COLUMBIA HILLS, MARS: FE-POOR, P-RICH, S-RICH AND OTHER VARIETIES OF LAYERED ALKALINE ROCKS ARE SIMILAR TO NEPHELINE SYENITES OF LAYERED LOVOZERO MASSIF, KOLA PENINSULA, RUSSIA; G. G. Kochemasov, IGEM Russian Academy of Sciences, 35 Staromonetny, 119017 Moscow, Russia; kochem@igem.ru

A specific martian feature – lobate ejecta blankets around craters extending up to 1.5 times of a crater diameter (much wider than continuous ejecta of lunar – 0.6-0.7 diameter, and mercurian – 0.4-0.5 diameter, craters) is usually attributed for the frozen water in the martian crust. This water could fluidize under impact excavated material and make it flow like liquid. The geomorphological evidences show that the ejected material really behaves like liquid (resembles the heavy clay liquid for drilling), flows and skirts obstacles but usually does not show any significant settling. One would expect this settling for water rich material. Could it have, along with some water, compositional peculiarities? It seems that after Gamma-spectrometry of "Odyssey" and two landers – "Spirit" and "Opportunity" analyses one can say that a "peculiar rock' is marked out.

"Odyssey" show rather low silica over highlands (20-21% [1]) and, that is especially interesting, over high standing Tharsis bulge (18-20%) [1]. Low Fe signifies that this lowering in silica is not due to the basic rocks which were postulated in "entirely basaltic Mars' model (the martian meteorites as a proof). MGS gravity data [2] have clearly shown that the martian southern highlands are composed of "light" (not dense) lithologies, much less dense than the northrrn lowland Fe-basalts, otherwise relatively flat even gravity signals over two hemispheres were not possible [2]. The previous global albedo data also have shown that the southern highlands are much lighter (average albedo 0.25) than the dark northern lowlands (0.15)[3] hinting at different rocks. Very long lobate formations around huge Tharsis volcanoes also require very low viscosity lavas. Density of martian soils on surface and to a depth of about 10 m according to various geophysical methods (radar, polarimetry, IR, "Viking" data) is lower than that of the Moon and is lower for light areas than for dark ones [3].

Now this "whitish" low density material is partly characterized on Meridiani Planum by "Opportunity" [4] – it is salt: sulfates, chlorides, bromides covering and penetrating layered sedimentary (mainly eolian?) rocks. The salts are discovered in craters and, as it shown by an artificial very shallow impact crater (after fall of the "Opportunity"'s heat shield), under thin cover of eolian reddish Fe-rich drifts. The salts cover large areas on Meridiani Planum. Their most probable origin is due to widespread hydrothermal activity, vents being craters and deep cracks (faults) draining depths of the highland crust. So, salts are not just a thin veneer but a significant constituent part of the highland crust. That is why Tharsis is surprisingly low in Si. Silicates are partially replaced by salts (low density substance), this is required by necessity to diminish the mean density of highly standing tectonic blocks of Mars – a rotating planetary body that obeys the physical law of keeping equal angular momenta of hypsometrically different tectonic blocks. The aqueous salts with constituent water not only diminish a mean rock density and explain the presence of hydrogen (H_2O) at the equatorial zones in "Odyssey' data but also bring down the melting temperature of impacted rocks making ejecta easily flowing (like a dough for pan-cakes).

The "Spirit"'s results for the Columbia Hills at Gusev crater go farther [5, 6, 7]. They bluntly shown that an outlier of highlands consists of rocks completely different from lowlands basalts. Keeping the same as in basalts level of Si, these light color rocks are higher in alkalis, Al, P, Cl, S, Ti and lower in Fe, Mn, Mg, Ca, Cr. Al/Ca increases from basalts to this rock. Na is up to 4.5%, Al- 8.0%, P – 2.3%, Ti – 1.5% - these are values suitable for syenites. The thinly layered rocks of Columbia Hills resemble very much the layered nepheline syenites of the ring complexes of Kola Peninsula (Khibiny, Lovozero). One layer of the Columbia Hills massif (Wishstone rock) is high in phosphorus (calculated apatite is up to 13%), another – in sulfur (Peace rock). All this resembles layers of apatite and feldspathoids rich rocks of Lovozero massif. Sodalite (Cl and S) and noseane (S) rocks are known there. Near the top of Columbia Hills at the "Independent Rock" target researchers have found less iron than expected (Internet, July 11, 2005: "Spirit Scuffs" communication). Again, sharp Fe variations in thin layers of nepheline syenites (urtites, lujavrites, foyaites) are very typical. In some micro images of the Columbia Hills rocks (Internet) one can discern directional (lujavritic, trachytic) and massive (foyaitic) textures. Some larger light colored crystals contain darker isometric inclusions – a hint of the poicilitic structure.

A very typical process of feldspathoid alteration in the contact with water (ground and atmospheric) is formation of zeolites. These very soft and low density silicates (often shining like water ice) are perfect sinks for water, giving it out and taking back into their crystalline structure depending on P-T conditions and availability of water [8]. These syenites often containing also as a matrix albite – sodic plagioclase (detectd by "Spirit"'s Mini-TES [7]) are melted at temperatures much lower than basalts. Maybe, this is a reason why the lobate craters are widespread on the southern highlands. In addition, zeolitized syenites are soft, this property of Columbia Hills rocks was found by "Spirit"'s grinding instrument –these rocks are much softer than basalts [7]. Very thin layering of rich in alkalis and thus very fluid nepheline syenites is typical at Earth.

Gusev crater lies at the contact between lowlands and highlands. In an earlier work [9] , before "Pathfinder" landing, we insisted on "Possibility of highly contrasting rock types at martian highland/lowland contact", namely on finding albitites, syenites, granites in addition to basalts.

"Pathfinder" has found andesites, but more acid and alkaline lithologies were discovered by THEMIS (MGS) and "Spirit". Two localities at Syrtis Major have dacites originated probably from a crustal body long not less than 95 km [10]. "Spirit" has nepheline- normative rocks probably rich in salts penetraiting them in form of own minerals and in feldspathoids structures (sodalite, noseane,and others). So, salts helping to diminish rock density, simultaneously lower its melting temperature what helps to produce such characteristic martian structures as lobate craters.

One more remark. This water, alkali-rich easily fluidized crust is often masked by ubiquitous eolian dunes and drifts rich in Fe-minerals originating from the northern lowlands. Now orbiting Mars "Mars Express" with "Omega" instrument measuring reflected light from drifts discovers signatures of not only salts but also olivines and pyroxenes [11]. Researches often make hasty conclusions about wide presence of basic rocks. Sometimes they are right because the presence of plateau basalts, basic sills and layered basic intrusions at highlands is quite possible (compare with Earth), but often they are wrong taking surface reflectance from widespread Fe-minerals surface contamination for an indication of the deeper geology. In this sense, lobate craters luckily sample deeper horizons and better show the real geology.

To the left: Lovozero massif. Thin layering of nepheline syenites (complex of foyaites-lujavrites-urtites). Author's photo, 1957. **To the right**: Mars, Columbia Hills. Thin layering of light colored rocks (Credit NASA/JPL/Cornell, 18 Aug. 2004).

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