THE CHEMICAL COMPOSITION OF MARTIAN ROCKS AND SOIL: PRELIMINARY ANALYSES.

T.E. Economou[1], R.Rieder.[2], H.Wänke.[2], A. Turkevich.[1], J.Brueckner.[2], G.Dreibus.[2], J. Crisp.[3] and H.McSween, Jr[4]., [1] Enrico Fermi Institute, University of Chicago, 933 East 56th Street, Chicago, IL 60637, [2]Max-Planck Institut für Chemie, Mainz, Germany, [3]Jet Propulsion Laboratory, Pasadena, Ca 91109, [4]Department of Geological Sciences, University of Tennessee, Knoxville, TN 37996.

Mars Pathfinder landed on the Ares Vallis landing site on July 4, 1997. Besides being an engineering mission, it carried a payload of several science instruments that returned a large quantity of scientific information.

The Alpha Proton X-ray Spectrometer (APXS) was designed to provide the chemical composition of martian rocks and soil. The APXS has benefited enormously from the presence of a rover because it provided mobility and enabled it to analyze many rock and soil samples selected from the IMP and rover images. The APXS is a complex instrument with three modes of operation and provides three different energy spectra. Data from these three modes are partially complementary and partially redundant. The alpha mode is particularly useful in the detection of the light elements C, N, O while the proton mode contributes to the accuracy of the intermediate Z elements Na, Mg, Al, Si and S. The X-ray mode can detect all the elements above Na. Due to a need for a re-calibration of the alpha and proton modes at the measured martian pressures only the results from the X-ray mode are reported here. The results from the alpha and proton will provide information on the presence of carbonates on Mars and will also help to reduce the uncertainties associated with some elements.

All three modes of the APXS instrument performed well during the entire period of operation on the surface of Mars and provided high quality data. The performance of the X-ray mode was best during night time measurements when the ambient temperature of the surface was very low. The low Martian temperature and the extremely good stability of the electronics of the X-ray system contributed enormously in obtaining high resolution X-ray spectra. A temperature variation of more than 100 °C during the data accumulation produced a shift in peak position smaller than a fraction of a channel.

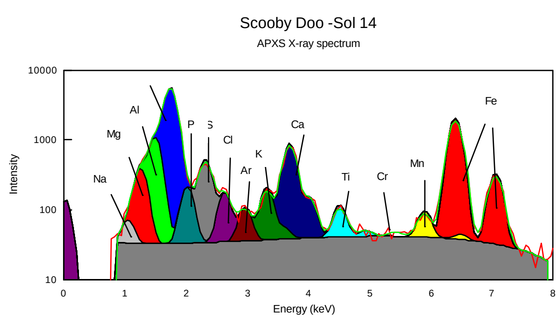

Fig.1 The X-ray spectrum of A-10 site – Scooby Doo The appearance looks like a rock, but the analysis is more soil-like.

A total of seven soil and 8 rock samples were measured during the three months of the Pathfinder operation on the surface of Mars. However, not all have been analyzed yet.

Samples were selected by the science team from the images returned by the lander and rover cameras. The actual navigation to the selected sample and the deployment of the APXS to a particular sample was done by rover personnel. It turned out that the navigation and accurate deployment of the APXS was more difficult than was initially expected. Several times the intended sample was missed completely or several tries were required for proper positiong.

The procedure for the data analysis started with conversion of the APXS binary data into an ASCII format and a quick look at all the X-ray spectra on a PC display screen. The data files from the same sample were analyzed individually or combined together for better counting statistics. The ASCII files were then inputted into a least-squares fitting program that subtracted the background, found all the peaks present in the sample and calculated the peak areas and their uncertainties. Fig. 1 shows the decomposition of the X-ray spectrum from the Scooby Doo sample into individual elemental contributions. All pertinent peaks are identified and labeled. These data were subsequently fed into an X-ray fundamental parameter program that calculated the elemental abundance.

Another quick way of analyzing the APXS Mars data was to use calibration curves of peak areas vs concentration for each element that was obtained by analyzing terrestrial samples of known composition during the APXS calibration at the laboratory. The results of analyses then were normalized to 100% assuming that there is no water, carbonates or nitrates in any of the analyzed samples. Presently, oxygen is assumed to occur in stoichiometric proportion with the oxide forming elements, but it will be determined later directly from the alpha data.

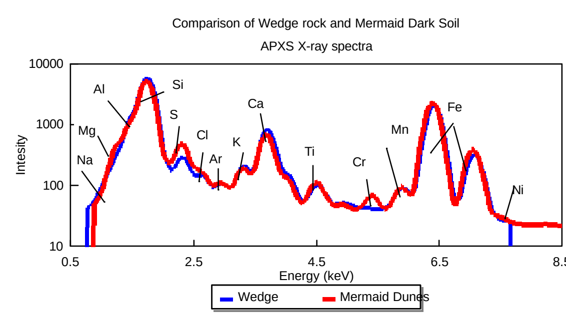

Fig.2 Comparison of X-ray spectra from a typical soil and a rock Wedge. Higher Mg, S and Cr on the soil is clearly visible as compared to the rock.

Table 1. Elemental abundances of six soil and five rock samples at the Ares Vallis Pathfinder landing site expressed in weight %.

Name		Na_2O	MgO	Al_2O_3	SiO_2	SO_3	Cl	K_2O	CaO	TiO_2	FeO
SOILS											
A-2	After Deploy	2.3 ± 0.9	7.9 ± 1.2	7.4 ± 0.7	51.0 ± 2.5	4.0 ± 0.8	0.5 ± 0.1	0.2 ± 0.1	6.9 ± 1.0	1.2 ± 0.2	16.6 ± 1.7
A-4	Next to Yogi	3.8 ± 1.5	8.3 ± 1.2	9.1 ± 0.9	48.0 ± 2.4	6.5 ± 1.3	0.6 ± 0.2	0.2 ± 0.1	5.6 ± 0.8	1.4 ± 0.2	14.4 ± 1.4
A-5	Dark Next to Yogi	2.8 ± 1.1	7.5 ± 1.1	8.7 ± 0.9	47.9 ± 2.4	5.6 ± 1.1	0.6 ± 0.2	0.3 ± 0.1	6.5 ± 1.0	0.9 ± 0.1	17.3 ± 1.7
A-8	Scooby Doo	2.0 ± 0.8	7.1 ± 1.1	9.1 ± 0.9	51.6 ± 2.6	5.3 ± 1.1	0.7 ± 0.2	0.5 ± 0.1	7.3 ± 1.1	1.1 ± 0.2	13.4 ± 1.3
A-10	Next to Lamb	1.5 ± 0.6	7.9 ± 1.2	8.3 ± 0.8	48.2 ± 2.4	6.2 ± 1.2	0.7 ± 0.2	0.2 ± 0.1	6.4 ± 1.0	1.1 ± 0.2	17.4 ± 1.7
A-15	Mermaid Dune	1.3 ± 0.7	7.3 ± 1.1	8.4 ± 0.8	50.2 ± 2.5	5.1 ± 1.0	0.6 ± 0.2	0.5 ± 0.1	6.0 ± 0.9	1.3 ± 0.2	17.1 ± 1.7
ROCKS											
A-3	Barnacle Bill	3.2 ± 1.3	3.0 ± 0.5	10.8±1.1	58.6 ± 2.9	2.2 ± 0.4	0.5 ± 0.1	0.7 ± 0.1	5.3 ± 0.8	0.8 ± 0.2	12.9 ± 1.3
A-7	Yogi	1.7 ± 0.7	5.9 ± 0.9	9.1 ± 0.9	55.5 ± 2.8	3.9 ± 0.8	0.6 ± 0.2	0.5 ± 0.1	6.6 ± 1.0	0.9 ± 0.1	13.1 ± 1.3
A-16	Wedge	3.1 ± 1.2	4.9 ± 0.7	10.0±1.0	52.2 ± 2.6	2.8 ± 0.6	0.5 ± 0.2	0.7 ± 0.1	7.4 ± 1.1	1.0 ± 0.1	15.4 ± 1.5
A-17	Shark	2.0 ± 0.8	3.0 ± 0.5	9.9 ± 1.0	61.2 ± 3.1	0.7 ± 0.3	0.3 ± 0.2	0.5 ± 0.1	7.8 ± 1.2	0.7 ± 0.1	11.9 ± 1.2
A-18	Half Dome	2.4 ± 1.0	4.9 ± 0.7	10.6±1.1	55.3 ± 2.8	2.6 ±0.5	0.6 ± 0.2	0.8 ±0.1	6.0 ± 0.9	0.9 ± 0.1	13.9 ± 1.4

Fig. 2 is a comparison of the raw X-ray spectra from the rock Wedge and the dark soil Mermaid Dune. This comparison shows clearly that the soil contains more Mg, S, Ti, Cr and Fe. Cr appears to be present at the level of 0.3% only on the soil samples but not detected on any of the rock samples.

Table 1 shows the preliminary results of analyses of the X-ray data for six soil and five rock samples. A more detailed description of the results and their interpretation is given in [1]. Especially surprising in the APXS analyses is the finding of high silica content on all of the rocks at Ares Vallis Pathfinder landing site. The significance of this evidence is explained by Wänke in [2]. The soil samples on the Pathfinder site closely resemble those on the two Viking sites separated apart by several thousands kilometers [3]. That would imply that most of the soil on Mars is of the same composition. There are, however, small differences among them that will become more pronounced after the error uncertainties will be better understood.

Most of the rocks on Mars seem to be covered, to some degree, by dust that precludes the analysis of a pristine rock. We have tried to minimize this effect by selecting to analyze rocks with the smallest amount of dust contamination.

The alpha spectra of the APXS are somewhat affected by the CO_2 gas in the Martian atmosphere. However, after subtracting the gas contribution, preliminary data analysis of the alpha spectra indicate that there is no evidence that carbonates are present on any of the analyzed samples.

References:

[1] Rieder et al., *Science 278*, 1771-1774, (1997). [2] Wänke et al., AGU Abstracts, San Francisco, (1997). [3] Clark et al., *Jour. Geophys. Res., 87*, 10059, (1982).