

POSSIBLE SPECTRAL SIGNS OF SERPENTINES AND CHLORITES IN REFLECTANCE SPECTRA OF CELESTIAL SOLID BODIES

V. V. Busarev¹, M. N. Taran², V. I. Fel'dman³ and V. S. Rusakov⁴

¹ Lunar and Planetary Department, Sternberg State Astronomical Institute, Moscow State University, 119992 Moscow, Universitetskij pr., 13, Russian Federation (RF); e-mail: busarev@sai.msu.ru;

² Department of Spectroscopic Methods, Institute of Geochemistry, Mineralogy and Ore Formation, Academy of Sciences of Ukraine, 03142 Kiev, Palladina pr., 34, Ukraine;

³ Division of Petrology, Geological Department of Moscow State University, 119992 Moscow, RF;

⁴ Division of Mossbauer Spectroscopy, Physical Department of Moscow State University, 119992 Moscow, RF.

Introduction: Serpentes and chlorites are known as usual hydrothermal products of mafic minerals (olivines, pyroxenes, etc.) in terrestrial conditions [e. g., 10]. They are also major constituents of matrix minerals in the most primitive carbonaceous chondrites (CI, CM) [e. g., 5, 11, 12]. According to our laboratory spectral investigations, serpentines and chlorites have prominent visible to near-IR spectral characteristics allowing to distinguish them from those of other mineral specimens in carbonaceous chondrites. It is probably the main reason of why reflectance spectra of a large number of celestial solid bodies, from primitive C-, P-, F-, G-type asteroids [8, 9] and hydrated M-, S-, E-type asteroids [2] to Kuiper belt objects [1, 6], are similar to spectral characteristics of serpentines and chlorites. Therefore we may suppose that the phyllosilicates are widespread on silicate or silicate-icy solid bodies of the Solar System.

Laboratory Measurements and Results: Visible and near-IR reflectance spectra of serpentines and chlorites as powders of <0.20-0.30 mm grain size were measured. Previously we have obtained reflectance spectra of some carbonaceous chondrites [3] (Fig. 1). All the spectra were scanned in the 400-1000-nm range with a single-beam spectrophotometer based on a SpectraPro-275 triple-grating monochromator and controlled by an IBM 486 PC. The incident and reflected beam angles and the light beam diameter were 45°, 0° and 5 mm, respectively. Compressed powder of MgO was used as the reflectance standard. The root mean square relative error (RMSRE) for the reflectance spectra does not exceed 0.5–1.0% in the visible region and increases gradually to 1–2% at the red end of the operational spectral region. The reflectance spectra of serpentines and chlorites are shown in Fig. 2 and 3. A brief description of the samples is given in the Table 1.

A wide absorption band or a pair of more narrow ones (up to 30% in relative intensity) (see Fig. 2 and 3) presents in the reflectance spectra of serpentines and chlorites in the range of 500-1000 nm. There is also a specific absorption band (up to 25% in relative intensity) in the reflectance spectra of serpentines at 440 nm.

We have performed also measurements of the main oxide content in the samples by a scanning electron

Table 1. A brief description of the samples.

The sample names	Numbers	Physical state of the samples	
			particle sizes
Orguel (CI)	2476	powdered	<0.25 mm
Mighei (CM2)	1856	powdered	<0.25 mm
Murchison (CM2)	15044	powdered	<0.25 mm
Old Boriskino (CM2)	198	powdered	<0.25 mm
Terrestrial quartz-chlorite schist	3	powdered	<0.25 mm
Terrestrial clinocllore	22	powdered	<0.25 mm
Terrestrial chloritoid	32	powdered	<0.25 mm
Terrestrial Fe-clinocllore	35	powdered	<0.25 mm
Terrestrial serpentine (~85% lizardite-ophite)	1a	powdered	<0.25 mm
Terrestrial serpentine (~70%) developed on olivine	4b	powdered	<0.25 mm
Terrestrial serpentine	10a	powdered	<0.25 mm
Terrestrial serpentine (~95% β-lizardite)	28	powdered	<0.25 mm
Terrestrial serpentine (~85% α-lizardite) developed on pyroxene	2540	powdered	<0.25 mm

microscope (CamScan-4DV). Briefly, the samples do not include some anomalous quantities of oxides of transitional metals (with the exception of ferrous and ferric iron) which could influence considerably on the reflectance spectra.

Mossbauer measurements (with a mossbauer spectrometer MC1101E) were performed additionally to check contents of Fe(3+) in the serpentine samples investigated. The obtained relative quantities of Fe(3+) (in reference to values of total iron) for the serpentine samples are: 77.3% (1a), 48.4% (4b), 68.8% (10a), 88.5% (28) and 91.9% (2540).

Discussion: As seen from figures 1, 2 and 3, absorption bands at 600-900 nm in reflectance spectra of the CI-CM- carbonaceous chondrites are similar to those of serpentines and chlorites. Therefore, the spe-

Fig. 1. Normalized reflectance spectra of carbonaceous chondrites.

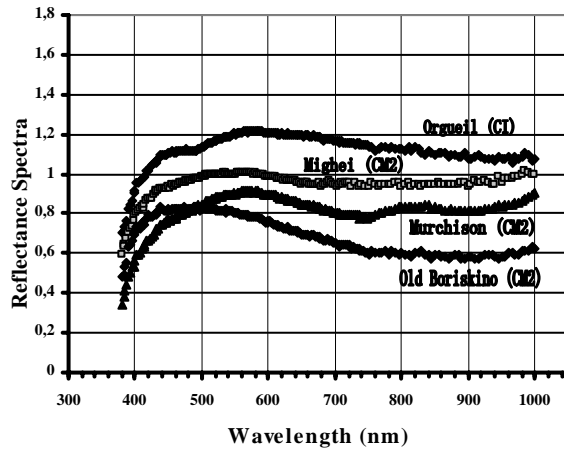


Fig. 2. Normalized reflectance spectra of terrestrial chlorites.

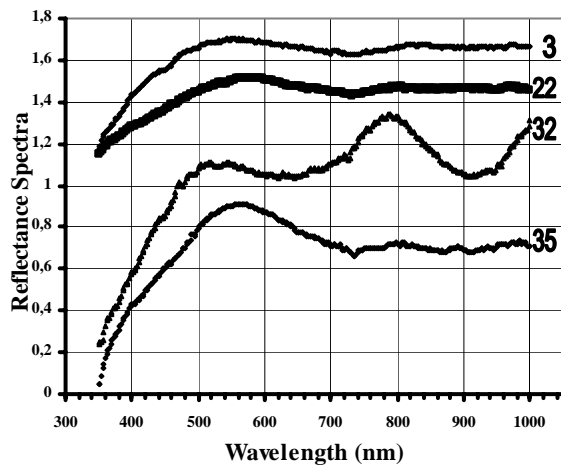
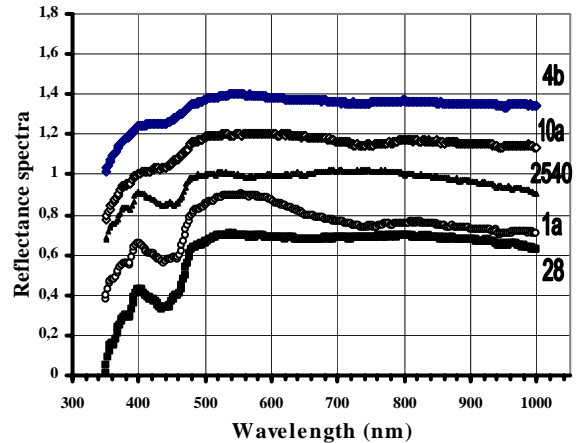


Fig. 3. Normalized reflectance spectra of terrestrial serpentines.



cial features of carbonaceous chondrites may originate mainly in serpentines and chlorites. As authors of previous works [4, 7], we assume that the spectral features are caused by intervalence charge-transfer electronic transitions between iron ions ($Fe^{2+} \rightarrow Fe^{3+}$).

As for nature of an absorption band at 440 nm in the reflectance spectra of investigated samples, we have no a definite opinion yet. The obtained intensity of the band (in particular for 1a, 28 and 2540 samples) is considerably more than that for similar serpentine samples in earlier investigations [e. g., 4, 7] where it was interpreted as a spectral feature produced by crystal-field spin-forbidden electronic transitions in $Fe(2+)$ ions. As follows from our spectral and mossbauer measurements, at a qualitative level intensity of the absorption band depends on $Fe(3+)$ contents in the serpentine samples. To solve the problem accurately, we plan to perform additional investigations of more pure serpentine samples (petrographic, mossbauer, X-ray and so on).

Thus, we suppose that the above-mentioned spectral features of serpentines and chlorites may be used as indicators of silicate matter in oxidized and/or hydrated states on different solid bodies of the Solar System.

The authors thank T. A. Smirnova (VIMS, Moscow) for help in mineralogical-petrographic investigations of the serpentine samples.

References: [1] Boehnhardt H. et al. (2002), *Proc. of ACM 2002*, 47-50. [2] Busarev V. V. (2002), *Solar Sys. Res.* 36, 35-42. [3] Busarev V. V. and M. N. Taran (2002), *Proc. of ACM 2002*, 933-936. [4] Clark R. N. et al. (1990) *JGR*, 95, 12653–12680. [5] Dodd R. T. (1981) *Meteorites*. Cambridge Univ. Press, New York. [6] Fornasier S. et al. (2004), *Astron. & Astrophys.*, 421, 353-363. [7] King T. V. V. and Clark R. N. (1989) *JGR*, 94, 13997–14008. [8] Vilas F., Gaffey M. J. (1989),

Science 246, 790-792. [9] Vilas F. et al., 1993, *Icarus* 102, 225-231. [10] Winchell, A.N., Elements of Optical Mineralogy: An Introduction to Microscopic Petrography, Part 2, 1933. Translated under the title "Opticheskaya mineralogiya", Moscow: Inostrannaya Literatura, 1949. [11] Zolensky M. E. et al. (1989) *Icarus*, 78, 411-425. [12] Zolensky M. E. et al. (1993) *Geochim. et Cosmochim. Acta*, 57, 3123-3148.