



Subsurface water content distribution measured by the DAN instrument along the MSL traverse (Sol 0 – 200)

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On behalf of MSL DAN Team and MSL Science Team

Nuclear Science Symposium

Seoul, Korea

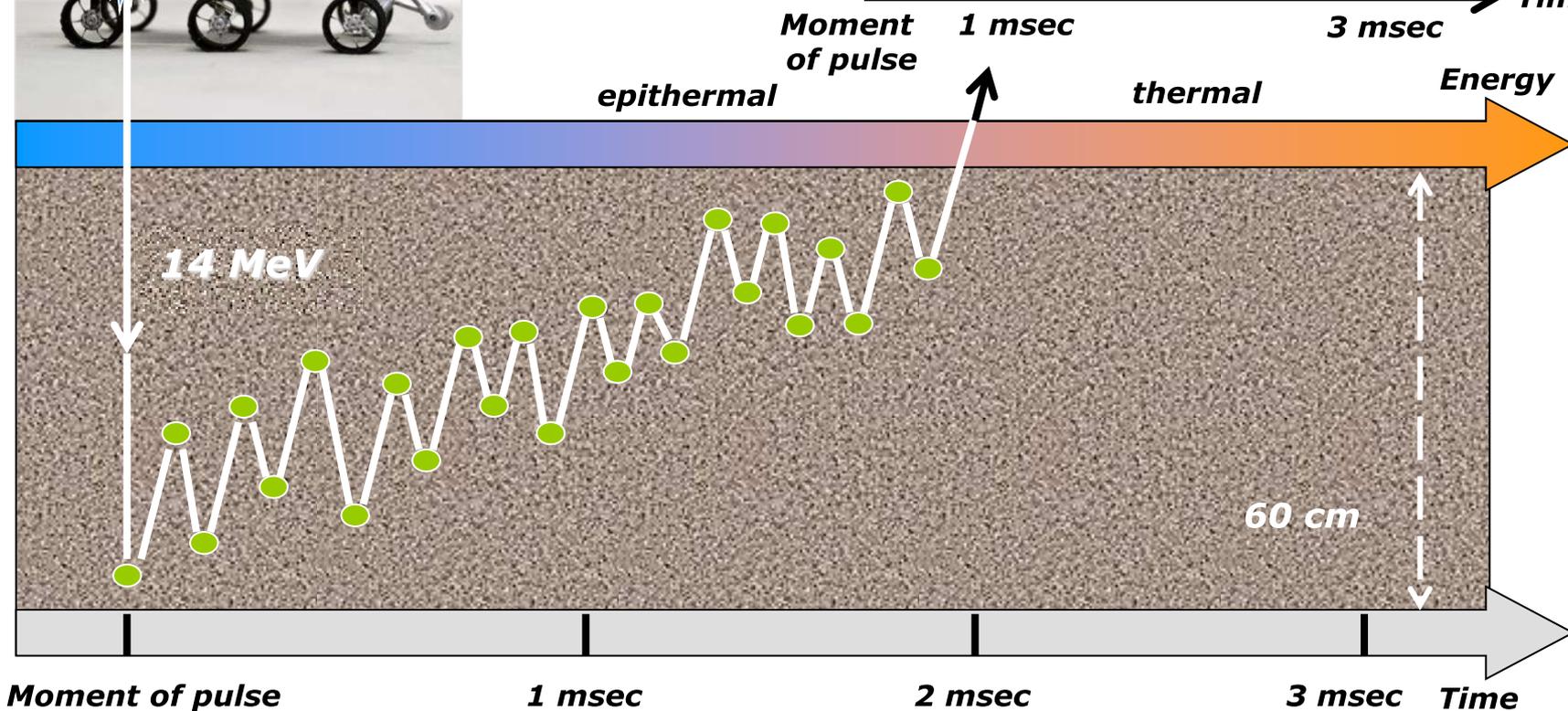
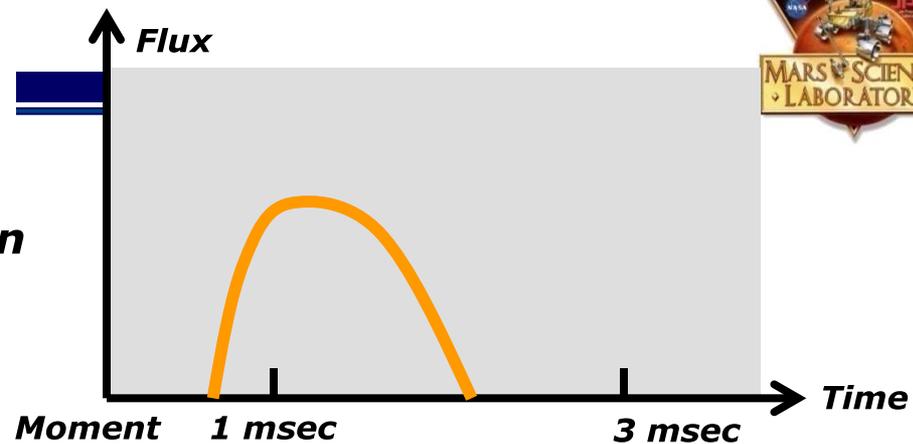
October 27 – November 1, 2013

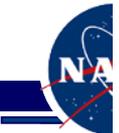


Physics of DAN measurements: Dynamic Albedo of Neutrons



**No hydrogen
in the soil**





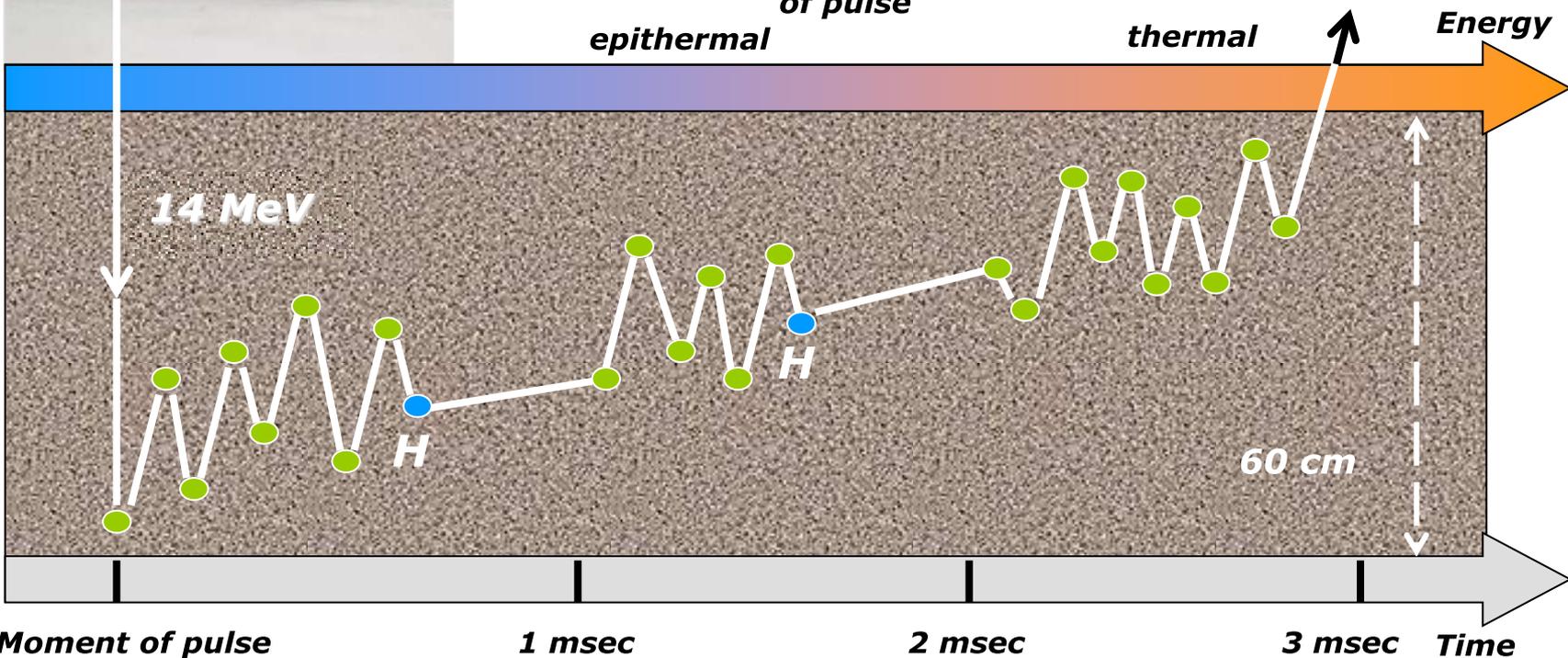
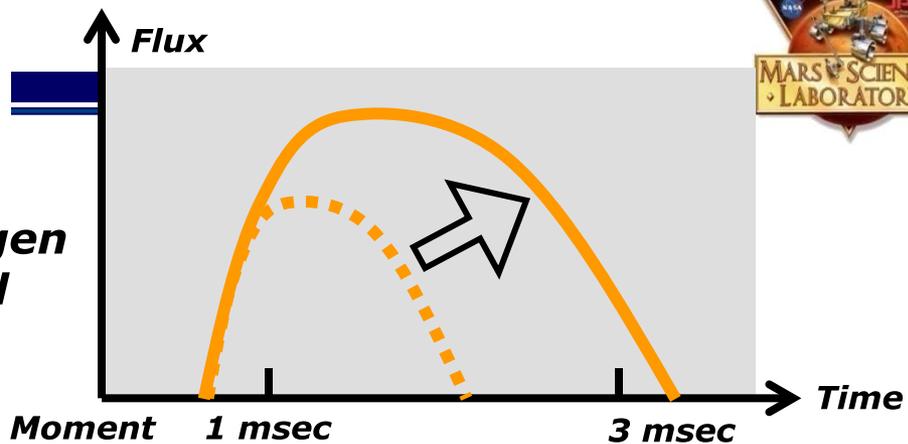
Physics of DAN

measurements:

Dynamic Albedo of Neutrons



With hydrogen in the soil



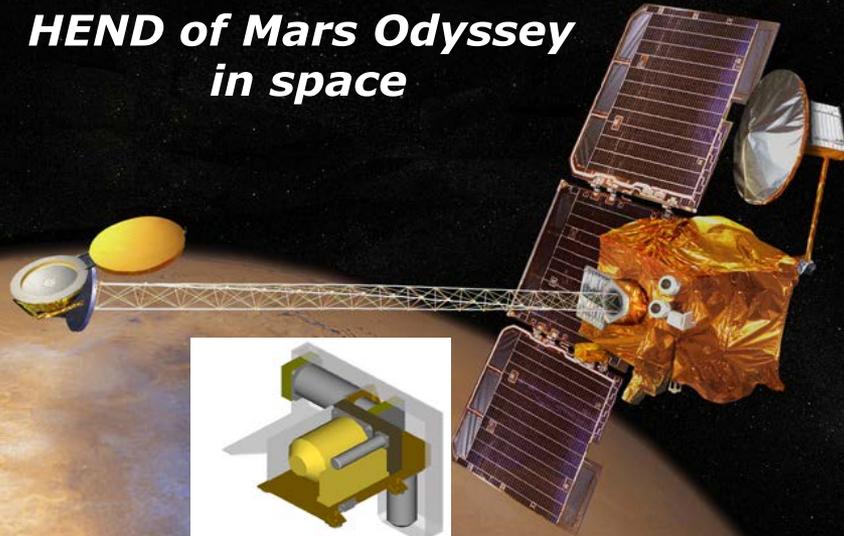
DAN has the active part DAN PNG and the passive part DAN DE



**Industrial PNG
for geology**



**HEND of Mars Odyssey
in space**



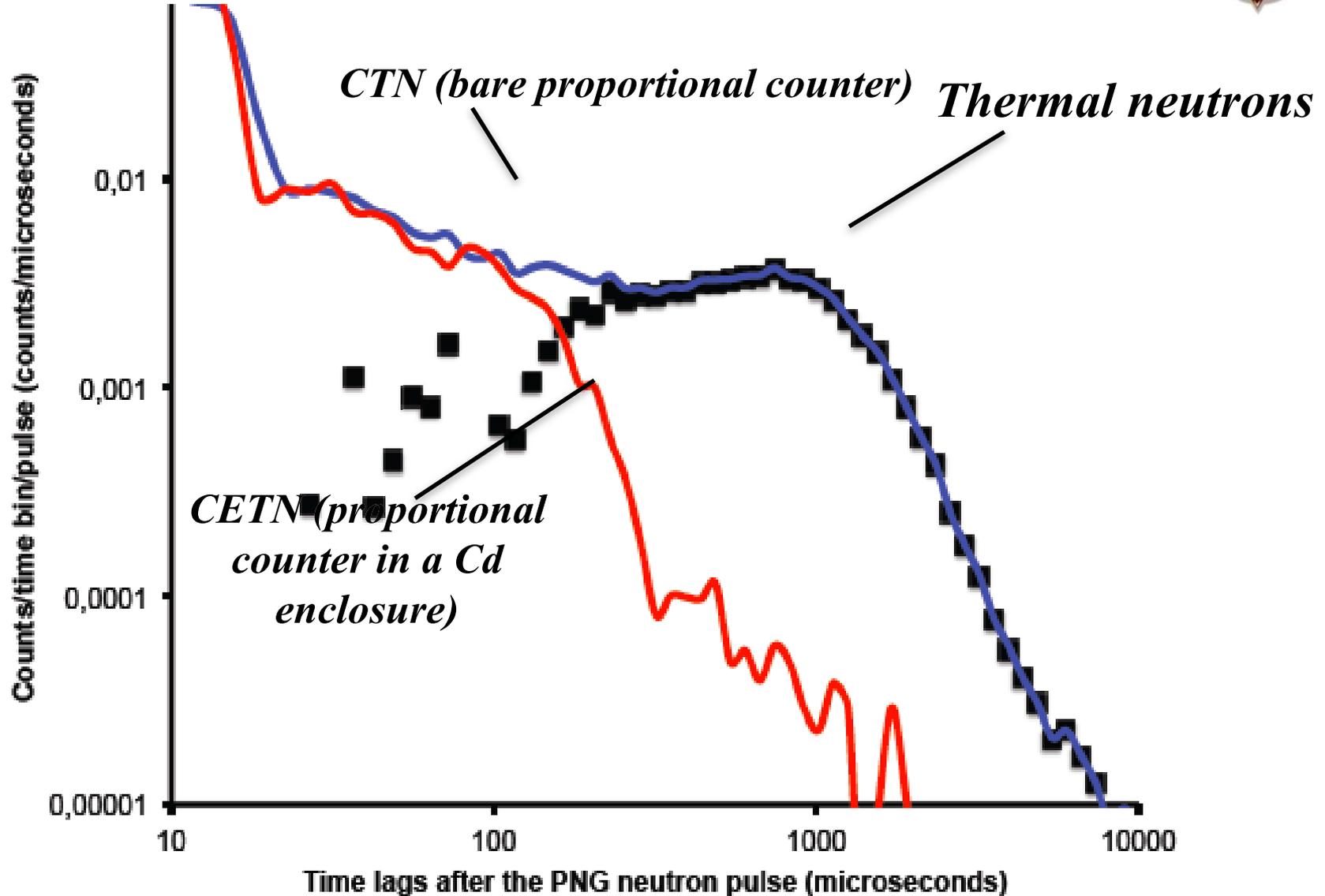
Two GOALS of DAN investigation:

(1) To measure the content of subsurface water

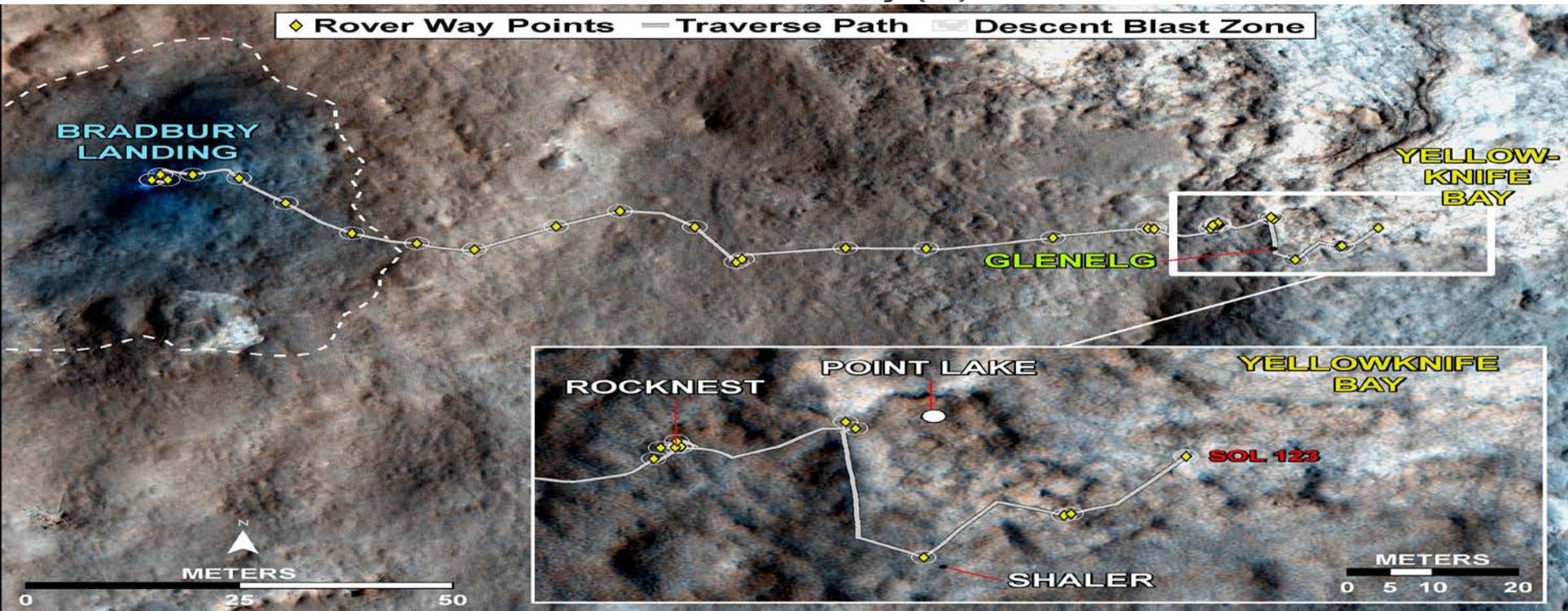
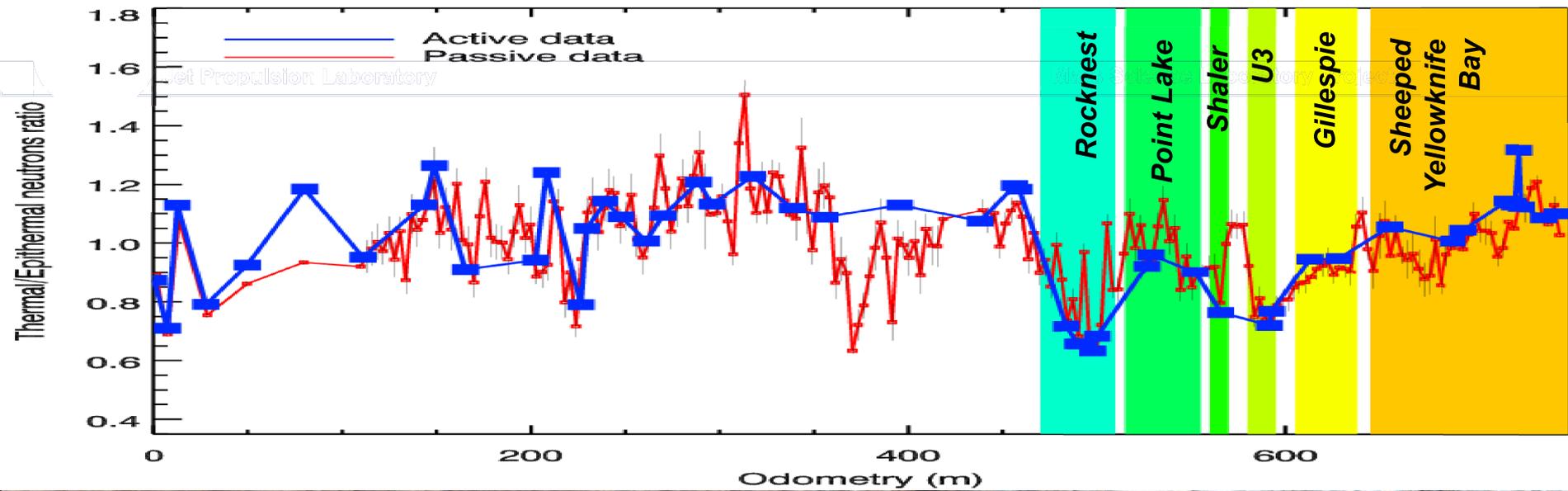
(2) To measure the radiation dose from the neutron emission of the surface



Example of DAN active measurements



Variations of DAN data along the Curiosity traverse



Four different models:

1-layer model

Variable Content of water

1. Homogeneous model with one free parameter: subsurface water content. The contents of chlorine and density are fixed, respectively, at 1% and 1.8 g/cm³.

1-layer model

Variable Content of water and Chlorine

2. Homogeneous model with two parameters: content of water and content of chlorine. The density is fixed at 1.8 g/cm³.

1-layer model

Variable Content of water and variable density

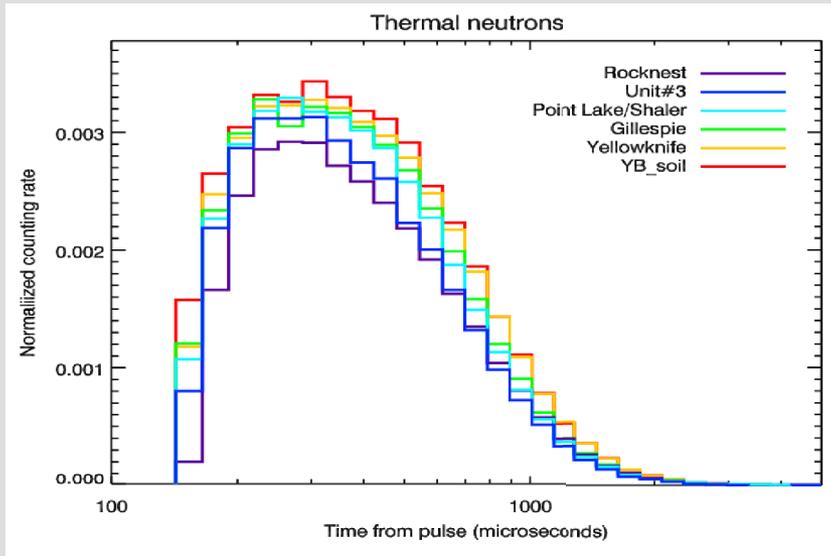
2. Homogeneous model with two parameters: content of water and variable density. The content of chlorine is fixed at 1.0%.

2-layer model

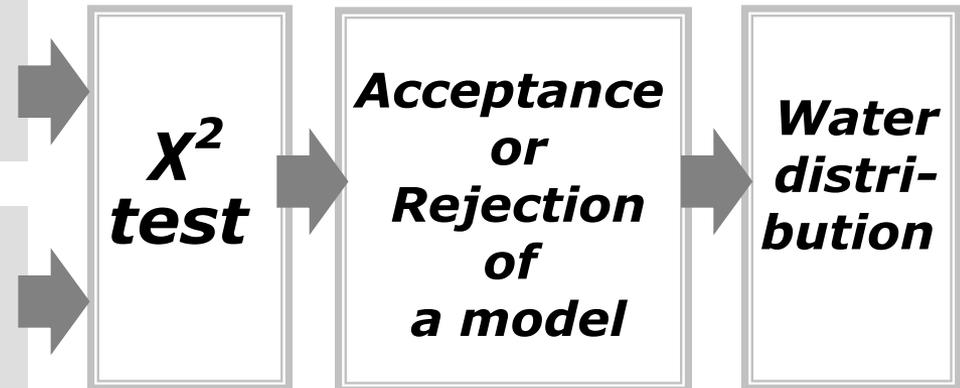
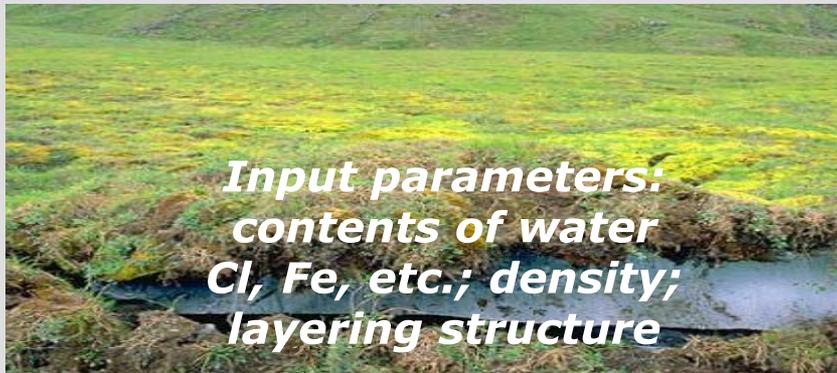


2. Two layers model with four parameters: content of water in the top layer, thickness of the top layer, content of water in the bottom layer and content of chlorine. The density is fixed at 1.8 g/cm³.

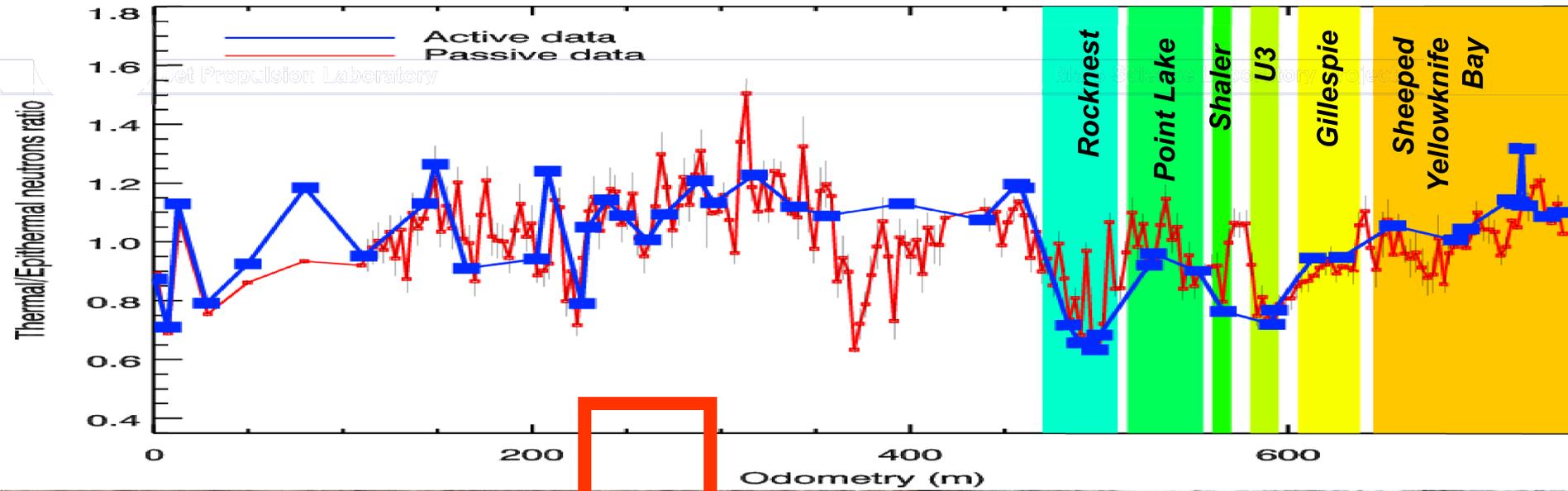
Measured time profiles



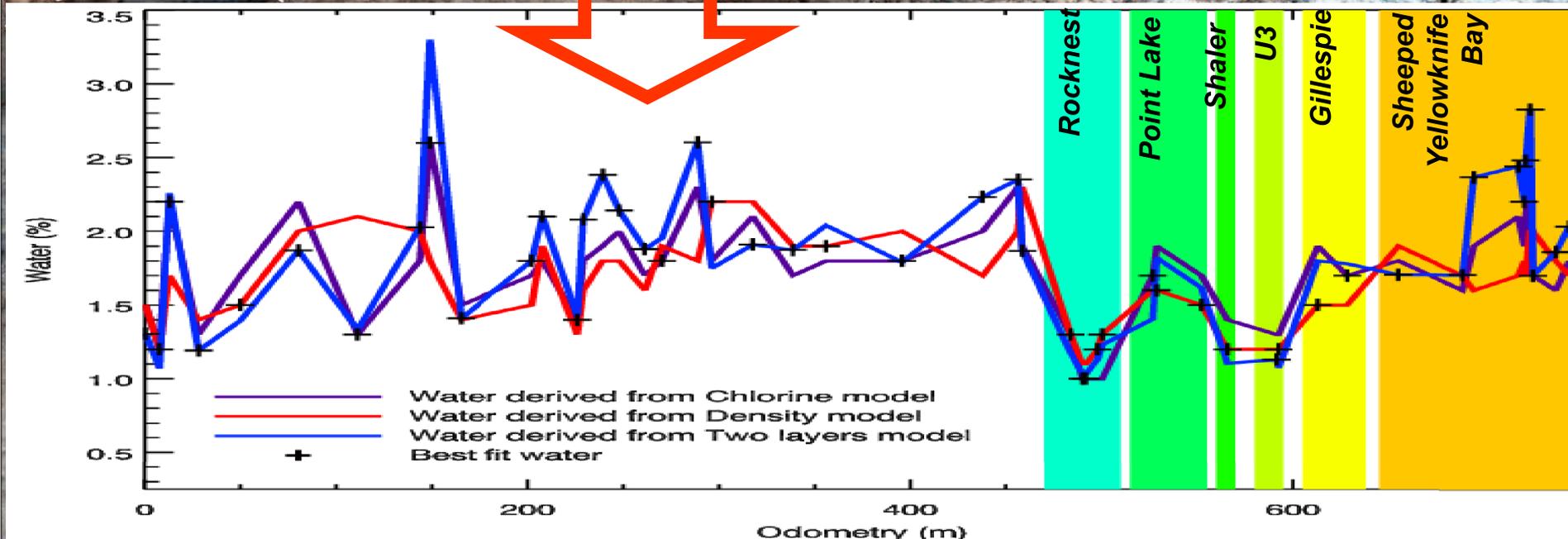
Simulated time profiles for tested model of subsurface



Variations of DAN data along the Curiosity traverse



Variations of water content in the soil along the Curiosity traverse

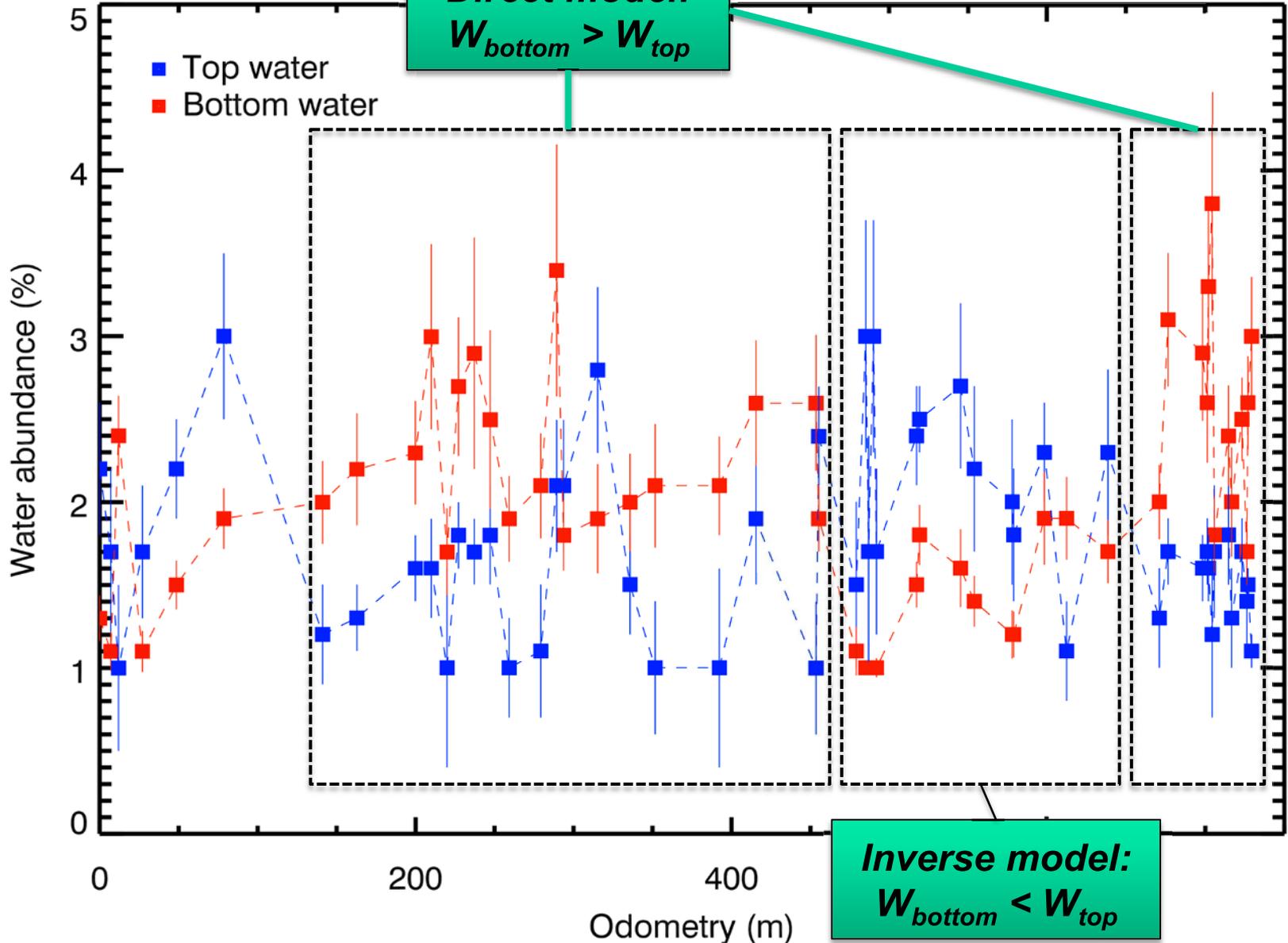


Variations of DAN model parameters along the Curiosity traverse derived from 2 layer model



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Mars Science Laboratory Project

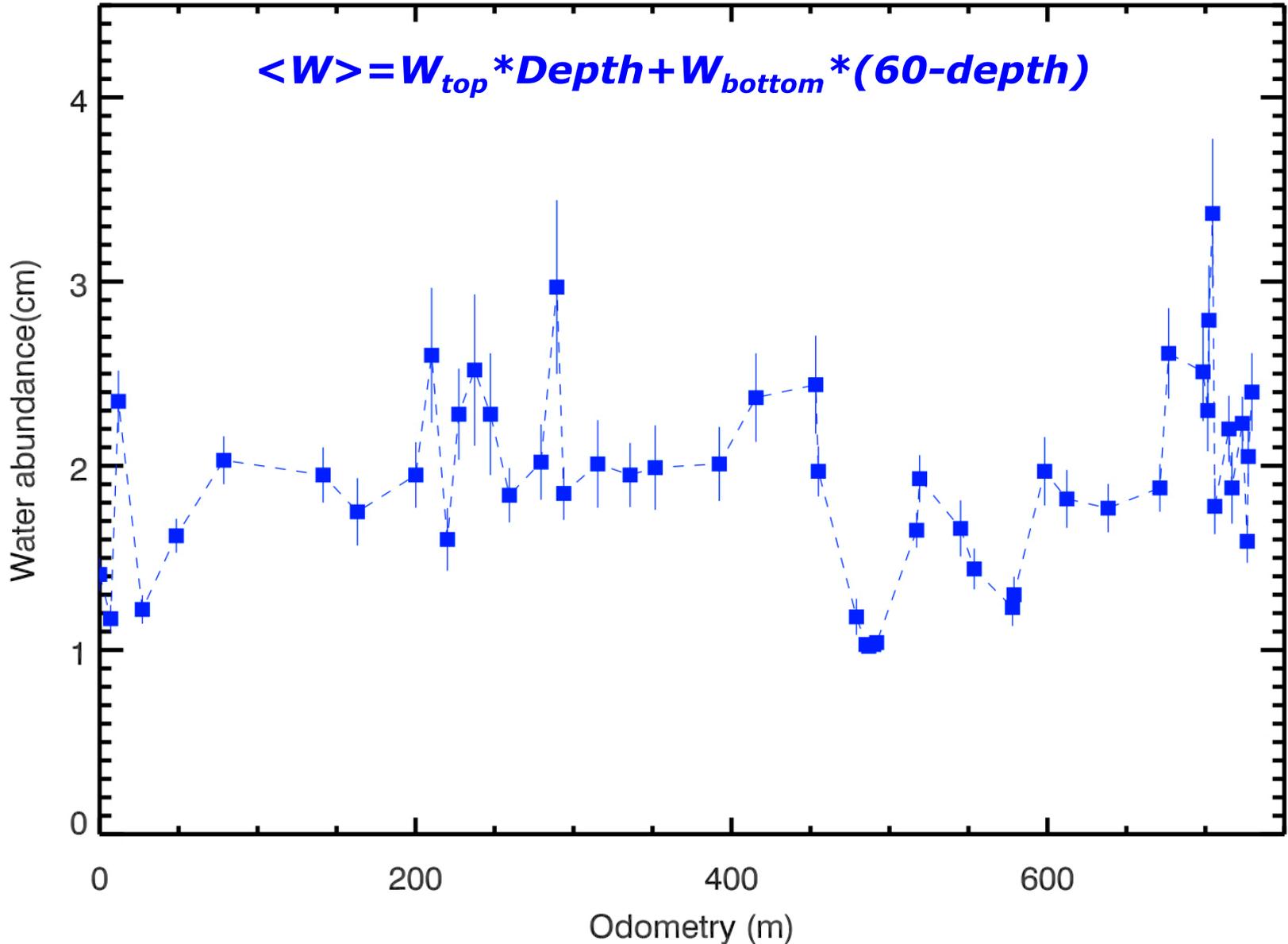


Variations of DAN model parameters along the Curiosity traverse derived from two layers model: average water down to 60 cm depth (instrument sensitivity depth)



Jet Propulsion Laboratory

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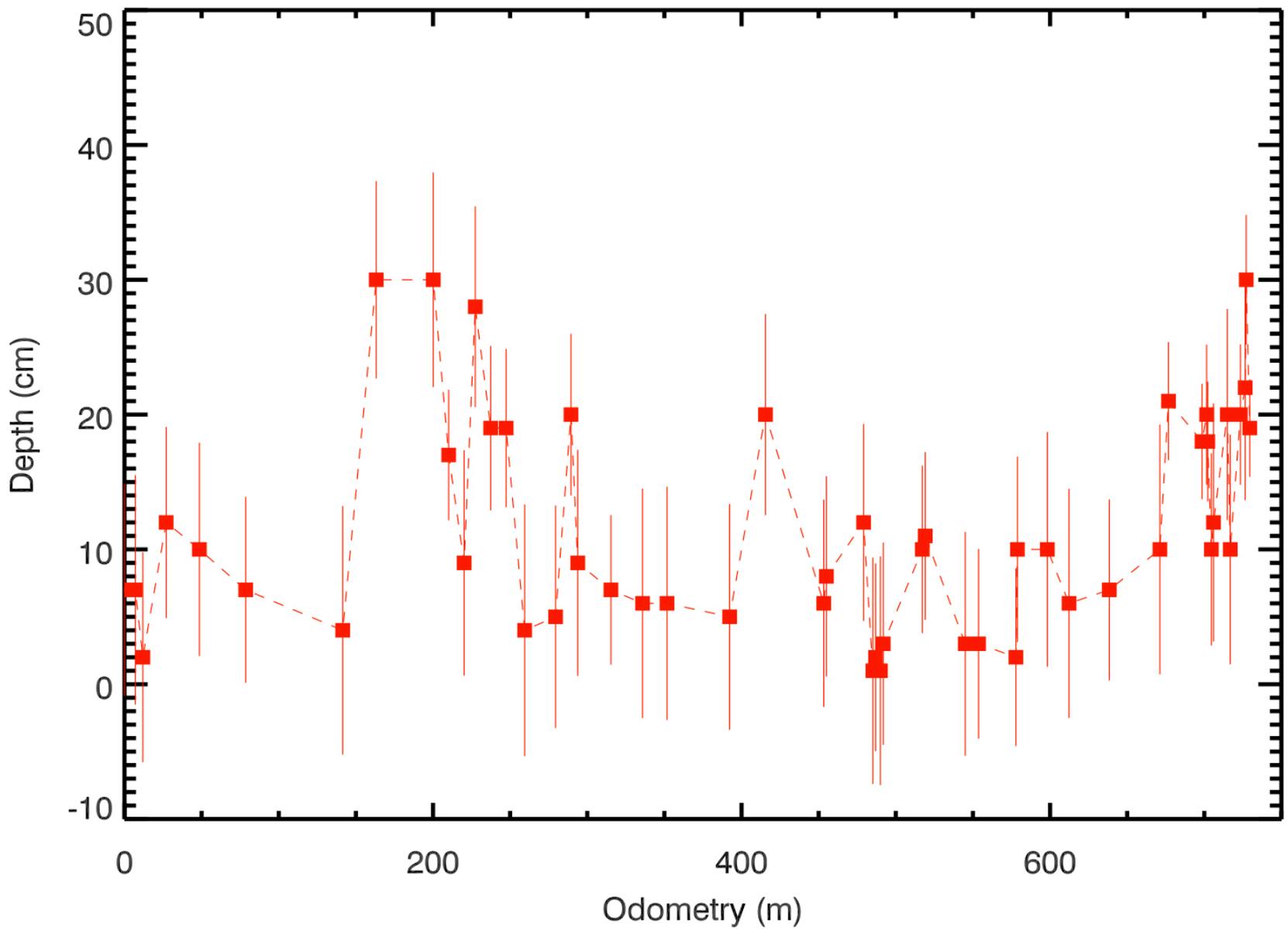


Variations of DAN model parameters along the Curiosity traverse derived from two layers model: depth variations



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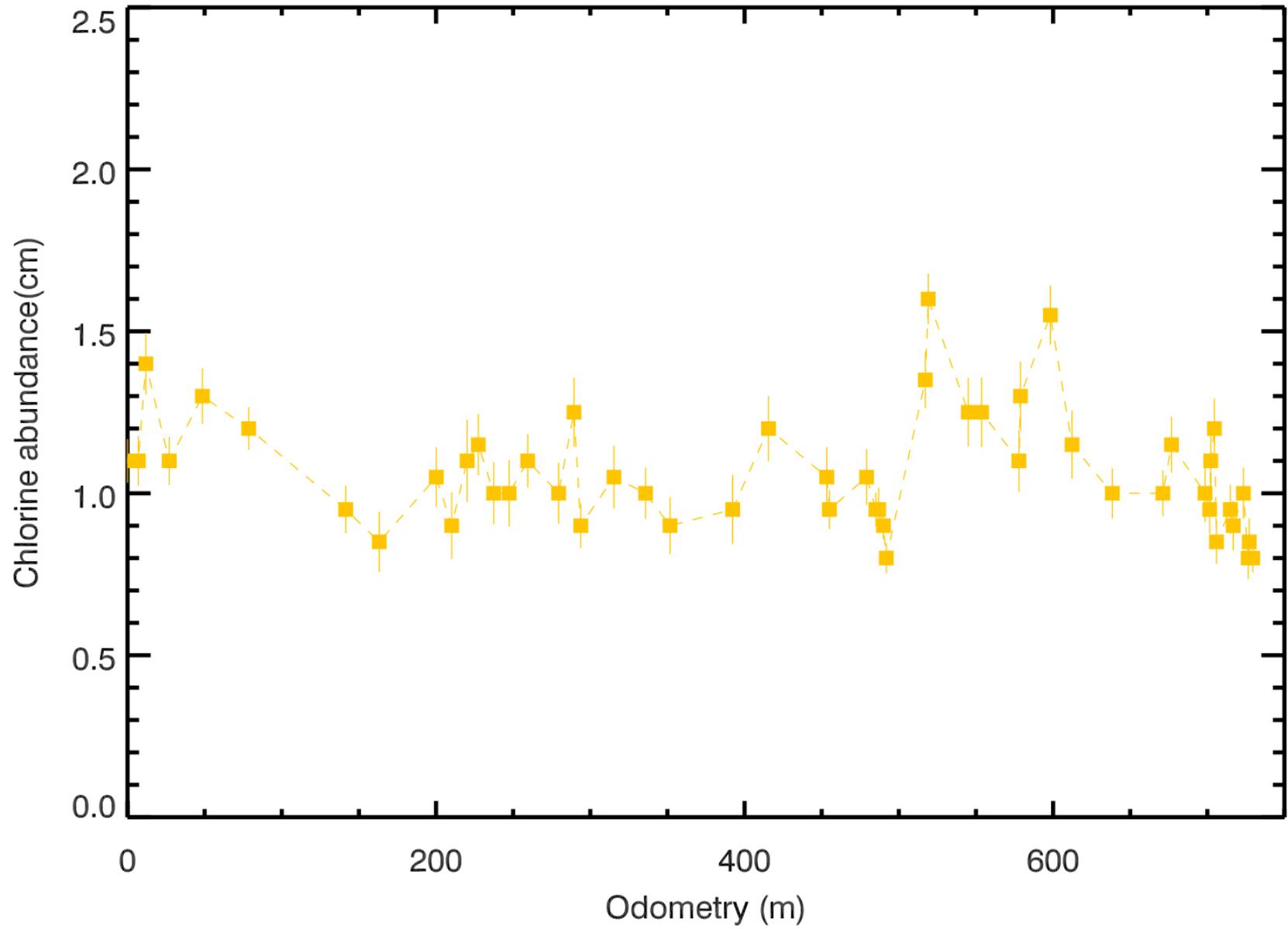


Variations of DAN model parameters along the Curiosity traverse derived from two layers model: chlorine content



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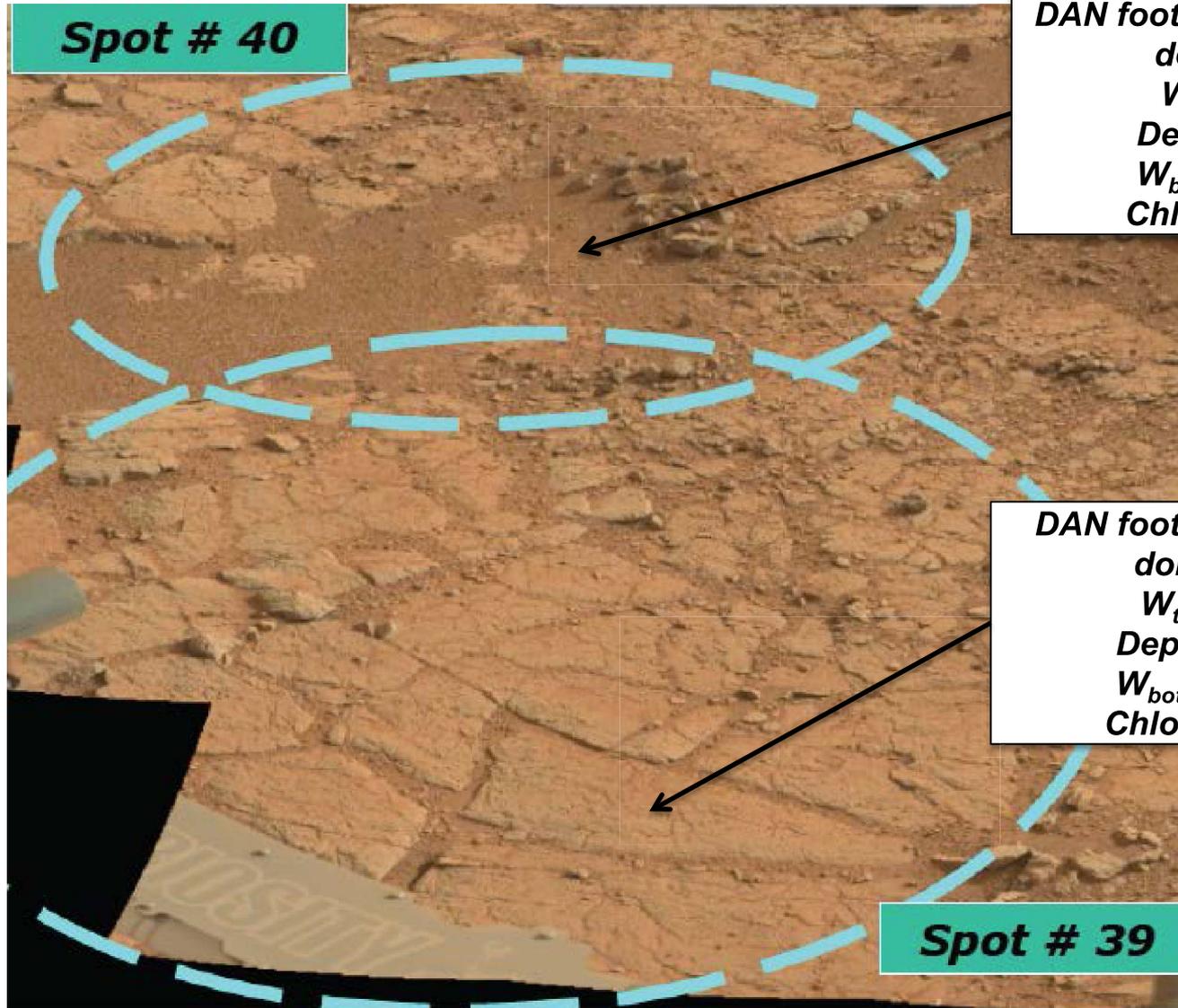


Example of local DAN local measurements performed at Yellowknife Bay formation



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Spot # 40

DAN footprint: loose soil is dominating:
 $W_{top} = 1.2\%$
 $Depth = 10\text{ cm}$
 $W_{bottom} = 3.8\%$
 $Chlorine = 1.2\%$

DAN footprint: rocks are dominating:
 $W_{top} = 1.6\%$
 $Depth = 18\text{ cm}$
 $W_{bottom} = 3.3\%$
 $Chlorine = 1.1\%$

Spot # 39

Comparison between HEND/GRS/Odyssey and DAN/MSL observations of Gale crater



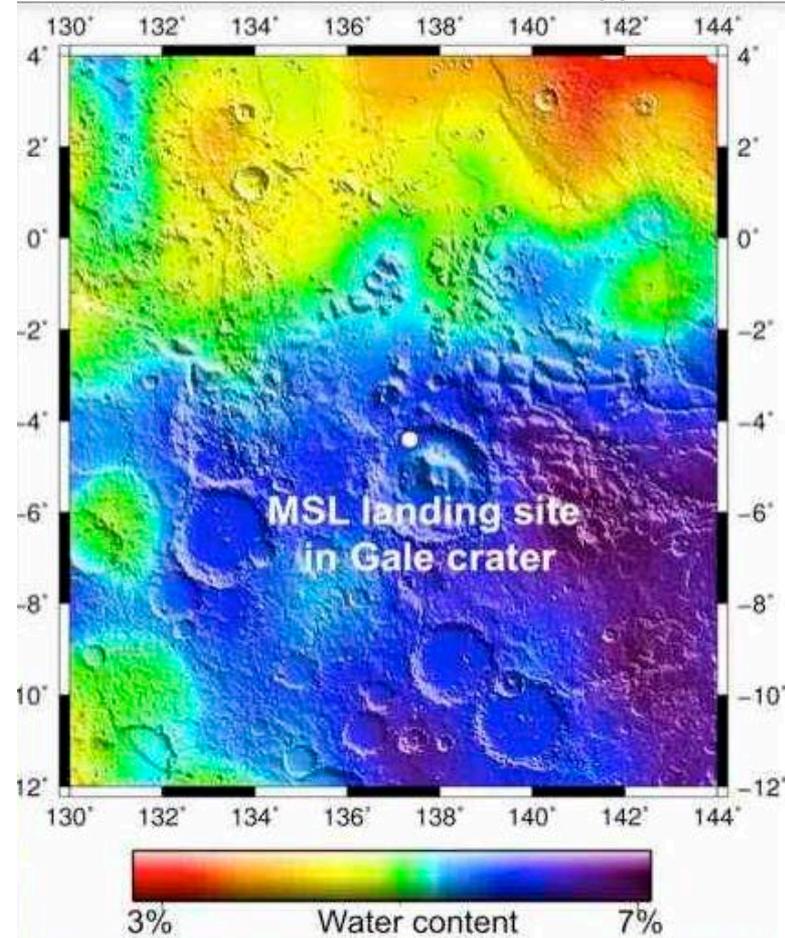
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The DAN data and numerical simulations show that the area around the landing site can be characterized with average content (along all rover stops) of water equivalent hydrogen (WEH) $\sim 2.3\%$. The average content of chlorine is about 1.2%.

The orbital data from Odyssey GRS and HEND are compared with the DAN measurements. The HEND footprint is about 300 km radius, which is significantly larger than Gale area. But it could characterize the average water content distribution in Gale and its vicinity. Analysis of the HEND data shows that the average content of water in the vicinity of Gale is about 4-6% of WEH. GRS observations show a similar (as HEND) water content and only 0.6-0.8% chlorine content.



Summary: Results of the DAN investigation during the first 200 sols on Mars

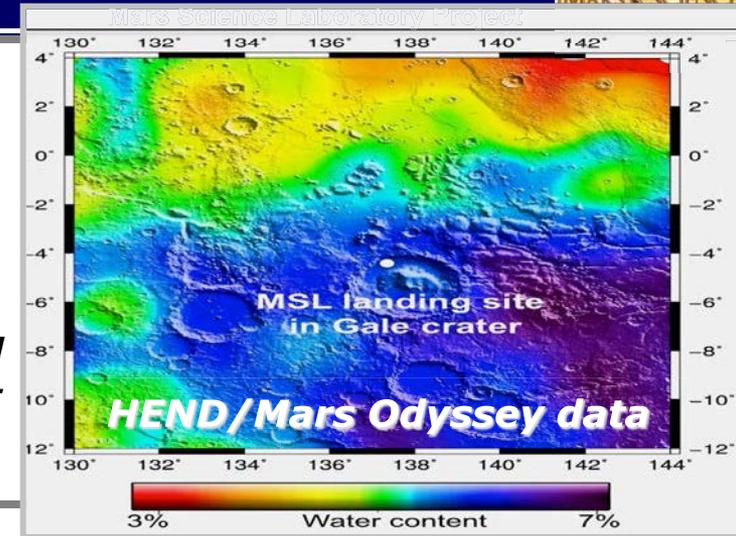


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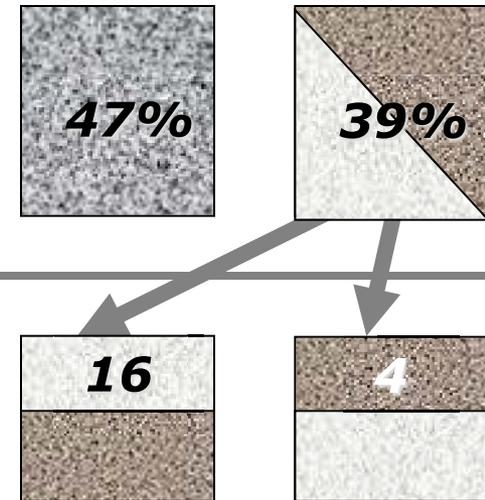


(1) *The DAN data show that the average water content varies from 1.0 up to 2.8 wt% within 60 cm of subsurface.*

These values are much less than the estimated content of water of ~5 wt% based on the orbital neutron data from the Russian HEND instrument onboard the NASA's Mars Odyssey.



(2) *The water in-depth distributions are found to be homogeneous for 47% and non-homogeneous (two-layer) for 39% of the DAN active spots. And 14% of the DAN active spots do not agree with any of 4 subsurface model used.*

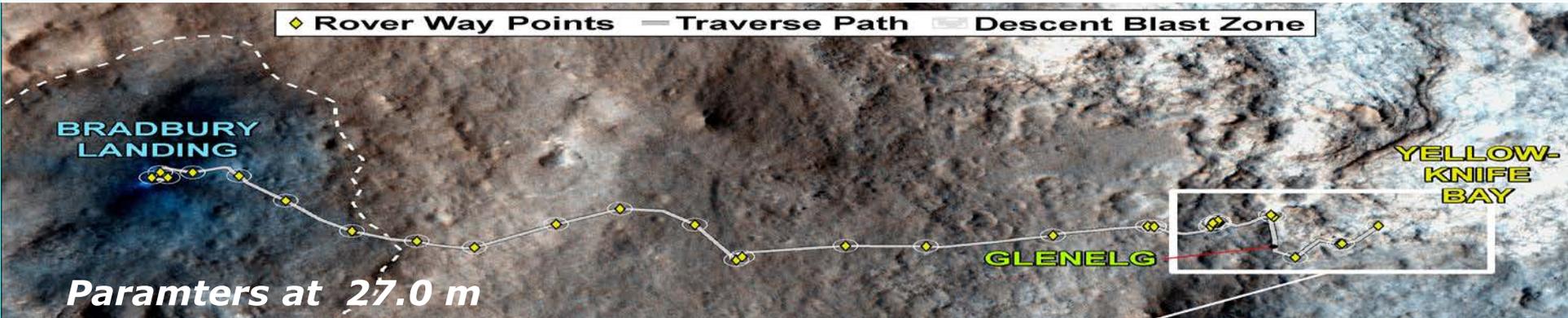
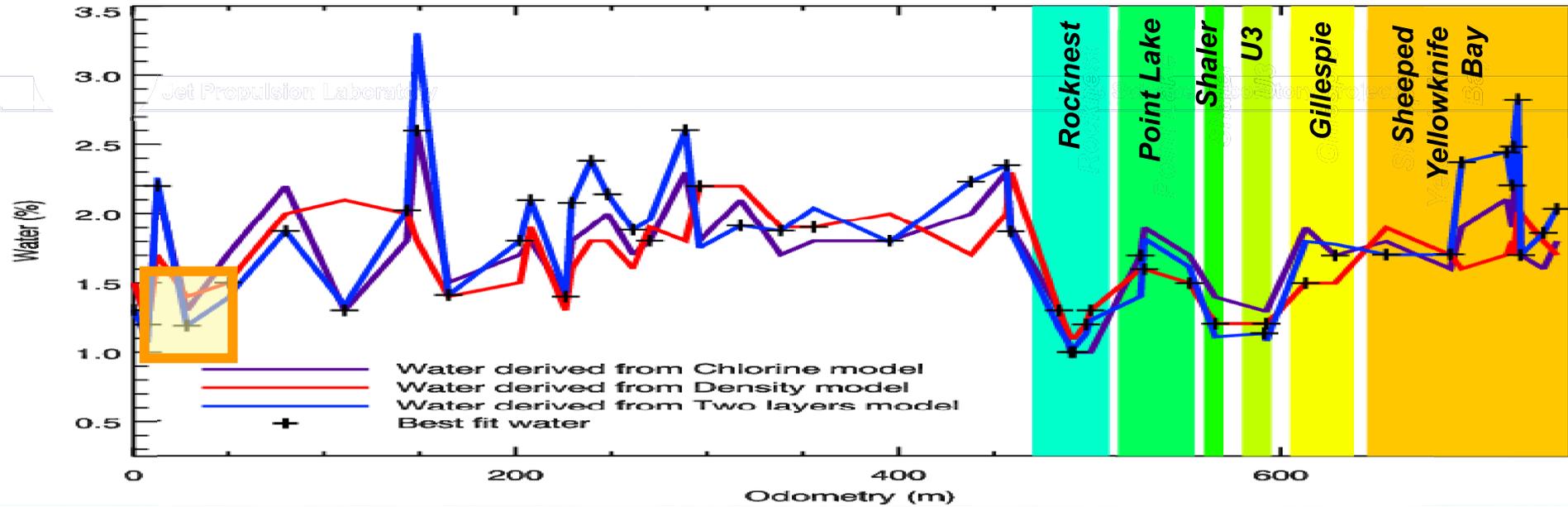


(3) *Out of 39% (20 spots where the two-layer model better fits), the water contents increase at 16 spots (direct cases) and decrease at 4 spots (inverse cases)*



BACKUP

Variations of water content in the soil along the Curiosity traverse

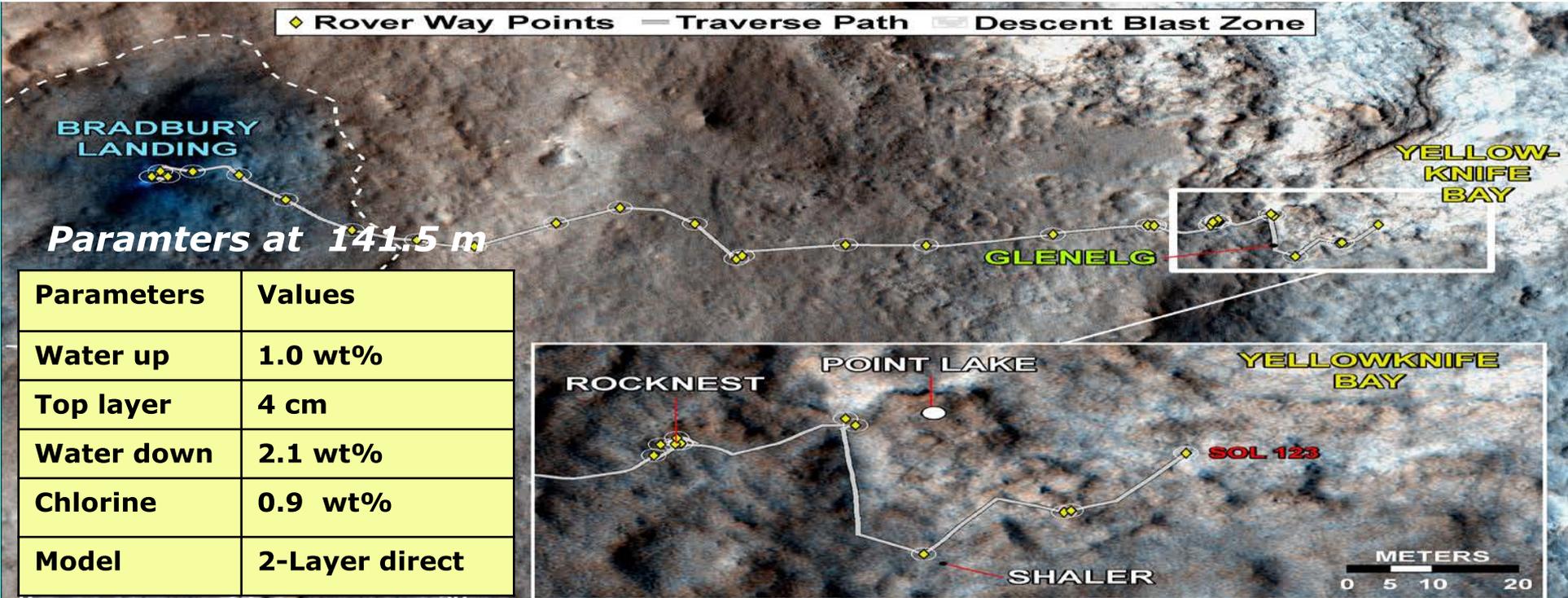
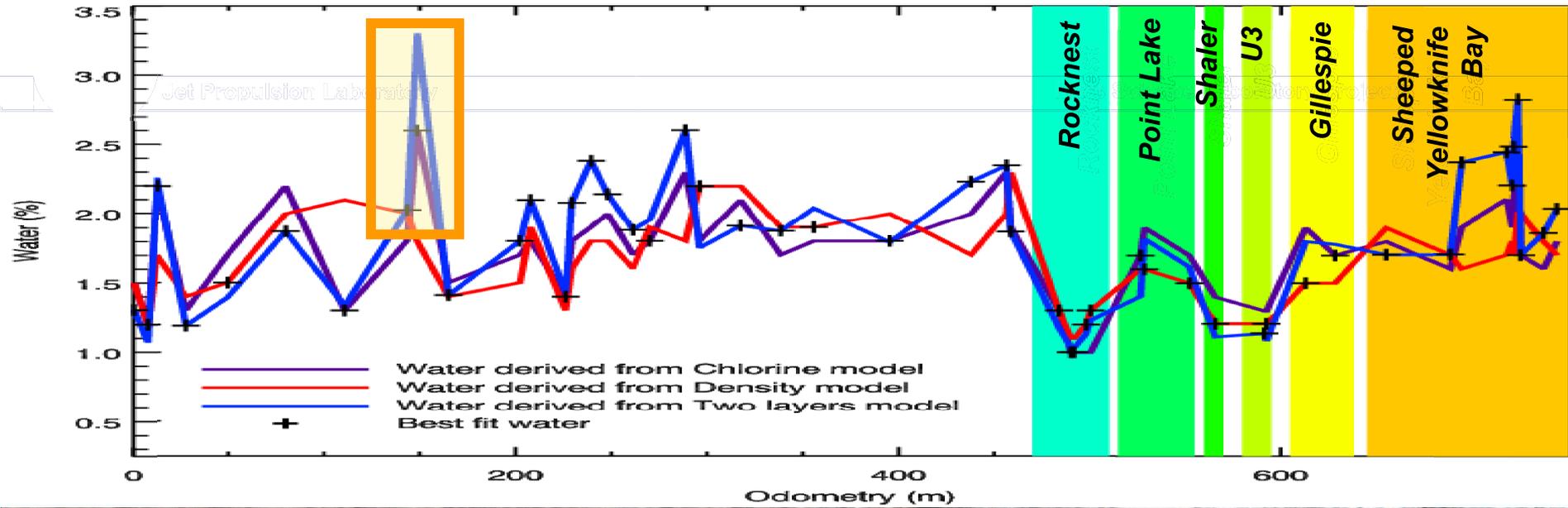


Parameters at 27.0 m

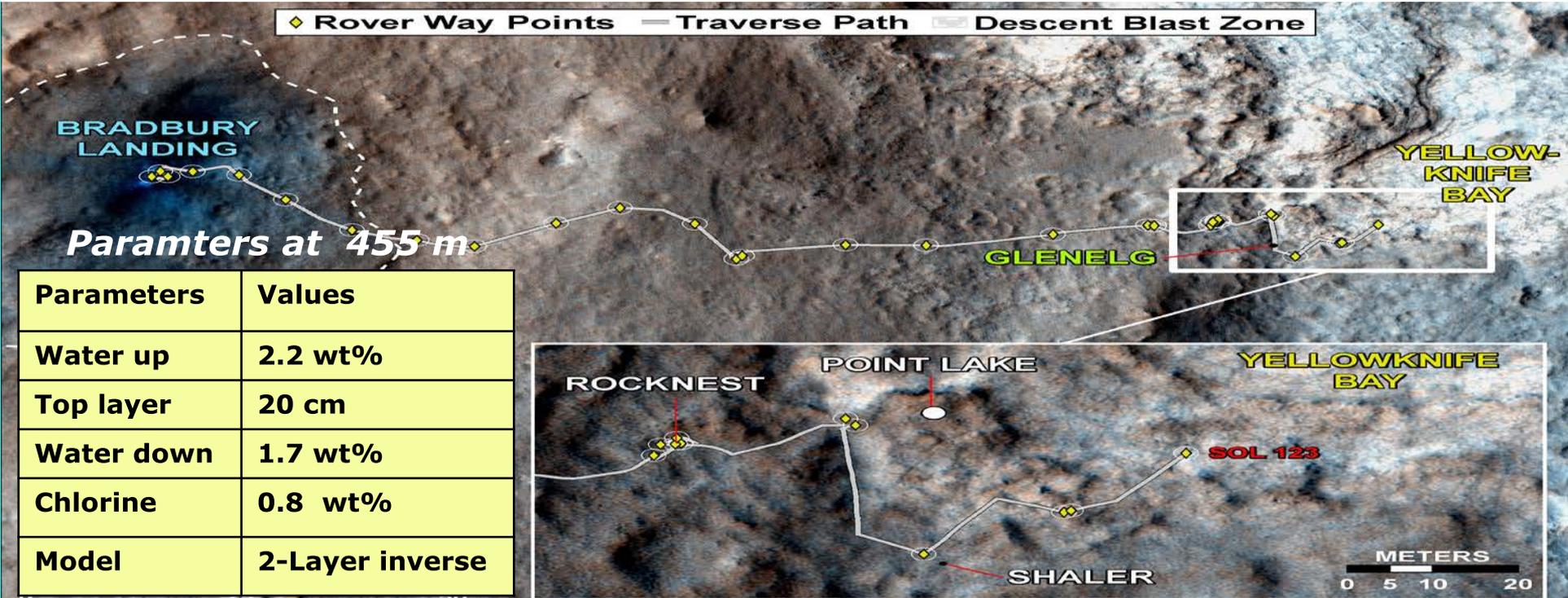
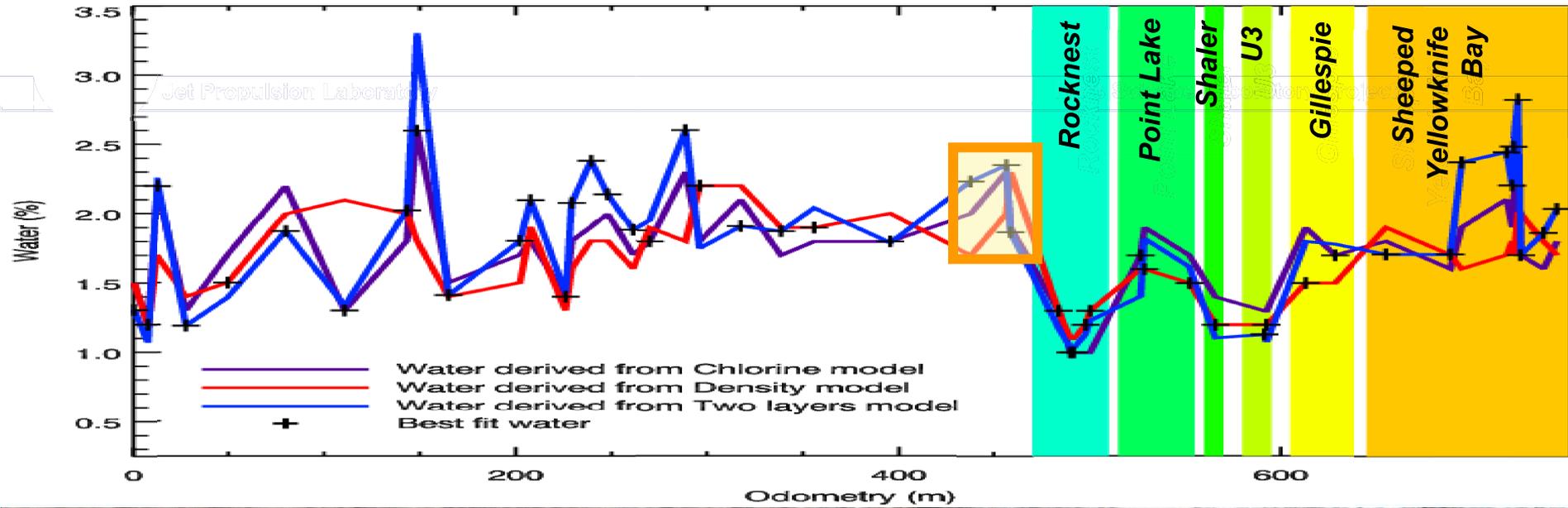
Parameters	Values
Water	1.2 - 1.4 wt%
Density	1.8 g/cm ³
Chlorine	0.95 wt%
Model	Homogeneous



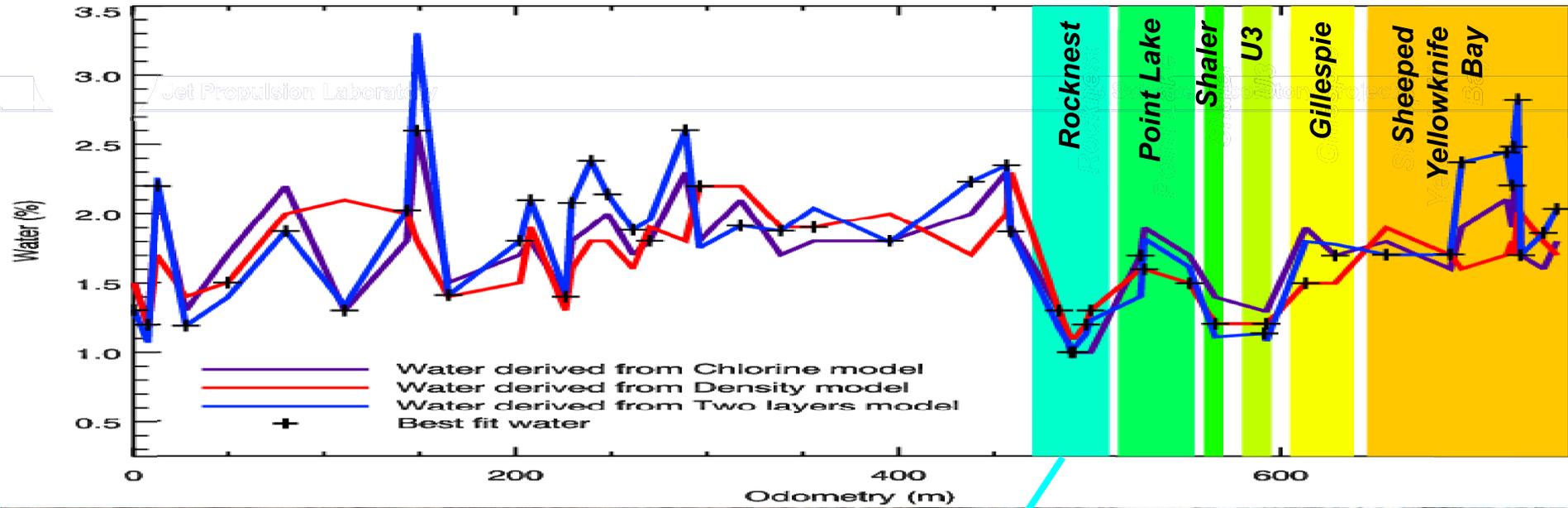
Variations of water content in the soil along the Curiosity traverse



Variations of water content in the soil along the Curiosity traverse



Variations of water content in the soil along the Curiosity traverse

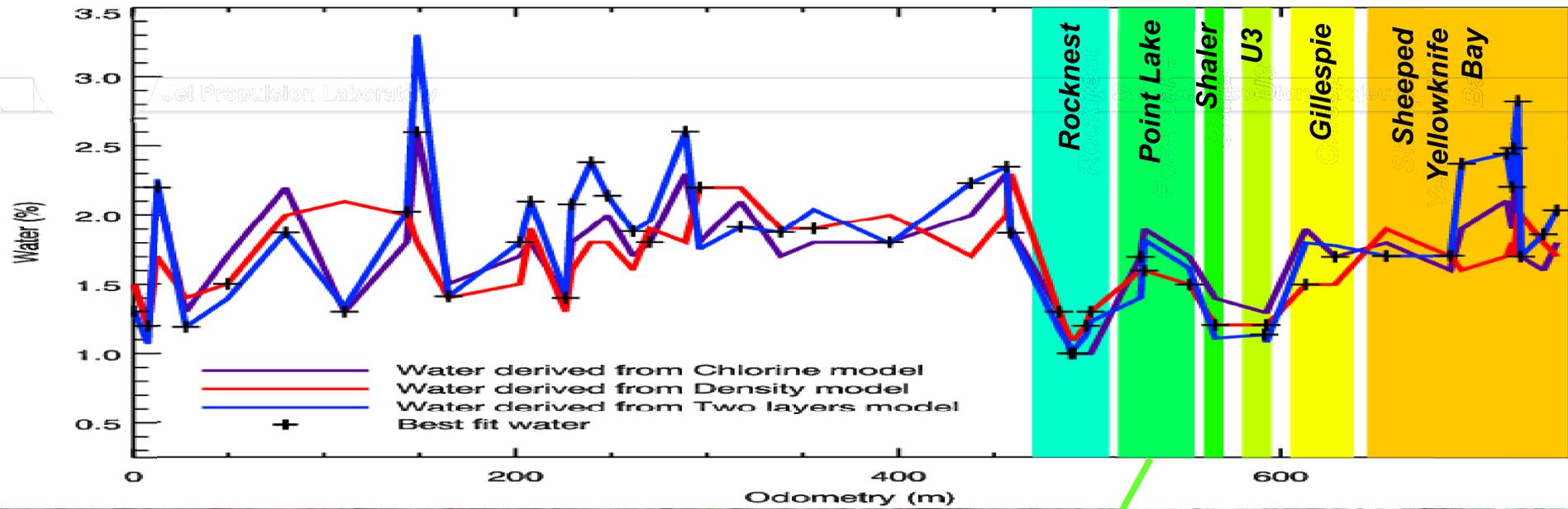


Rocknest parameters

Parameters	Values
Water	1.0 - 1.3 wt%
Chlorine	0.8 - 1.0 wt%
Model	Homogeneous



Variations of water content in the soil along the Curiosity traverse

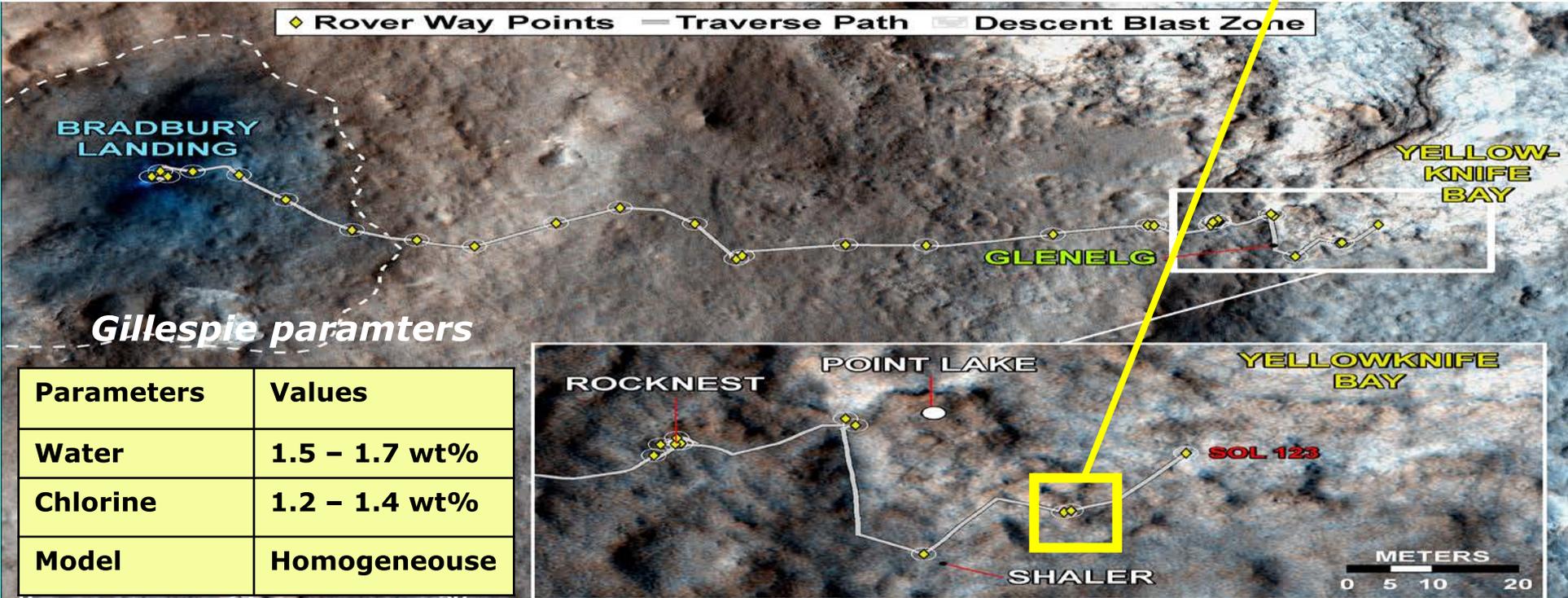
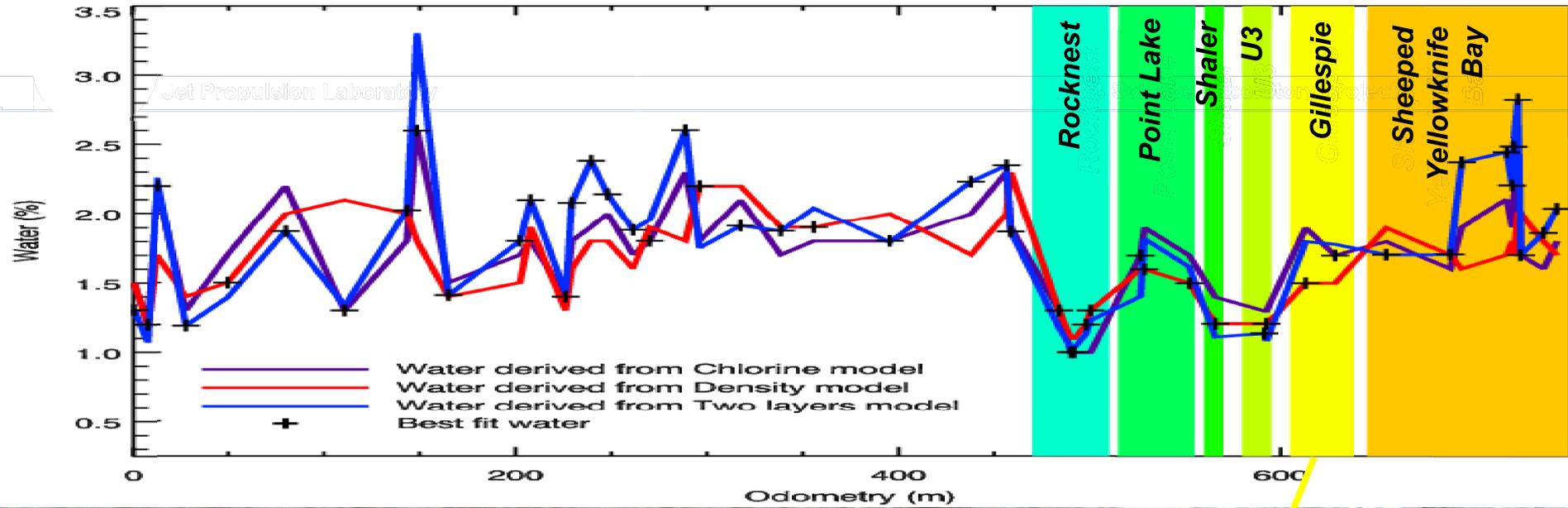


Point Lake parameters

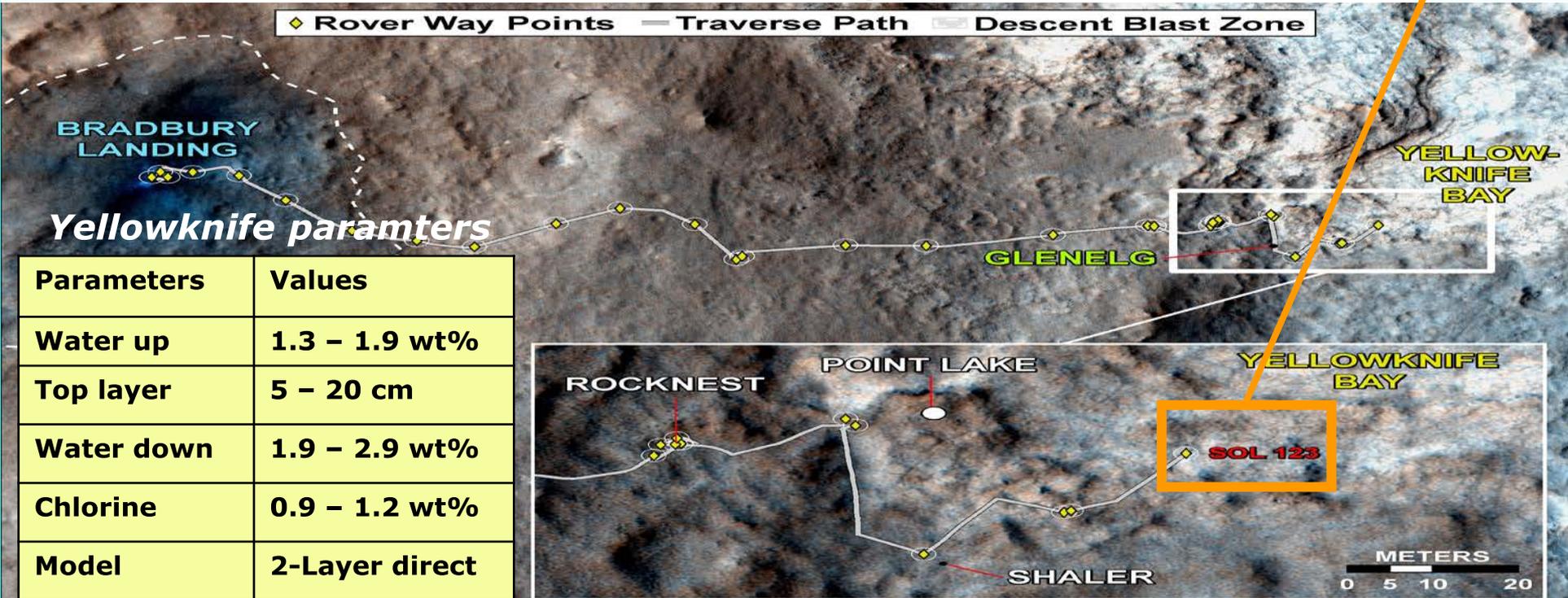
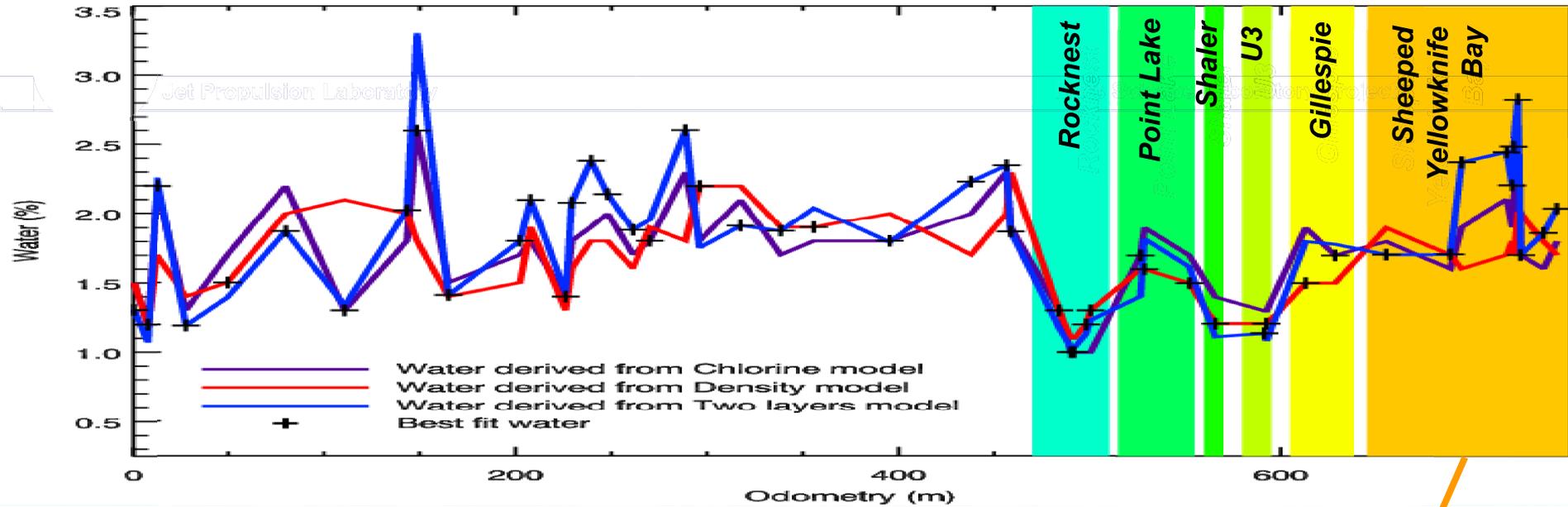
Parameters	Values
Water	1.5 - 1.7 wt%
Chlorine	1.2 - 1.3 wt%
Model	Homogeneous



Variations of water content in the soil along the Curiosity traverse



Variations of water content in the soil along the Curiosity traverse





Conclusions



- DAN has measured water and chlorine abundances along the Curiosity traverse since the landing. The average content of subsurface water equivalent hydrogen (WEH) varies around a mean value of 2.3%. The average chlorine abundance is about 1.2%.
- It was found that in many cases the water distribution as a function of depth is not homogenous. The simplest way to describe the water distribution is to implement two-layer model of subsurface with three parameters: water in the top subsurface, thickness of the top layer, and water content of the bottom layer down to instrument sensitivity depth (~60 cm). It works for 99% of observed sites.
- In the majority of cases such approach shows that subsurface under the rover can be described with following parameters: ~1.5% of WEH in the top of a subsurface down to the depth ~ 18 cm where it changed to ~2.8% WEH. There is also minor part of cases where water distribution is inverse with ~2.2% of WEH on the top with small thickness ~6 cm and ~1.4% of WEH below this layer. It may indicate different geochemistry and shall be investigated in more details.
- On average, DAN shows significantly less water and significantly more chlorine abundances which are expected from the orbital measurements onboard Odyssey (but derived from much larger footprint than surface measurements)