectrum of the sample. The four vertical lines are the emission lines of a pulsed argon laser used for wavelength calibration. The optical density of the negative on two scans is plotted on the right. The shift in the transmitted light peak from ~450 nm in the unshocked crystal to ~400 nm in the shocked sample arises from the shift in the $^4A_2 \rightarrow {}^4T_2$ absorption from 555 to 460 nm and the shift of the 500-nm ($^4A_2 \rightarrow {}^4T_1$) band out of the present spectral window (Figure 6).
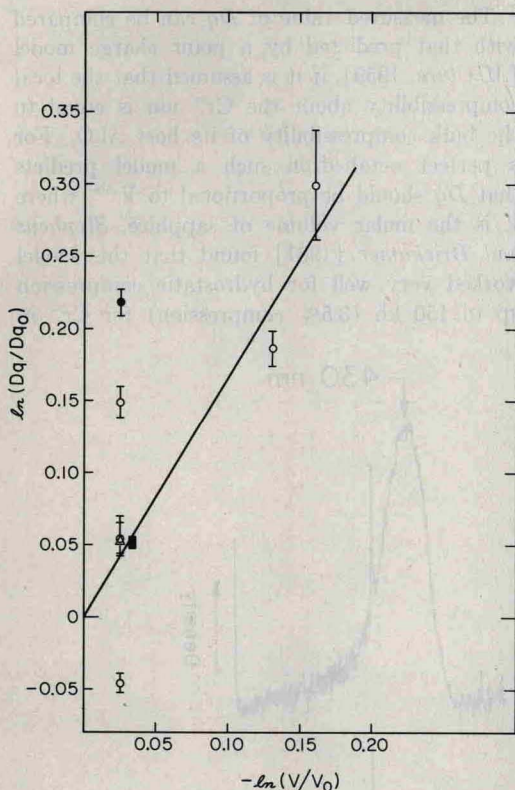
Fig. 11. Observed absorption bands and the variability of Dq with R for shock-loaded rubies. Hydrostatic spectral data of Stephens and Drickamer are shown for comparison. The diagonal line is the variation of Dq with V predicted by the point charge model. Open circles indicate absorption behind the shock front ($^4A_2 \rightarrow {}^4T_2$); solid circle, absorption in shock front; open triangle, average (Dq/Dq_0) for transitions to nongenerate $^4T_2$ states; solid rectangle, upper limit of hydrostatic data [Stephens and Drickamer, 1961].

Al_2O_3 and up to ~60 kb for Ti^{3+}, V^{3+}, Ni^{2+}, and Ni^{3+} in Al_2O_3 [Minomura and Drickamer, 1961]. However, when a transition metal ion was substituted in MgO, the increase in Dq was found to be somewhat more rapid than $V^{-5/3}$ [Minomura and Drickamer, 1961]. Increases of Dq greater than the $V^{-5/3}$ law of from 10 to 60% as observed in MgO are probably more likely to occur if the substituting transition metal ionic radius is markedly smaller than that of the host element normally occupying the cation site. If the substituting ion is larger than that of the host element normally occupying the site, Dq will likely be somewhat

less than that predicted by the $V^{-5/3}$ law, as in the case of high-spin Fe^{++} [Shankland, 1968]. In addition to size, of course, covalency and relocation of the lattice in the vicinity of the impurity will be important.

The present results demonstrate the usefulness of the point charge model for determining the effect of volume compressions of nearly 15% on the crystal field spectrum of Cr^{3+} in Al_2O_3. To the extent that the corundum type of close-packed structure is typical of some of the mineral phases of the lower mantle, we conclude that the effect of pressure on the crystal field absorption spectrum is at least approximately predictable when this model is used.

Finally, the good agreement of the present data with those of Stephens and Drickamer demonstrates that above the HEL the shock states produced in Al_2O_3 are essentially hydrostatic.

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