INFRARED SPECTRAL ANALYSIS AND PALE-ENVIRONMENT RECONSTRUCTION ON MARS. A. Kereszturi[1] [1]Research Center for Astronomy and Earth Sciences, Konkoly Thege Miklos Astronomical Institute, H-1121 Budapest, Konkoly Thege Miklós út 15-17. (e-mail: kereszturi.akos@csfk.mta.hu).

Introduction: Using the large and diverse datasets that are available from Mars, several models are published that aim to connect different data types to build a coherent model for the evolution of Mars [1,2,3,4,5,6,7]. Despite these efforts there are still problematic issues to connect different observations under the same model, including: 1. abundance of morphological evidences for past liquid water on the surface, 2. rarity of weathered minerals at these sites, 3. difficulties to confirm a relatively warm and wet early Mars by climate models. Despite the uncertanties other evidences suggest liquid water might play an important but specific role, making any paleo-environmental reconstruction even more complex, including: 1. mixture of intact and weathered minerals, 2. possibility of liquid brines at low temperature, 3. occurence of old weathered minerals mainly at impact craters. Below some connections and problematic issues are also outlined toward the aim of building a coherent model of the geological history of Mars.

Methods: While surface morphology provides information on the type of geological processes, this is rarely enough to infer such important parameter like ancient temperature and its duration. Here comes infrared compositional analysis into the picture, as the joint analysis of morphological and mineralogical data might provide more accurate results for paleo-environmental reconstruction. To improve our understanding three main guidelines were used to characzterize the temporal and thermal parameters of ancient environments: 1. morphometry based discharge and active period calculations for ancient channels (MOLA and HRSC based DTMs for eroded-deposited volume calculation [8] and image analysis for morphology), 2. spectral based identification of surface minerals (phyllosilicates, hydrous sulfates and oxides), 3. model based calculations for cooling, freezing and alteration timescales.

Results: To resolve these issues a small but important step that helps to integrate the above mentioned issues into one, unified model of the Martian environmental changes is a database of paleo-environment indicators for Mars. Below some elements of this system based approach are listed, which should be considered during such synthesis including a case study.

There is strong need for cross-cutting analysis and connecting different type of results and models [9] to overcome these difficulties. While the surface morphology provides information relatively well on the formation conditions of surface structures, at the level of the conditions for mineral formation the situation is worse, although the growing number of laboratory measurements is available. An important next step is to connect morphology with mineralogy regarding the formation conditions. Below some of those critical issues are listed where such synthesis has started at the Astrophysical and Geochemical Laboratory (CSFK Hungary) under the COST TD 1308 action.

Question of indicator minersals: examples to infer certain conditions to reconstruct past environment are:

- hydration/dehydration (H_2O containing sulfates: with water content changes according to environmental conditions, jarosite by dehydration [10]),
- neutral-weakly alkaline pH: carbonates, nontronite (cold, reductive conditions, pH>6), smectites (high water/rock ratio, pH=6-12), zeolite (analcime),
- acidic pH: sulfates (pH=7-1), opaline (pH<9),
- temperature: chlorite (present only in craters [11], prehnite (200-300 °C, metamorphosis), zeolite (analcime <200 °C),
- metamorphosis: smectite → chlorite (200-300 °C).

The formation of these minerals is influenced by several conditions together (summarized in Table 1.).

Table 1. Physical effects on mineral weathering:

temperature (increases reaction rate, supports decomposition)	water (pH, salinity, rock/water ratio with complex relationship)
duration (increased duration supports alteration, durations at different temperature domain plays a role)	particle size (smaller size enhances weathering rate, but also total surface area by porosity does matter)

Question of generalization: While it is possible to give the range of formation conditions for a given mineral, it is difficult to identify exactly in which range was it present or which type of alternative formation methods worked. The outstanding examples are phyllosilicates, which could form under water action [12,13] with global surface/subsurface wet conditions [14,15] or impact induced hydrothermal alterations [16]. While phyllosilicates are good indicator of altertions, their simple abundance is not an indicator for the degree of alteration [17].

Question of timescales: problem exists in the identification / estimation of different time scales of water related processes:1. during the geological history of a terrain some events after the original formation could be identified in the kick points of CSFD curves, showing resurfacing [20], but uncertainty from small area for crater size frequency distribution based age values exists, 2. poorly known temporal properties of fluvial discharges and alteration durations even at Earth analog locations [18,19], 3. lack of information on the past existence of multiple wet periods at channels and lakes..

Temperature / time scale connection: Some surface feature types that could be used to infer past conditions are indicated in Figure1. (axis values are not linear).

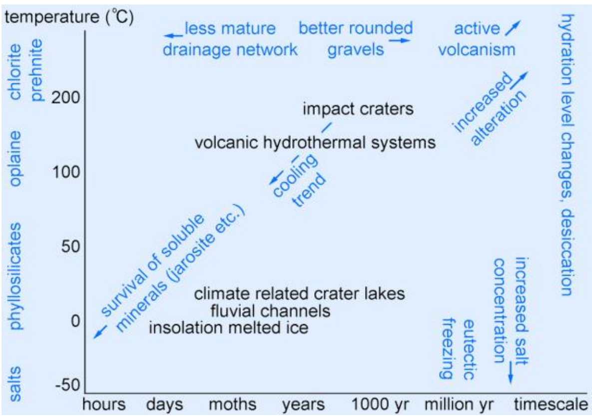

Figure 1. Comparison of temporal / thermal characteristics of various environment types on Mars

Guidelines for case studies: To reduce error and connect different information types two main approaches should be used for certain targets on the surface for paleo-environment reconstruction: 1. remote analysis to compare IR spectra based mineralogy (estimated durations: crater size based cooling timescales and duration of fluvial activity), 2. local scale: particle analysis in ideal case with context (sedimentary structures for example borehole wall imaging as planned for ExoMars rover drill). Main methods where information is/will be available in the near future are:

- channel + sediment characteristics: calculating the eroded / deposited volume for formation timescale estimation (uncertainties: porosity, transport rates, and the dominant/average discharge).
- grain analysis: shapes, size distribution of small grains and their IR spectral based composition are indicative of transport methods, distances and source area's characteristics (here core drill provide excellent context in the future by EXM).

An example location can be seen in Figure 2. where effect of fluvial activity and occurrence of opaline can be analyzed together. Although their formation are not necessarily connected, it is worth jointly analyzing them [21].

Conclusion and outlook: Infrared mineral analysis connected to morphology provides useful method to reduce error and uncertainty in modeling the origin and selection from alternative models. To apply such approach on Mars a list of paleo-environment indicators would be of high importance. In a recently started project we aim the compilation such database. In this work emphasis is given on ESA's planned ExoMars rover with its core drill ability. Although the top surface on Mars shows certain level of homogenity, shallow depth might be quite different, as current Martian conditios are almost static (except for the wind-blown surface layer) thus local differences could be maintained for long period, and results of weathering could be highly terrain specific and point to local differecies.

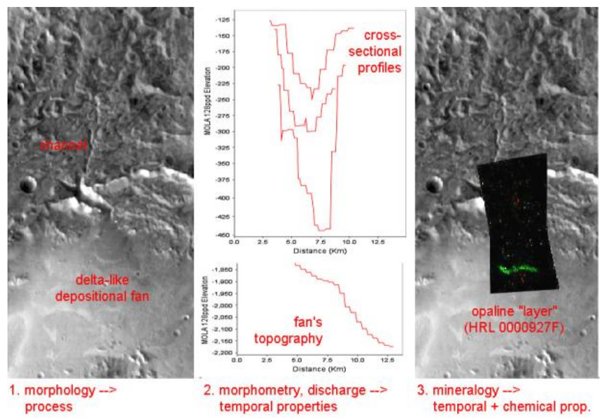

Figure 2. Example location for morphology-mineralogy joint analysis at Chamicel delta in Xanthe Terra

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