



Fig. 2. Spectra and locations of newly identified hydrated phase in Mawrth Vallis. (a) CRISM spectra (median-filtered) from Mawrth Vallis (top) and lab spectra of hydrated minerals (bottom). CRISM spectra correspond to numbered locations in (b) and (c). Spectrum 1 (FRT00009326) is most consistent with bassanite, while 2 (FRT00009326) and 3 (FRT00012E72) are less definitive and may be consistent with other hydrated salts or zeolites. Bassanite ($\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$) is sample GDS145, gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) is HS333.3B, carnallite ($\text{KMgCl}_3 \cdot 6\text{H}_2\text{O}$) is NMNH98011, analcime (Na-zeolite) is GDS1, and stilbite (Na/Ca-zeolite) is GDS8 from Clark et al. (2007); hexahydrate ($\text{MgSO}_4 \cdot 6\text{H}_2\text{O}$) is LASF57A and nontronite (Fe-smectite) is NBJB26 from CRISM spectral library. (b) CRISM FRT00009326 parameter maps overlain on HiRISE ESP_014007_2030; red is Fe/Mg-phyllsilicate, green Al-phyllsilicate, and blue a hydrated mineral with strong 2.5 μm band. See Fig. 1 for location. (c) CRISM FRT00012D3C on HiRISE ESP_013229_2050, colors same as in (b). (d) Stereo anaglyph covering same area as (c), from HiRISE ESP_013229_2050 and ESP_013295_2050.

4. Discussion

On the basis of their distribution across terrains of different ages, Bibring et al. (2006) proposed that martian sulfates generally formed later than phyllosilicates. This hypothesis can be tested by observations of places where these two minerals are found in contact. Here we have shown that sulfate-bearing beds in Mawrth Vallis underlie Fe/Mg-smectite-bearing beds, which had previously been identified as the lowest stratigraphic unit exposed in the region (Wray et al., 2008; McKeown et al., 2009). Although the timing and location of smectite formation are unknown, the principle of superposition implies that the beds hosting the sulfates predate

those hosting the phyllosilicates. Taken together with stratigraphic analyses of several other regions where phyllosilicates and sulfates are interbedded or intimately mixed (Poulet et al., 2008a; Wray et al., 2009; Milliken et al., 2010; Weitz et al., 2010), our results suggest that the alteration history of at least several regions on Mars may have been different or more complex than the model of Bibring et al. (2006) suggests.

However, an alternative explanation at Mawrth Vallis could be that sulfates formed in the subsurface coevally with (or after) phyllosilicates. Specifically, if at least some of the region's phyllosilicates formed via top-down weathering that leached mono- and divalent cations (Na, Ca, Mg) from the upper horizons (e.g.,