CERBERUS PLAINS, MARS: CHRONOLOGY OF VOLCANIC EVENT AND EVIDENCE OF RECENT TECTONIC ACTIVITY.

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Introduction: Since the release of the Viking images, the Cerberus plains have given numerous evidences for being the most recently active martian geological place showing youthful exposed surface (<200 My) [1,2]. Volcanism and waterfloods sources have been identified [3,4,5], dispatched all over the plains, leading to complex interactions and yet debated datations [3,4,5,6]. Recent flood eruptions of low viscosity lavas have been proposed to originate also at the fissures [1,3,5]. New ages by crater count [7,8,9,10] of the most recent units have been derived from the combination of HRSC, THEMIS-VIS and MOC data with a joint morphologic analysis to localize lavas [11,12,13] and avoid known secondary crater clusters [10]. Some fractures affect these most recent lava flows which imply their activity since the last volcanic events. Cerberus fractures have been studied and are assumed to originate from dykes [14,15,16]. Some evidences of very recent collapsing have been found.

Datation: Lavas were dated by the crater counting method [6,8,9], using isochrons updated by Hartmann [6]. Figure 1 shows 15 dated areas over the Cerberus plains. Linear uncertainties were not satisfying for the purpose of comparing so close ages (<100 My). We thus define a probability law associated with each datation in order to derive the probability to get a given lava older than another one, with the objective of studying the distribution in time and duration of the volcanic events.

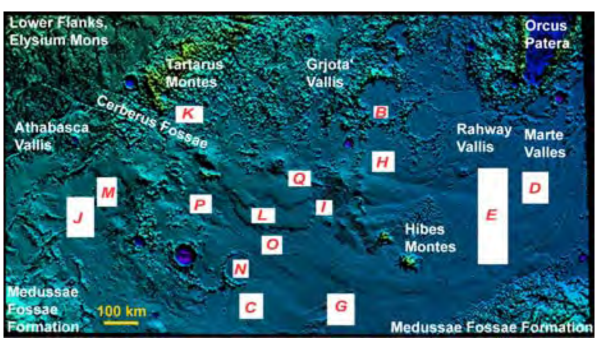

Fig. 1. Shaded relief MOLA topography from Cerberus plains. Letters are the dated surfaces.

Approach: Crater counts are fitted on Martian isochrones using non-linear least squares inversion method. An isochrone is defined by:

$$f(t) = N_{3.5}(D)\frac{g(t)}{g(3.5)}$$

where $f(t)$ is the number of craters per surface unit for the crater class centered on the diameter D and t is the age in billions years. $N_{3.5}(D)$ is the number of craters per surface unit for a given class and for a surface aged of 3.5 billions years. The function g(t) represents the evolution of the impact rate through time [8].

In the non-linear least squares method [Krauss, 1993], the age is found by an iterative correction given by:

$$dt = (A^T PA)^{-1} A^T Pl$$

where P is the diagonal weight matrix. Each term on this matrix is equal to the inverse of the square of the count uncertainty $\sigma = \sqrt{N}/S$ where S is the counted surface. The vector l is the deviation between the crater counts and theoretical isochron. Each element of the vector A is given by:

$$A_i = \frac{\partial f(D_i)}{\partial t} = \frac{N_{3.5}(D_i)}{g(3.5)} * \frac{\partial g(t)}{\partial t}$$

Age uncertainties are estimated from:

$$\Delta t = \sqrt{\frac{l^T Pl}{n-1}}\sqrt{(A^T PA)^{-1}}$$

where n is the number of crater classes.

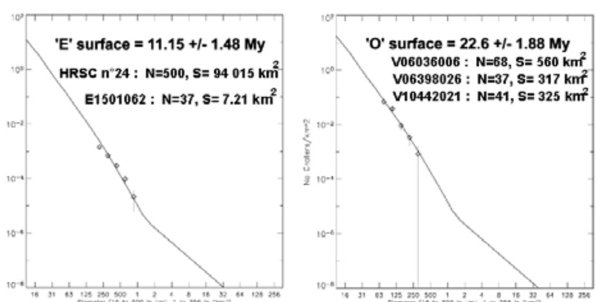

Fig. 2. Two of the 15 surfaces isochrons from Cerberus lavas giving youthful ages.

From the vector of residuals l we define a probability law for the age. The density of probability associated with a given surface is defined by:

$$P(t) = \frac{A}{l^T Pl}$$

with A the normalization factor of the probability law

$$A = \frac{1}{\int_0^\infty (l^T Pl)(t)dt}$$

Thus the probability that surface S_1 is younger than S_2 is given by:

$$P(S_1 < S_2) = \int_0^\infty [P_1(t) * \int_t^\infty P_2(t').dt'].dt$$

Probability estimated for all couples of dated surfaces are listed in Table 1.

	K	N	G	Q	C	E	M	J	O	H	D	I	L	P	F
K	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N	59.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G	59.9	50.7	-	-	-	-	-	-	-	-	-	-	-	-	-
Q	64	56.6	55.8	-	-	-	-	-	-	-	-	-	-	-	-
C	65.4	59.2	58.3	52.7	-	-	-	-	-	-	-	-	-	-	-
E	68.1	62.6	61.8	57.1	56.6	-	-	-	-	-	-	-	-	-	-
M	71.5	66.9	66.2	62.4	64.1	57	-	-	-	-	-	-	-	-	-
J	72.4	68.3	67.6	64.2	67.2	59.5	52.1	-	-	-	-	-	-	-	-
O	72.8	68.8	68.1	64.8	67.7	60.3	53.1	51.3	-	-	-	-	-	-	-
H	75	71.4	70.8	67.9	70.8	64.1	57.9	57.7	56.4	-	-	-	-	-	-
D	77.6	74.3	73.8	71.2	73.8	68	63	63.5	62.5	57.1	-	-	-	-	-
I	75.2	71.7	71.1	68.3	71.6	64.8	58.7	59	57.6	50.4	42.5	-	-	-	-
L	79.2	76.5	76	73.8	77.1	71.4	66.8	68.6	67.5	61.5	52.6	62.7	-	-	-
P	87.3	85.8	85.4	84.3	86.6	83.2	80.8	82.6	81.9	78.7	72.4	80	74.9	-	-
F	88.9	87.5	87.3	86.2	88.2	85.2	83.1	84.6	84	81.2	76	82.3	77.9	59.2	-

Table 1. Probability percentage to get a surface younger than the others (horizontal versus vertical). K is the younger (2 My) and F the older surface (200 My). For example, C surface (10 My) has 70.8% of chance to be younger than H surface (26.8 My).

We have grouped the lava units according to the probability gap of confidence. The results show several volcanic episodes distributed for the last 50 My.

Tectonic: From our datation results, the Cerberus fossae fractures cutting the most recent lava flows (<10 My) and post dating them, are evidences for extremely recent martian tectonic activity. Figure 3 and 4 give evidences of present collapsing, with highly fractured walls, and not dust-covered fallen rock prints along the inner slopes of the fossae.

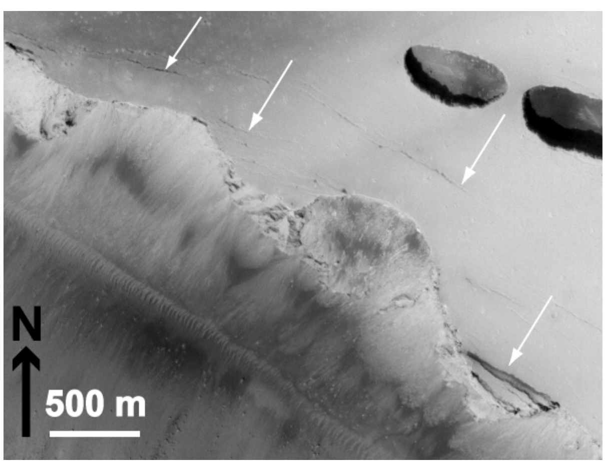

Fig 3. Cerberus fractures cutting the most recent lavas. Fracture bottom is in the left downpart of the image while cut lava surfacse are upper right. The fracture walls are weakened by collapsing faults visible on the lavas between the two northern pits and the crumbling fracture rim (white arrows). MOC R1401446, illumination from south.

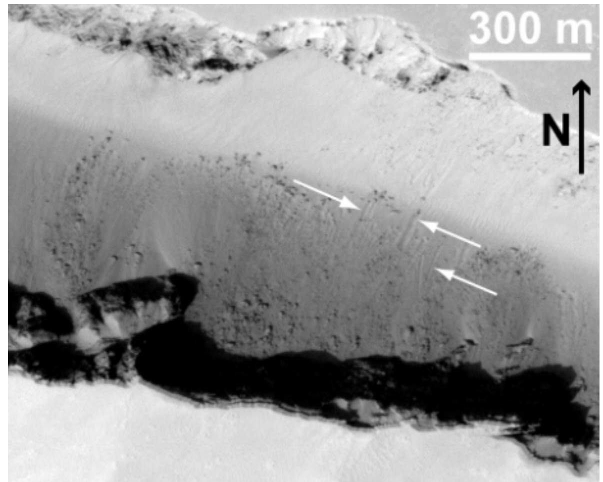

Fig 4. Fallen rocks prints (arrows) not eroded or dust-covered. MOC R1400425, illumination from south.

Conclusions and discussion : 15 Cerberus lava surfaces are dated with crater counting method and youthfull surfaces are found weither using small crater diameter (<250m) or larger ones [17]. Comparing the derived probability law for one surface versus an other we group ages and conclude in favor of a continuous volcanic activity in the Cerberus plains over the last 50 My. The observation of apparently fresh graben scarps observed in relation with fallen rocks and new opening fractures which cut extremely recent lavas suggests a recent and eventually present tectonic activity. However these fresh features could also result from erosive processes of the steep slopes faults without invoking any tectonic activity. If erosion is the only process affecting remnant fault scarps, then these observations could constrain the end of tectonic events.

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