LONG DISTANCE HYPERSPECTRAL IMAGING PANORAMA OVER THE DUNITIC TRANSITION ZONE / MOHO CONTACT OF THE OMAN OPHIOLITE: IN SITU TESTING AND SCIENTIFIC ASSESSMENT OF A NEW ADVANCED SENSOR. P.C. Pinet[1], Y.D. Daydou[1], M. Rospabé[2], G. Ceuleneer[2], B.L. Ehlmann[3,4], E. Leask[3], R.N. Greenberger[3,4], M. Benoît[2], [1]Institut de Recherche en Astrophysique et Planétologie (Toulouse - France, patrick.pinet@irap.omp.eu), [2]GET (Toulouse, France), [3]Caltech (Pasadena, CA, USA), [4]Jet Propulsion Laboratory, California Institute of Technology (Pasadena, CA, USA).

Introduction:

The Maqsad area of the Oman ophiolite has been previously documented through an airborne hyperspectral survey [e.g., 1,2,3]. The present *in situ* study focuses on a majestic landscape where a wide diversity of mafic ultramafic lithologies is exposed and where the primary igneous stratigraphy of the mantle/crust boundary (oceanic “Moho”) is perfectly preserved (Fig. 1). A 150m-thick horizon of dunite (made of almost pure, partly serpentinized olivine) is sandwiched between altered mantle harzburgite (olivine + opx) at the bottom and interlayered wehrlites (olivine + cpx) and olivine gabbros on the summits.

Figure 1: Field work section (~500m of vertical extent). Red and light green squares: harzburgite; dark blue and yellow: dunite unit; cyan: cpx dunite; pink and dark green: wehrlite and gabbro.

Instrument description / data acquisition / Field Campaign:

The Caltech imaging spectrometer system [4] is field-portable. It consists of a quad-core processor and two sensors (f/2.5 aperture vertical slit cameras), co-boresighted on an optical bench. The visible-near infrared (VNIR) sensor acquires data over a spectral range of 0.4-1.0µm with a 2560x2160 pixel CMOS (Complementary Metal-Oxide Semiconductor) array with a spectral resolution of 5nm (FWHM) and a sampling of 1.625 nm. The shortwave infrared (SWIR) sensor acquires data over a spectral range of 0.97-2.60 µm with a 640x512 pixel Stirling-cooled Mercury Cadmium Telluride (MCT) focal plane camera with spectral resolution 6nm and sampling interval 6nm (FWHM). The signal-to-noise ratio (SNR) is >100 over all channels. Images are built one image line at a time, viewing the scene through a slit. The system operates in macroscopic mode, using a tripod for imaging of large features, with a fine motion-control rotational stage to acquire panoramic images. The instrument scans over distances of ~7m to infinity at a single focus.The effective instantaneous field-of-view (IFOV) on target is 0.6(3)cm (VNIR) and 1.7(8.5)cm (SWIR), respectively, from a standoff distance of 20(100)m, with the resolution varying with distance to the outcrop. Scan rates are typically on the order of 1-2°/second, depending on the lighting conditions and resulting exposure times. Exposure times are set manually and optimized to obtain maximum signal without saturating on the brightest scene elements. Dark current and flat field corrections are performed on each image to correct for instrumental effects. Calibration panels are placed in the scene for radiometric/atmospheric correction. During the test field campaign which took place on 2016, January, 9th-22nd, several acquisitions of the scene have been acquired under different conditions and are currently under processing. We discuss here a subframe (~120° in azimuth of a wider panorama (~180° in azimuth)).

Image Processing and preliminary results:

A first step is co-registration of the VNIR channels over the SWIR ones throughout the whole scene of observation, leading to a 0.55-2.45µm cube, with a 5-6nm sampling. The pixels are then binned by a factor of 2 in order both to minimize any leftover residual misregistration effect and to increase the SNR. The resulting spatial scale of the spectral investigation of the outcrops is thus on the order of 0.18 (1.8)m at 100 (1000)m distance, which is the typical range within the scene.This scale of analysis represents a significant improvement in resolution over airborne/ spaceborne hyperspectral survey (~6-20m/pixel), extending the capability for the mineralogy /petrology mapping purposes of the outcrops.

The next step is an attempt at correcting atmospheric effects. The QUAC algorithm has been tested but it requires more knowledge than expected as the atmospheric path for the line of sight is basically horizontal and not nadir-looking. After masking the sky portion of the scene and the highly shadowed or vegetated patches across the scene, a heuristic approach has been implemented here, based on a PCA analysis of the dimensionless dataset (centered coordinates), in the scaled reflectance space for minimizing the photometric effects associated with the variation of lighting and geometry conditions across the scene.

We notice that the variability along the 3rd principal axis appears driven by the distance to the detector (Fig. 2); this is used for renormalizing the spectral information to a standard distance which corresponds approximately to the distance of the spectralon calibration panel.

The channels in the atmospheric windows are then discarded and the resulting set is used for exploring the mineralogical variability across the scene and creating a first-order lithological mapping (Fig. 3) of the section, mainly driven by mafic absorptions in the 1µm domain in agreement with [2,5].

Implications and future steps / Perspectives:

A true atmospheric correction is still to come, but the results produced here are promising and demonstrate the great potentiality of hyperspectral survey for landscape lithology mapping and mineralogical reconnaissance both for terrestrial and planetary in situ exploration.

References: [1] Pinet P.C. et al. (2006) *LPS XXXVII,* Abstract #1346. [2] Combe J.-P. et al. (2006) *Geochem. Geophys. Geosyst.*, 7, Q08001**.** [3] Clenet H. et al. (2013), *JGR Planets, 118,* 1-24. [4] Greenberger R.N. et al. (2016) *IEEE Whispers Conf. 8th*, 4p. [5] Roy, R. et al. (2009) *Geochem. Geophys. Geosyst.*, *10*, Q02004.

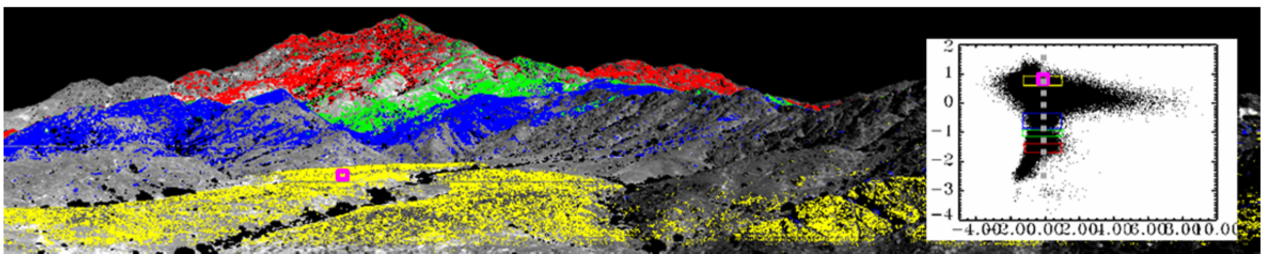

Figure 2: Color units across the scene are associated with the same color rectangles in the PC space. Variation along the 3rd principal axis (y-axis, displayed by the grey-dashed line) is driven by the distance to the detector (x-axis variation driven by 'atmosphere' photometric effects (involving topographic slope and backlight geometry)). Pink square corresponds to the approximate distance for the spectralon panel (which was actually to the left of the complete scene).

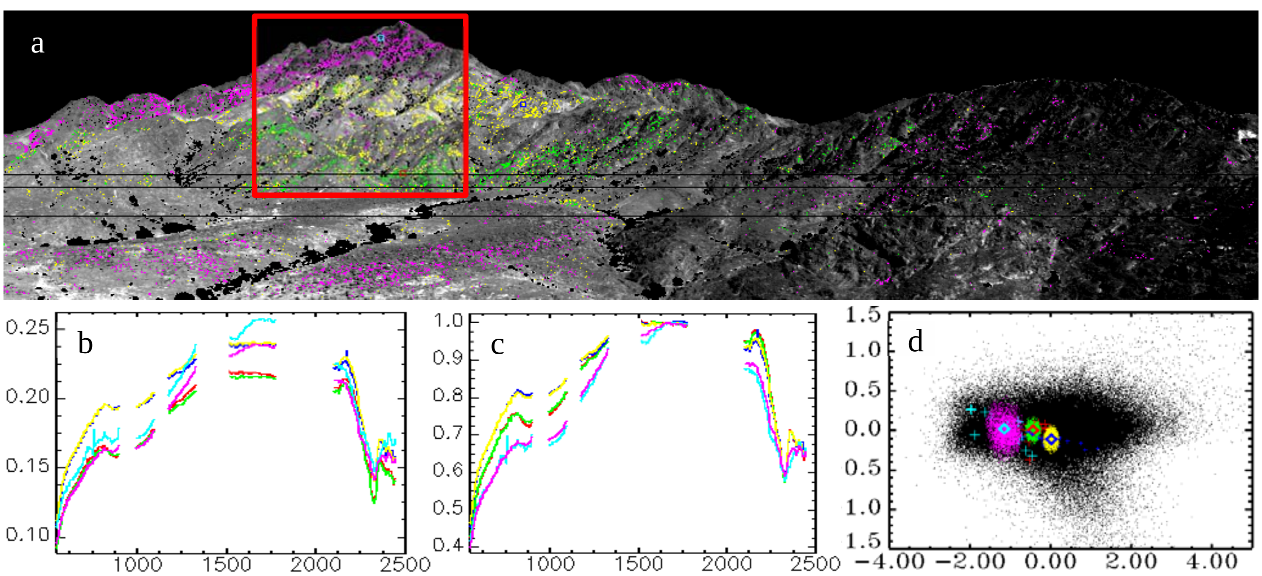

Figure 3: First-order mineralogical mapping (a) derived from a PC space clustering analysis (d), red frame for location of Fig.1. Cyan (reference) and pink (cluster) spectra (b: reflectance, c: reflectance scaled at 1665 nm; wavelength on both plots in nm) and distribution (d) highlight forefront quaternary deposits of gabbro boulders and exposed upsection interlayered gabbros / wehrlites; dark blue (reference) and yellow (cluster) spectra (b,c) and distribution (d) display dunitic exposures; red (reference) and green (cluster) spectra (b,c) reveal harzburgite outcrops. The 2 µm domain is dominated by an ubiquitous 2.3µm absorption feature (carbonate /serpentinization effects) and hydroxyl group (OH) features at 2.13 and 2.25 µm.