Table 3.   Comparison of slopes and equilibrium pressures obtained from our data with that of others.

	Crawford and Hoersch	Boettcher and Wyllie (1968)	Johannes and Puhan (1971)
Slope of the boundary curve (bars/degree C)	13.8*	13.7**	16.7***
Pressure of 0° C Intercept (kbars)	3.04	2.82	1.99
Pressure at 100° C (kbars)	4.42	4.19	3.66

* Slope based on least squares determination from data presented in Table 2.
** Slope calculated from points 480° C, 9.4 kbar and 400°, 8.3 kbar (Fig. 1).
*** Slope calculated from points 300°C, 7 kbar and 180°, 5 kbar (Fig. 1).

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THE USE OF FAR INFRARED INTERFEROMETRIC SPECTROSCOPY FOR MINERAL IDENTIFICATION

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ABSTRACT

Interferometric infrared spectroscopy in the range 20–400 cm^{-1} can provide a simple method for differentiation of the major mineral groups, and of individual types within each group. Results are shown for some representative micas and clay minerals.

Introduction

Mineralogists have made many successful applications of spectroscopy in the near and mid-infrared (10,000 cm^{-1} to 500 cm^{-1}), but with a few exceptions (Angimo, 1964; Aronson and McLinden, 1966; Estep, Kovack, and Kass, 1968) the far infrared has been given little attention. There are several advantages to be gained from working at long wavelengths. The particle size of many naturally occurring specimens is such that while they scatter shorter wavelengths they will act as simple absorbers for long wavelengths. These long wavelengths correspond to fundamental lattice frequencies of compounds containing all but the lightest elements. An additional advantage is that quartz, which is likely to be present in many mineral samples, becomes relatively transparent below 200 cm^{-1}. Thus there is a useful region in the far infrared in which the characteristic absorptions of other constituents may be found.
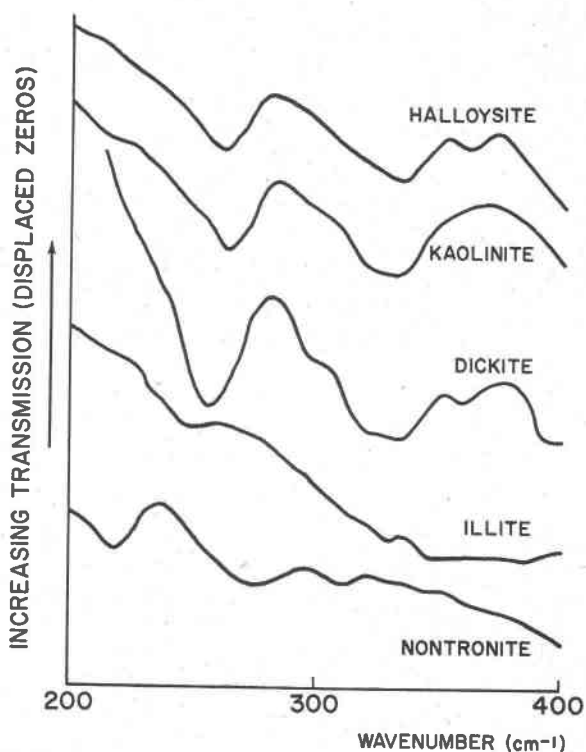

Fig. 1. Far infrared transmission spectra of some clay minerals. Distinct similarities can be seen between the spectra of individual members of the kandite group (curves A, B, and C).

RESULTS AND CONCLUSIONS

In Figures 1 and 3 we give examples of transmission spectra of some clays and micas. They were all obtained by a Michelson interferometer (Chantry *et al.*, 1969) used in combination with a signal analyser. A spectral resolution of 4 cm⁻¹ was sufficient to locate absorption features to ± 2 cm⁻¹. The clay samples, after being ground to a fine powder and mulled in petroleum jelly, were supported on a polyethylene or KRS-5 window in the evacuated sample space of the interferometer. The particle size, although less than 100 μm, was still large enough to give considerable scattering loss at high frequencies. As a result the characteristic absorption spectrum of the clay is superimposed on a background intensity which increases in the direction of high frequencies. The mica specimens were cleaved to give samples of the order of a hundred micrometers thick. The spectra were then obtained for a direction perpendicular to the cleavage plane.

Figure 2 gives a list of the clay minerals studied, with a pictorial display of their characteristic absorption frequencies derived from spectra, of which examples are shown in Figure 1. The height and width of the triangles give a representation of the relative intensity and width of the observed absorption features. From these illustrations
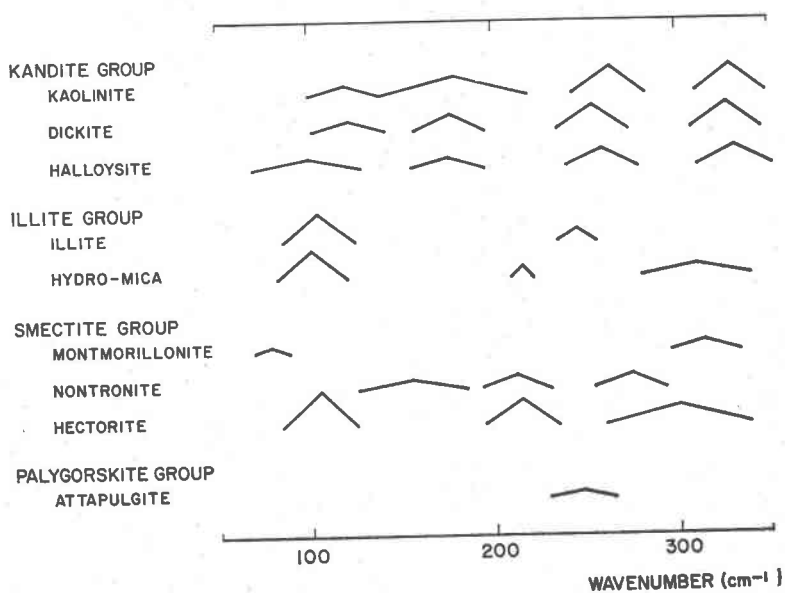

FIG. 2. Schematic representation of the major far infrared absorptive features of some clay minerals.
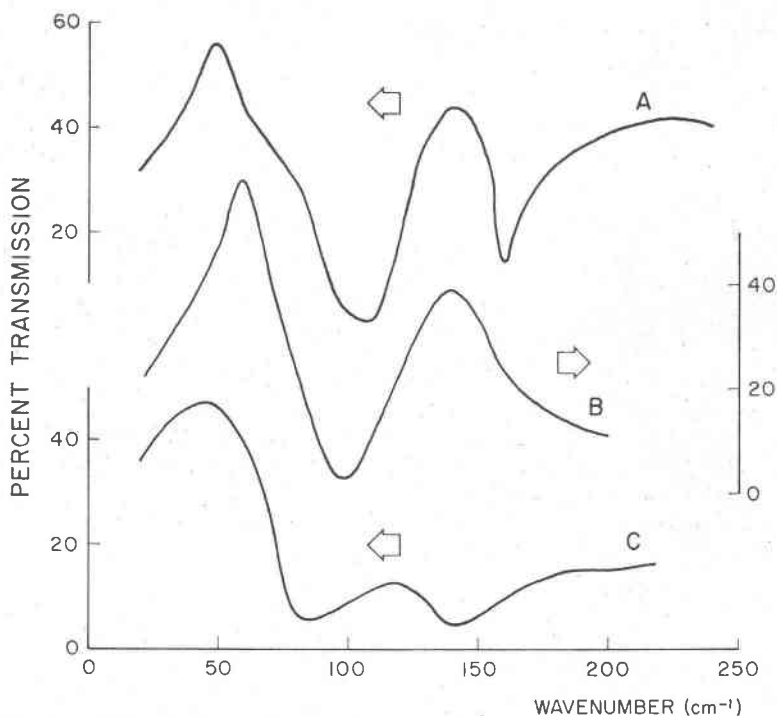
FIG. 3. Far infrared transmission of some micas: A, muscovite (0.04 mm); B, lepidolite (0.04 mm); C, biotite (0.10 mm).

it can be seen that no two of the clays studied have identical far infrared spectra. However, within a particular group, the spectra show definite similarities. This is also illustrated in Figure 1 which shows three members of the kandite group; halloysite, kaolinite, and dickite. We also verified that samples of the same clay obtained from different localities had the same absorption features.

When we compare our spectra of clays with those in the literature (Angino, 1964), we find that in general we confirm the results of the earlier work for frequencies higher than 250 cm^{-1} but that there are substantial disagreements with the earlier observations at lower frequencies. We believe that this kind of discrepancy may come from the very great difficulty in avoiding stray radiation effects in grating spectrometers at long wavelengths when these are used to measure samples having large radiation losses.

In Figure 3 we show spectra of some members of the mica group in the range 20 cm^{-1} to 250 cm^{-1}. Again it can be seen that they are so

markedly different that they could readily be used as a means of recognizing the mineral.

We believe that interferometric spectroscopy may be extended to both qualitative and quantitative analysis of many other mineral groups. Also, since the far infrared spectrum generally has its origins in forces giving rise to lattice vibrations, it is sensitive to structural as well as to chemical variations in minerals. Thus this technique may be especially useful in the identification of the particular structural state of a mineral. An excellent example for study might be the potassium feldspars.

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