

NEUTRON ABSORBING ELEMENTS IN VERA RUBIN RIDGE AND GLEN TORRIDON: DIFFERENCE BETWEEN DAN AND APXS MEASUREMENTS. D. I. Lisov¹, M. V. Djachkova¹, R. Gellert², M. L. Litvak¹, I. G. Mirtofanov¹ and S. Yu. Nikiforov¹, ¹Space Research Institute of the Russian Academy of Sciences (IKI), 117997, 84/32 Profsoyuznaya st., Moscow, Russia, lisov@np.cosmos.ru, ²University of Guelph, Guelph, N1G2W1, ON, Canada.

Introduction: The dynamic neutron probing experiment DAN operating onboard the MSL Curiosity rover since its landing is sensitive to neutron moderators and absorbers in the Martian surface on the scale of a few tons of subsurface material under the rover[1]. In the seven years and over 21 km driven to date inside the Gale crater DAN has performed active measurements in more than 700 locations on the Martian surface providing information on the subsurface composition for depths up to 0.5 – 1 m.

About 150 of these locations belong to the two latest regions studied by Curiosity: Vera Rubin Ridge (VRR, sols 1800 to 2300, 109 active measurement locations) and Glen Torridon (GT, sols 2300 to 2470, 42 active measurement locations).

In this abstract we focus on neutron absorbing elements and compare the DAN data on neutron absorption with the compositions measured by APXS in the Vera Rubin Ridge and Glen Torridon regions.

Experiment description: The DAN instrument operates by producing short neutron pulses with 14 MeV initial energy and observing the dynamic albedo of neutrons from the pulses[1]. The neutrons go through multiple scattering events in the subsurface, losing energy in various processes, until they either escape the subsurface or are captured in a collision with a neutron-capturing nucleus.

The DAN detector unit houses two ³He-filled counters sensitive to neutrons of less than about 100 eV energy. One of them (CTN) observes both thermal and epithermal neutrons, while the other (CETN) discriminates thermal neutrons with a Cd shield, absorbing neutrons below a threshold energy of 0.4 eV.

The neutron scattering, moderation and diffusion processes in the subsurface are influenced by the subsurface composition, specifically, the mass fractions of neutron absorbing elements (Cl and Fe are the main ones) and neutron moderating elements (most efficient for light nuclei, especially hydrogen).

Data processing is based on numerical simulation of neutron propagation and neutron-nuclei interaction with the MCNPX software package[2, 3]. The subsurface composition model used for this work has two free parameters: H₂O mass fraction to account for neutron moderation process and Cl mass fraction to account for neutron absorption process. The composition of the remaining part is fixed and based on average

APXS composition from the initial part of the mission[4]. In particular, the baseline mass fraction of Fe is approximately 13.0%.

Hydrogen is the only common element that causes significant neutron moderation due to low atomic mass, so the H mass fraction expressed in terms of H₂O (Water Equivalent Hydrogen, WEH) does not require corrections for other elements. On the other hand, the Cl mass fraction used assumes constant concentrations of iron and possibly other neutron absorbing elements. For this reason we refer to it as the *equivalent Cl mass fraction* as it represents not the true chlorine concentration, but a proxy chlorine concentration adjusted for the differences in concentrations of iron and other neutron absorbing elements between the model and the real composition[2]. In this study we only consider iron as an additional neutron absorber as other common elements have negligible neutron absorption cross-sections.

Results: The average equivalent Cl value according to the DAN active data is $1.15\% \pm 0.42\%$ in VRR and $0.81\% \pm 0.18\%$ in GT. From the distributions shown in fig. 1 one can see that the GT distribution is more narrow than the VRR one, shows significantly more locations with equivalent Cl between 0.6% and 0.8% and almost completely loses the values of equivalent chlorine above 1.2%.

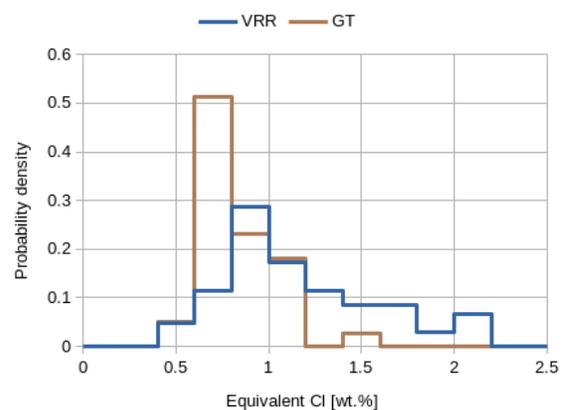


Fig. 1. Equivalent chlorine distributions in the VRR and GT regions according to the DAN active data: blue line for VRR, brown line for GT. Both distribution areas are normalized to 1.

As mentioned above, these values assume that the mass fraction of Fe in the subsurface is 13.0%, which

is the amount used in the MCNPX simulation. On the other hand, according to APXS data[4], the average Fe content is 13.9% in VRR and 15.9% in GT. As the cross-section ratio $\sigma_{\text{Fe}} / \sigma_{\text{Cl}}$ is approximately 0.076 at low energies, we can estimate the Fe-corrected chlorine content to be approximately 1.08% for VRR and 0.59% for GT. However, it should be noted that the Cl concentrations measured by APXS are $1.30\% \pm 0.52\%$ for VRR and $1.19\% \pm 0.43\%$ for GT, which is significantly higher than the DAN results both before and after applying the Fe correction.

We created a list of 99 DAN active measurement locations in VRR and GT regions that had one or several APXS measurements performed nearby. For these locations we've performed two separate checks. First, we've compared the Cl concentration measured by APXS and the Fe-corrected Cl concentration derived from DAN data and adjusted according to the difference between the APXS Fe concentration and the DAN baseline value. The results are shown in fig. 2.

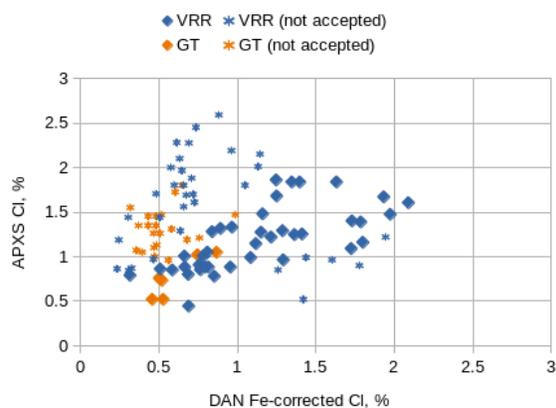


Fig. 2. Comparison between APXS chlorine concentration and DAN Fe-corrected chlorine concentration. The locations are grouped by region (VRR vs GT) and split into two groups each: the ones that the DAN model with fixed APXS-based Cl concentration accepts and the ones it rejects.

Second, we've reprocessed the DAN data with equivalent Cl mass fraction restricted to match APXS Cl mass fraction corrected for the difference between APXS Fe mass fraction and the baseline DAN one. This restricted model was accepted (for any WEH mass fraction) for 54% VRR locations (39 out of 72) and only 22% GT locations (6 out of 27). The accepted and rejected points are shown in fig. 2 with different markers. As expected, DAN accepts a model with APXS-derived equivalent Cl only when it's close enough to the DAN equivalent Cl mass fraction.

Conclusions and discussion: While DAN and APXS both provide data on iron and/or chlorine mass fraction in the Martian subsurface in VRR and GT, in a

significant fraction of cases (46% for VRR and 78% for GT) the composition measured by APXS is not consistent with the results of the DAN measurement performed near that location. In all cases of inconsistency for GT locations and in 82% cases of inconsistency for VRR ones the APXS derived composition has neutron absorption higher than the DAN models could accept with any hydrogen concentration.

DAN is sensitive to neutron moderation and absorption in a volume containing a few tons of matter, while APXS measurements are highly local and measure the composition of the very surface, so DAN and APXS data are not expected to be always consistent. However, in this case we find that the neutron absorption derived from the APXS composition is, on average, significantly higher than DAN data supports.

We can suggest several possible causes of this significant difference. First, it may reflect some bias due to APXS target selection. In this work we've looked at all APXS measurements in VRR/GT that had a DAN measurement nearby without considering the specific target. It might be possible that in a significant number of cases targets considered interesting for an APXS measurement have higher chlorine and/or iron concentration than the average for the subsurface.

Second, as a significant fraction of APXS measurements correspond to dusty surface, this difference may reflect elevated Cl values in the dust particles.

Third, it may be possible that the mean chlorine concentration is different on the surface and in the top meter of the subsurface and the difference between DAN and APXS reflects that fact. This point agrees with findings in the 6 cm deep drill holes, where often the surface has more elevated Cl values than the deeper extracted powder in the APXS data[5].

Finally, it may be possible that there's no physical difference in chlorine abundance and the difference observed is a result of some unknown factor not taken into account during data processing.

Overall, both instruments agree that the top meter of the Martian surface has high Cl concentrations of a few percent.

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References:

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