SIMULATING CRISM AND HIRISE DATA USING AIRBORNE HYPERSPECTRAL IMAGERY: LESSONS LEARNED FROM GROUND TRUTH

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Introduction

Hyperspectral data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) and geomorphology and broad-band color from the High Resolution Imaging Science Experiment (HiRISE) on the Mars Reconnaissance Orbiter (MRO) are excellent tools for understanding current and past environments [1-3]. However, the complexity of natural surfaces can cause ambiguity and lead to incorrect interpretations of the geology. Field verification is recognized as a fundamental component for most terrestrial remote sensing campaigns, a luxury not possible for Mars except at the lander and rover sites. As part of a study of terrestrial analogs of Martian habitable environments [4-6], we have generated synthetic CRISM spectral summary parameter maps and HiRISE color images of the analog study sites using converted airborne hyperspectral data. These have been used to make surface composition predictions which were then verified through field study and sample analysis. We show that the pseudo CRISM parameter maps identify geologic boundaries and approximate mineralogy, with mineral mixing complicating interpretations. Our results have implications for interpreting similar data for Mars.

Background

The presence on Mars of phyllosilicates overlain by sulfates, originally found by the OMEGA (Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité) spectrometer [7] and subsequently verified and mapped in greater detail by CRISM [8], forms the basis of the hypothesis of global-scale changes from alkaline to acidic conditions in the presence of water, followed by the dry environment that exists up to the present day [7]. An alternative proposal is that the apparent stratification is caused by chemical gradients, not temporal boundaries [6], similar to those found in modern acid-saline lakes in Australia [9-12]. As part of a broader effort investigating terrestrial analogs to habitable environments, we have obtained airborne hyperspectral data over two lake regions in southern Western Australia, the Brown-Campion-Chandler system (henceforth referred to as the Lake Brown region) and Lake Gilmore. These locations are applicable to Mars, as they contain a suite of clays, sulfates, and salts formed under variable pH and salinity - mineralogies similar to those observed in Noachian and Hesperian terrain. Visible and near infrared hyperspectral data for these sites were obtained from HyMap, an airborne imaging spectrometer built by Integrated Spectronics Inc., Sydney, Australia. HyMap has a similar spectral range and resolution to CRISM, OMEGA, and the ASD field spectrometer (Table 1). The bandpasses within the spectral range are also similar, except that HyMap does not have any bands near 1.9 µm due to atmospheric water vapor absorption.

Table 1: Comparison between HyMap, the ASD Field Spectrometer, CRISM, and OMEGA

	HyMAP	ASD	CRISM	OMEGA
Wavelength Range (µm)	0.45 to 2.5	0.35 to 2.5	0.362 to 3.92	0.5 to 5.2
Spatial Resolution	3 to10 m/pixel	25 degree fov	15.7 to 19.7 m/pixel	300 m to 4.8 km
Spectral Resolution/	~15nm/ channel*	3 to 10 nm/channel **	6.55nm/channel	14 nm/channel
Number of Bands	126	2151	544	352

*15-16nm from 0.45-1.8 and 18-20nm from 1.95 to 2.48
**3 nm at 700 nm and 10 nm at 1400 nm and 2100 nm.

The CRISM team uses spectral summary parameters and mapping browse products (parameter composites) to investigate the presence and distribution of minerals and amorphous phases [13]. Of relevance to this investigation are the IR_PHY and IR_HYD products, which parameterize spectral structure consistent with phyllosilicates and sulfates, respectively. Each product uses three different detection parameters, mapping them into the red, green, and blue channels. HiRISE color, especially when combined with coarser spatial resolution/higher spectral resolution CRISM, can be used to separate materials of different physical properties, dust content, primary mineralogy, and degree of alteration [3].

Methods

The HyMap data were acquired on Nov. 28, 2008 for the Lake Brown region and on Dec. 6, 2008 for Lake Gilmore. These were accomplished using nine ~1.8 x 32 km and eight ~1.8 x 17 km flightlines, respectively. Atmospherically-corrected reflectance data at ~ 3 m/pixel were provided by HyVista Corporation. These data were then resampled to the wavelengths and full width-half maximum of the CRISM 73 bandpasses used in multispectral mapping mode, except for gaps in HyMap spectral coverage corresponding to atmospheric water absorption bands. Ten relevant bands were extracted from available bandpasses and used to make simulated IR_PHY and IR_HYD maps (Fig. 1; Table 2). These maps differed from the CRISM products in not mapping the band depth at 1.9 µm (BD1900) into the blue channel, as HyMap has no spectral coverage in this region because of atmospheric water bands. Instead, reflectance at 1.6 µm was used. Similarly, the reflectance at 1.93 µm used in the CRISM 2.1 µm band depth (BD2100) parameter could not be used for HyMap. Instead reflectance at 1.9742 µm was used.

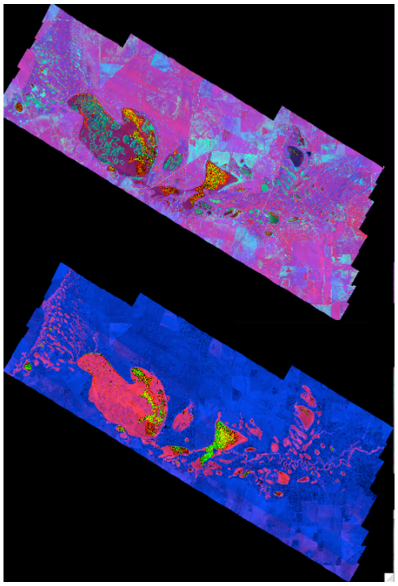

Figure 1: HyMap data of the Brown-Campion-Chandler system. Simulated CRISM IR_PHY product is at top, IR_HYD at bottom (with 1.6 µm albedo mapped to blue). Each strip is ~1.8 km wide.

CRISM Band	CRISM Center	HyMap Band	HyMap Center	HyMap FWHM	Param.	Map
44	1.97424	96	1.9692	0.021	BD2100	ir_hyd
		97	1.9884	0.0214		
48	2.11948	103	2.1017	0.0205	SINDEX BD2100	ir_hyd
		104	2.1198	0.207		
49	2.1393	105	2.138	0.0202	D2300 BD2210 BD2100	ir_phy, ir_hyd
		106	2.1558	0.0202		
50	2.16572	106	2.1558	0.0202	D2300	IR_PHY
		107	2.1736	0.0197		
51	2.20538	108	2.1905	0.0192	D2300 BD2210	ir_phy
		109	2.2088	0.0219		
53	2.25165	111	2.2446	0.0195	D2300 BD2210 BD2100	ir_phy , ir_hyd
		112	2.262	0.0184		
54	2.29133	113	2.2787	0.0184	SINDEX	ir_hyd
		114	2.2961	0.0194		
55	2.31779	115	2.313	0.0188	D2300	ir_phy
		116	2.3297	0.0194		
56	2.33102	116	2.3297	0.0194	D2300	ir_phy
		117	2.3468	0.0187		
58	2.39058	119	2.3799	0.0185	SINDEX	ir_hyd
		120	2.396	0.018		

Table 2: HyMap bands (columns 3-5) resampled to appropriate wavelengths for CRISM bands (columns 1-2) used to derive relevant parameter maps (columns 6-7 [13]). Units in µm.

Three principal morphologic/geologic units types were identified: Lunnettes, inter-lunette surfaces, and playa surfaces. Much of the coverage also included nearby farms and forests, which were not relevant to this investigation. Boundaries between derived parameters were common in both the IR_PHY and IR_HYD maps, such that regions could be correlated to a unique color in each map. Theses were identified for field investigation. Once at the sites, the units were located with GPS, photographed, sampled, and analyzed with a field spectrometer.

Results

Lunnetes: The IR_PHY/IR_HYD maps indicate a sulfate-dominated surface. In the field, these crescent-shaped duneforms are composed of gypsum-rich lake sediment and are commonly anchored by plants, consistent with the prediction. *Playa Surfaces*: 1) The maps predict a phyllosilicate-dominated surface with some sulfates. Field investigation shows these surfaces as crystal-free clay overlain by gypsum crystals. 2) Other playa surfaces, although having a similar gypsum cover, were predicted to have mixed (Fe/Mg + Al) phyllosilicates in addition to sulfates. These complexities may reflect mixing of clay-rich soil and mud with gypsum at the surface.

Discussion

Within the constraints imposed by our water-rich atmosphere, HyMap can be made to simulate CRISM data. Although detailed sample and spectral analysis remains to be undertaken, the use of the simulated CRISM parameter maps show their use in identifying geologic units and their component materials, with some caveats. Sulfate-rich surfaces correlate to predictions in the IR_HYD index, but the IR_PHY index exhibits variable responses, even for apparently similar conditions seen in the field. This may result from mixing of low albedo clay-rich materials in variable amounts with high albedo sulfates. This suggests caution in cases on Mars where surfaces are mixed. Where sulfates, such as gypsum and alunite, are found, phyllosilicates are intermixed or reside beneath the surface yet are not always detected. This shows that geologic complexities may mask phyllosilicate detection at or near the surface on Mars where only sulfates have so far been found.

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