

Supplementary Materials for

Nature, formation, and distribution of carbonates on Ceres

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Supplementary Materials

table S1. Main regions with a high 3.9- μm band depth. The values of band depth presented in table S1 are an average of 8 adjacent pixels chosen with the highest band center using HAMO dataset and, when available, LAMO (Low Altitude Mapping Orbit) dataset. For comparison, the average band center and band depth of Ceres are 3.95 μm and ~ 0.06 , respectively.

	Band Center (μm)	Band Depth	Lon	Lat	Figure
Unnamed crater 2	3.95	0.10-0.16	292.5	-42.5	S2
Unnamed crater 3	3.95	0.12-0.16	271.76	-49.22	S2
Ernutet	3.96	0.08-0.10	45.5	52.9	S1
Begbalel	3.96	0.09-0.10	322.56	17.05	3
Urvara	3.96	0.09-0.11	249.2	-45.6	S2
Consus	3.98	0.07-0.09	199.69	-20.92	-
Ikapati	3.98	0.07-0.09	45.6	33.8	S1
Unnamed crater 1	3.98	0.08-0.10	317.29	7.56	3
Xevioso	3.99	0.08-0.10	309.90	0.18	3
Haulani	3.99	0.08-0.12	10.8	5.8	-
Dantu	3.99	0.08-0.14	138.2	24.3	-
Azacca	3.99	0.09-0.15	218.67	-6.86	-
Ahuna Mons	4.00	0.09-0.12	316.2	-10.5	3
Kupalo	4.00	0.10-0.14	173.2	-39.4	-
Oxo	4.00	0.12-0.22	359.6	42.2	S3
Kahukura	4.01	0.10-0.16	221.84	61.17	-
Occator	4.01	0.24-0.44	239.3	19.8	-

table S2. Retrieved abundances in selected pixels showing the highest concentration of carbonates in the listed areas. The remaining component is a dark neutral material, here we used magnetite (MG-EAC-002/LAMG02). All spectra are from the RELAB database. SAMPLE ID/spectrum name: ¹JB-JLB-189/397F189, ²CL-EAC-049-A/LACL49A, ³AT-TXH-006/LAAT06, ⁴CB-EAC-003-A/LACB03A, ⁵CB-EAC-034-C/LACB34C, ⁶CB-EAC-034-A/LACB34A. Although the chemical species of the laboratory spectra here reported are defined in the corresponding files, the real hydration state is not well explained.

	Average Ceres	Oxo	Kupalo	Azacca	Crater 2
NH ₄ -phyll. ¹	8 %	6 %	7 %	4 %	10 %
NH ₄ Cl ²	-	-	-	1 %	-
Antigorite ³	5 %	-	-	4 %	3 %
Dolomite ⁴	3 %	1 %	1 %	-	16 %
Natrite ⁵	-	9 %	12 %	5 %	-
Hydrated Na carbonate ⁶	-	11 %	8 %	7 %	-
Grain size	100 μm	80 μm	120 μm	100 μm	30 μm

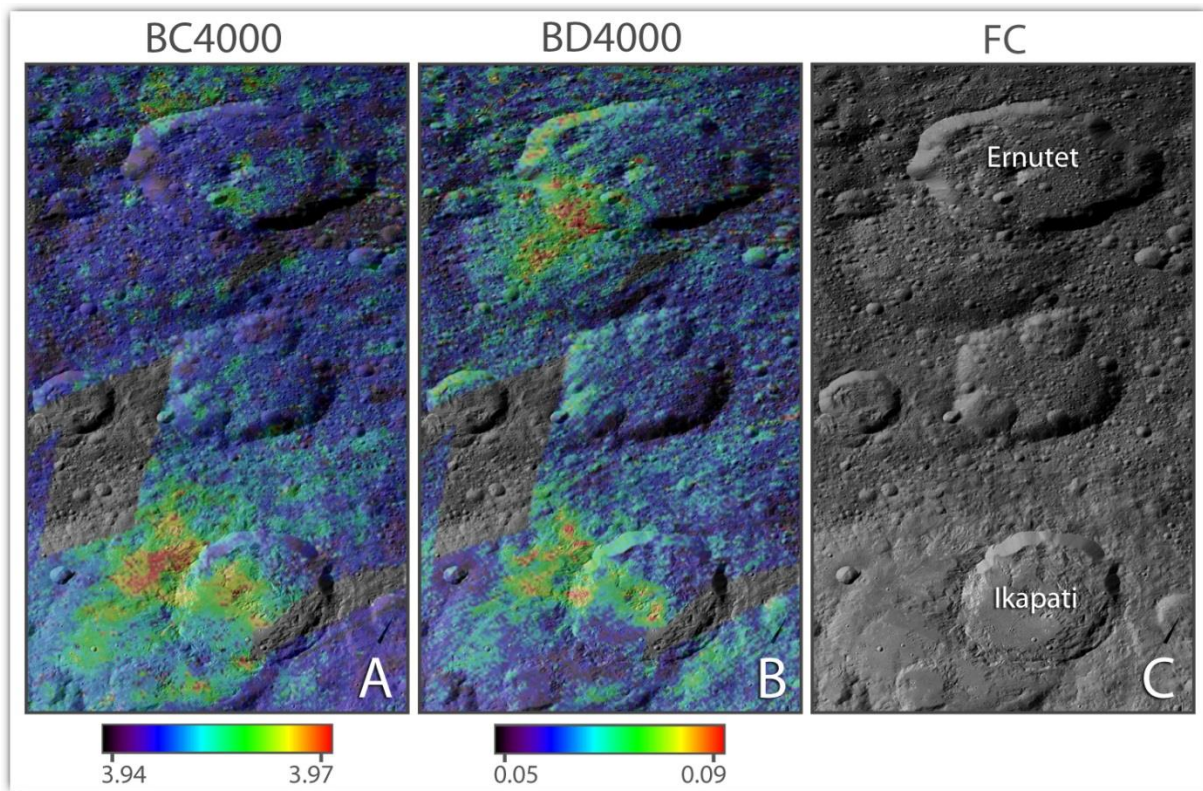


fig. S1. Main regions with high 3.9- μ m band depth. (A) Band center and (B) band depth map in the region of Ernutet and Ikapati superimposed on the FC images using a transparency of 25%; (C) corresponding FC image.

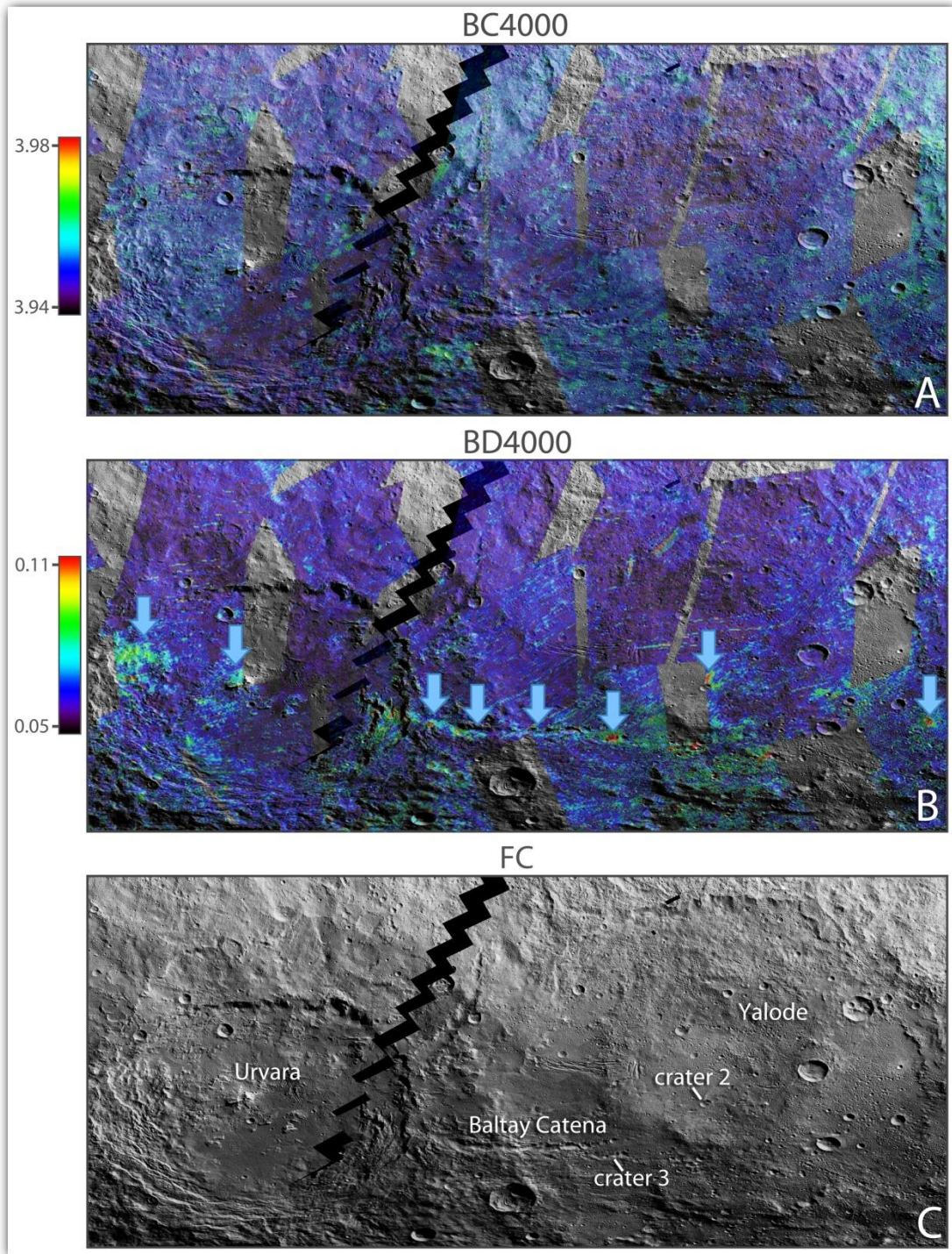


fig. S2. Retrieved abundances in selected pixels showing the highest concentration of carbonates. (A) Band center and (B) band depth map in the region of Urvara, Yalode and Baltay Catena superimposed on the FC images using a transparency of 25%; (C) corresponding FC image.

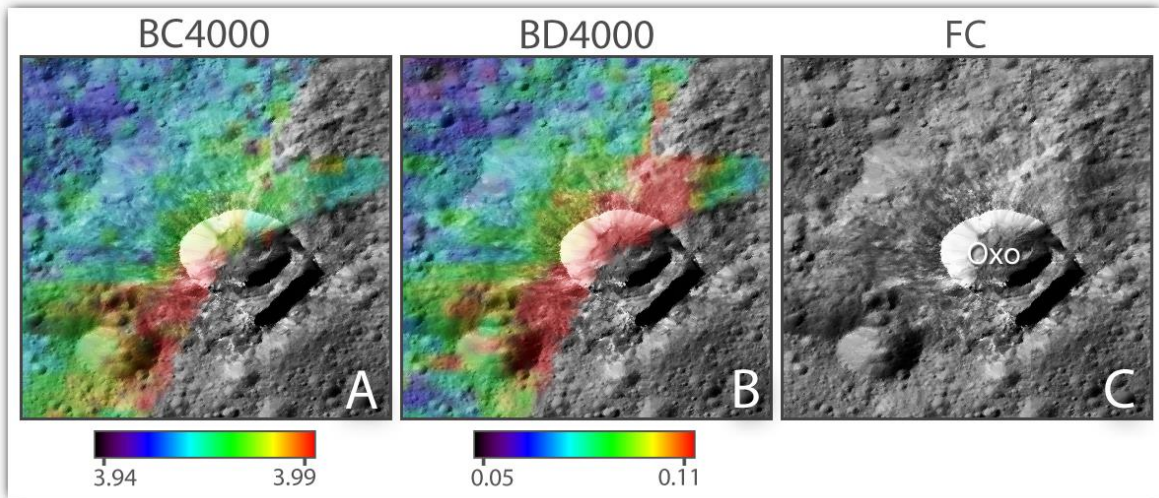


fig. S3. Band center and band depth maps in Ernutet and Ikapati craters. (A) Band center and (B) band depth map in the region of Oxo superimposed on the FC images using a transparency of 25%; (C) corresponding FC image.

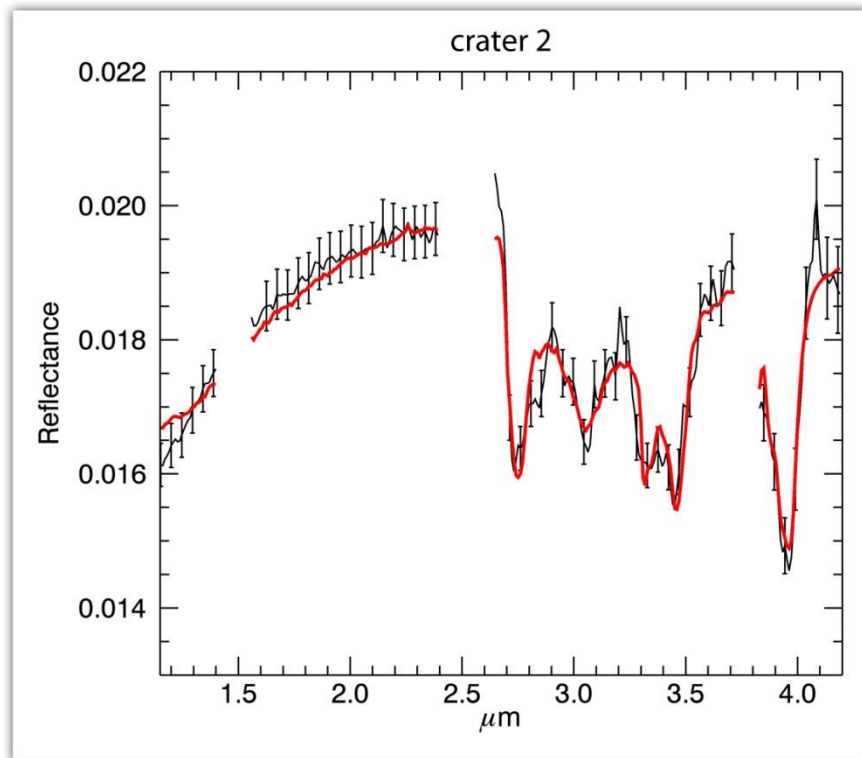


fig. S4. Spectral fits of carbonate rich area in crater 2. The retrieved abundances of the component of the mixture are given in tables S2. Error bars on the data are calculated according to calibration uncertainties (16) and Poisson noise. Details on the modelling are given in the text.

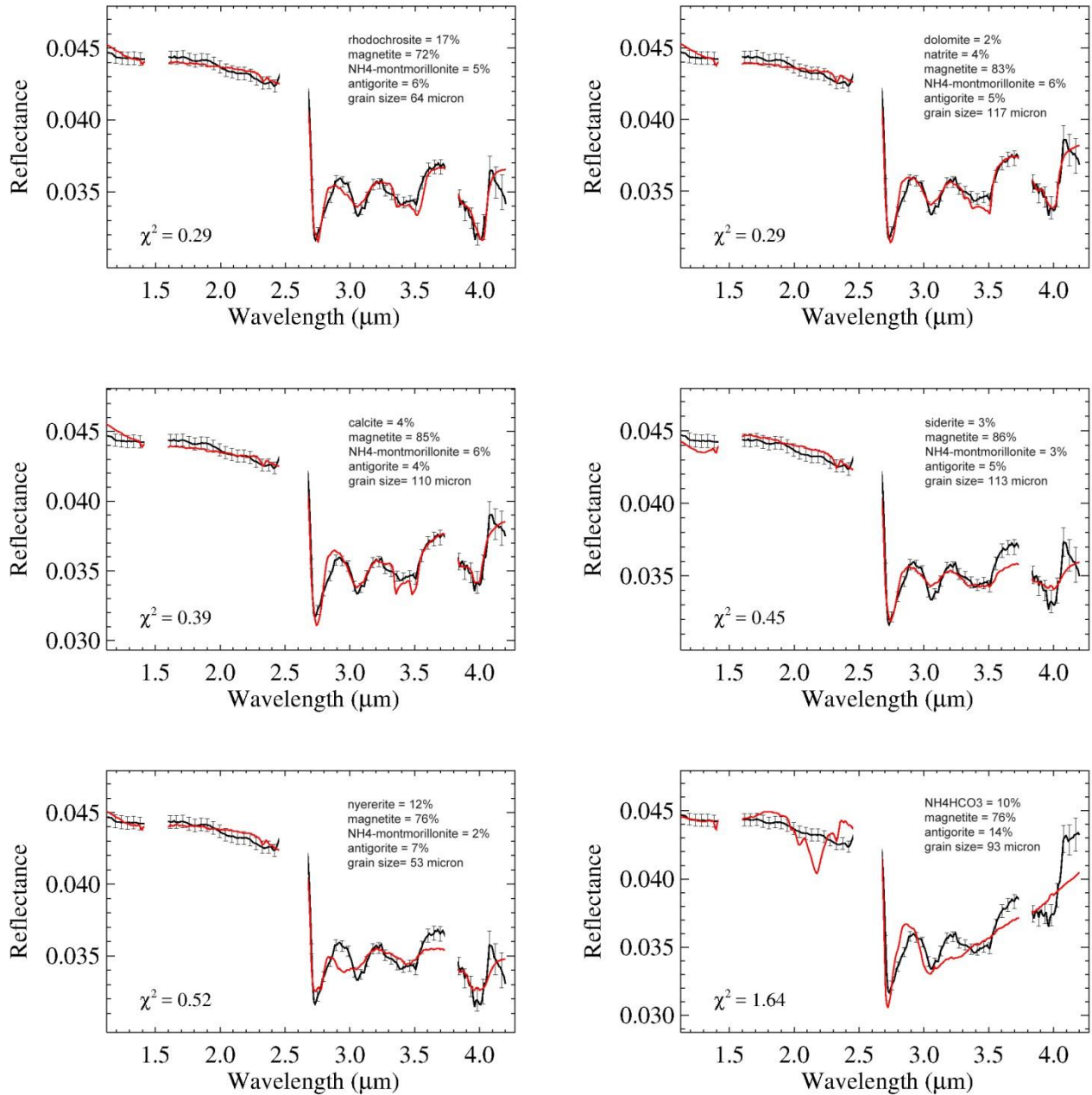


fig. S5. Spectral fits (red curve) of phyllosilicate-rich area (black curve). The retrieved abundances of the component of the mixture are given in the single panels. Error bars on the data are calculated according to calibration uncertainties (16) and Poisson noise. Details on the modelling are given in the text.

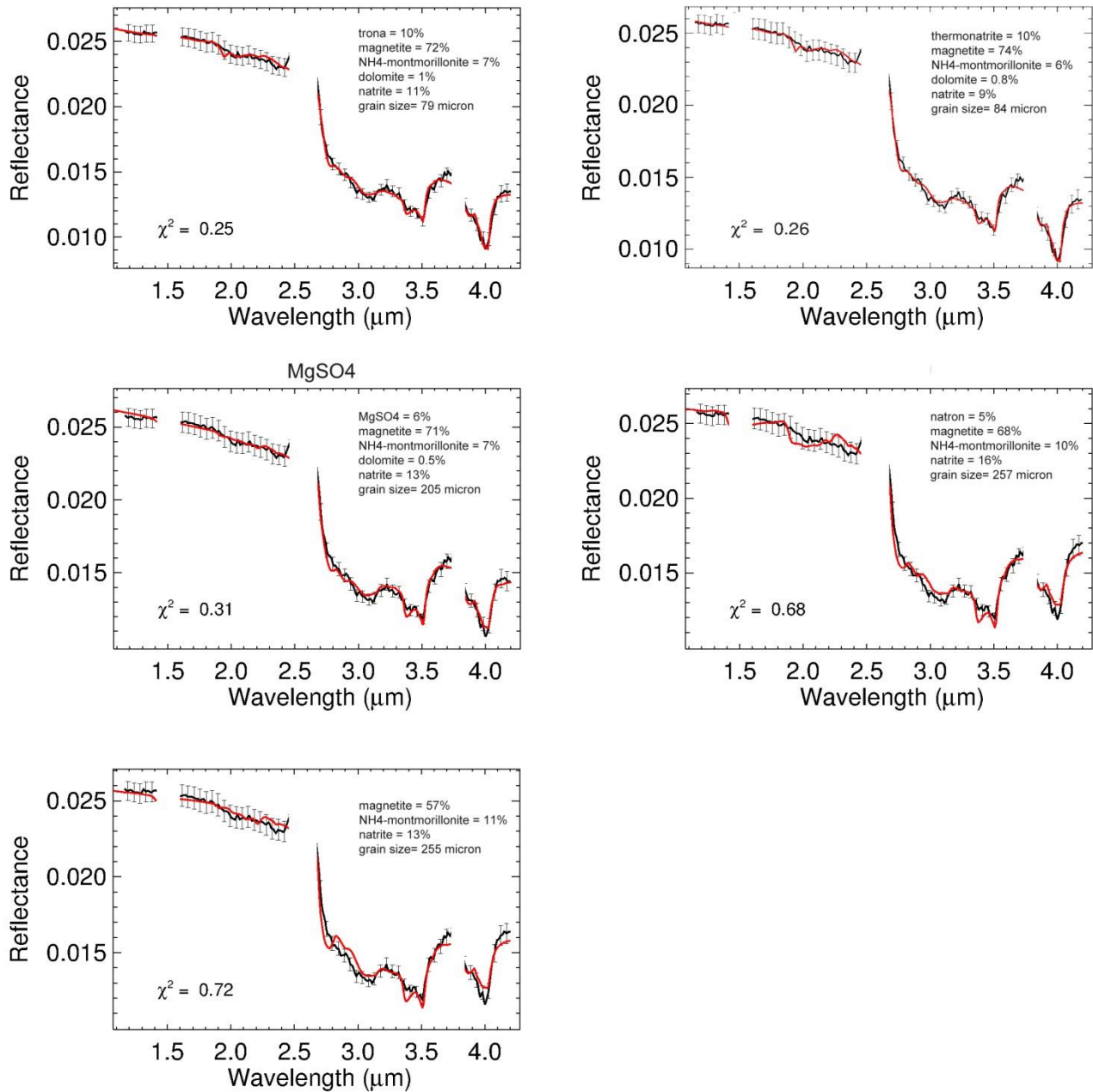


fig. S6. Spectral fits (red curve) of natrite-rich area in Oxo crater (black curve, the same spectrum as in Fig. 5). The retrieved abundances of the component of the mixture are given in the single panels. Error bars on the data are calculated according to calibration uncertainties (16) and Poisson noise. Details on the modelling are given in the text. SAMPLE ID/spectrum name: Magnetite = MG-EAC-002/LAMG02 (we remand to caption of figure S7 for details of other sample ID). Although the chemical species of the laboratory spectra here reported are defined in the corresponding files, the real hydration state is not well explained.

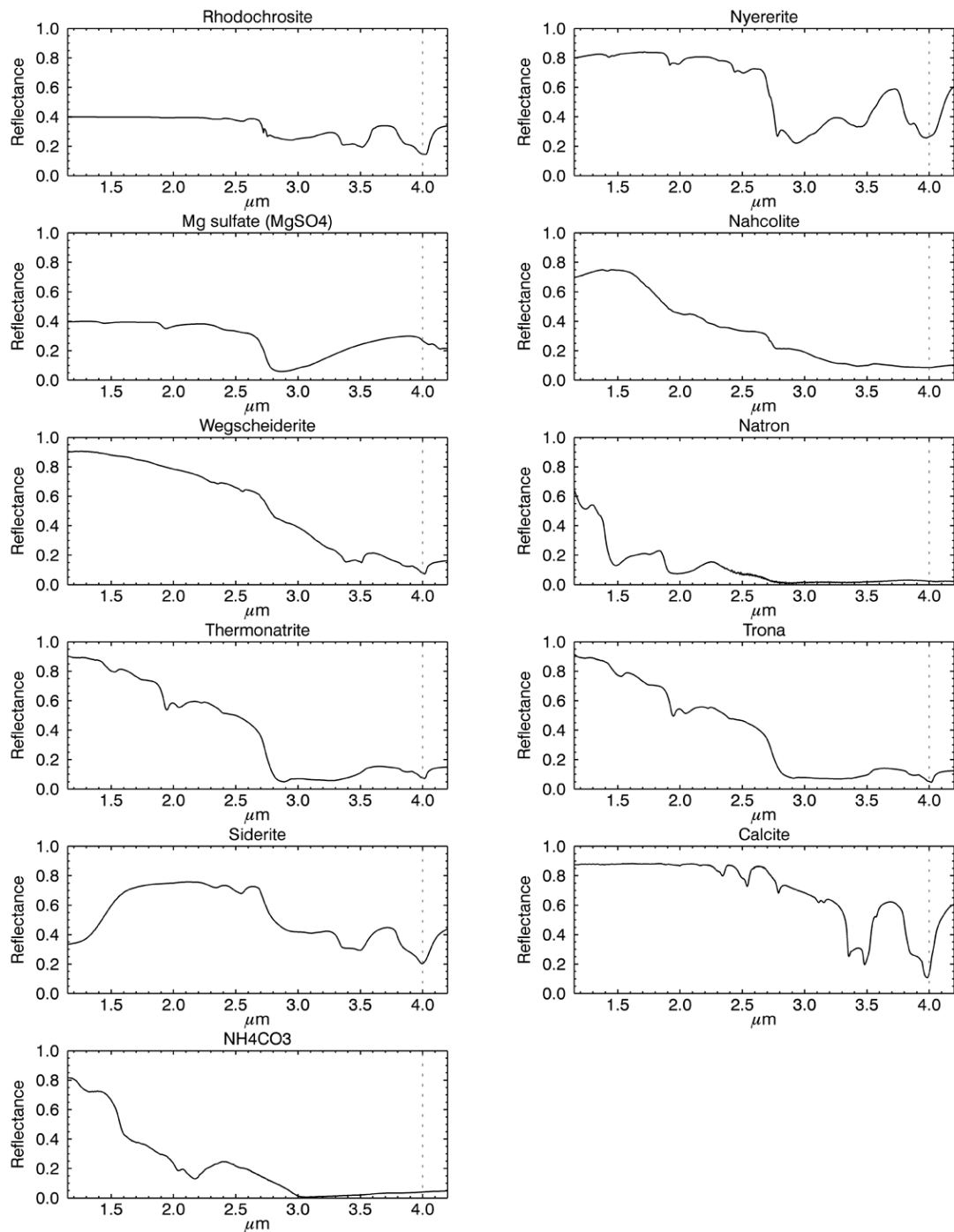


fig. S7. Spectra of the end members used in the spectral modeling. Apart natron taken from USGS database (usgs.perknic.mineral.carbonate.none.coarse.natron.spectrum), all spectra are from the RELAB database. SAMPLE ID/spectrum name: Rhodochrosite = CB-EAC-068-A/bir1cb068a, Nyererite = CB-EAC-031-C/lacb31c, MgSO₄ = CC-JFM-019/s1cc19, Nahcolite = CB-EAC-007-

A/lacb07a, Wegscheiderite = CB-EAC-033-C/lacb33c, Thermonatrite = CB-EAC-033-A /lacb33a, Trona= CB-EAC-034-A/lacb34a, Siderite = CB-EAC-008-A /lacb08a, Calcite = CA-EAC-010/laca10, NH_4CO_3 = CB-EAC-041-A/lacb41a. The dotted line crosses the band at 4 μm . Although the chemical species of the laboratory spectra here reported are defined in the corresponding files, the real hydration state is not well explained.