

ON ANCIENT SHORELINES AND HEAT FLOWS ON MARS. Javier Ruiz, Departamento de Geodinámica, Facultad de Ciencias Geológicas, Universidad Complutense de Madrid, 28040 Madrid, Spain, jaruiz@geo.ucm.es.

Introduction: The existence of features indicative of shorelines of ancient oceans on Mars has been proposed [1-4], and diverse efforts have been carried out to test validity of these proposal. Specifically targeted MOC images have not found support for the shoreline hypothesis [5,6], although these results have been disputed [4,7,8]. Another analyses find several features along putative shorelines in northwestern Arabia Terra, which have been interpreted as due to coastal erosion [9,10].

The present-day martian topography has also been used to test the shoreline hypothesis [11-13]. Of the two global proposed shorelines, revised and renamed by [4], the Deuteronilus shoreline slightly deviates from an equipotential surface, and thus has been considered to be an acceptable paleoshoreline candidate: the elevation of this shoreline is -3792 ± 236 m, and the total elevation range of is ~ 1.1 km [13]. Otherwise, the putative older and higher-standing Arabia shoreline deviates substantially from an equipotential surface, indicating that it is not representative of a true shoreline; according to [13], the Arabia shoreline shows a mean altitude of -2090 ± 1400 m, and a total elevation range of ~ 5.6 km.

If reality of global shorelines is accepted, then present-day topographic variations in these features post-date shorelines formation. So, their topographic range should provide information on large-scale vertical movement of the lithosphere, which in turn would provide information on the thermal evolution of Mars [14]. Here I discuss some aspect related to the link between shoreline elevation range and the evolution of the martian lithosphere.

Elevation range of putative paleoshorelines, thermal isostasy, and paleovariations of heat flows: In this point it is worth make clear that evaluation of possible paleoshorelines through assessment of topography data must be made cautiously, since it is not necessarily true that a paleoequipotential surface must fit well a present-day equipotential surface. Lithosphere rebound due to water unloading associated with the disappearance of an ocean with irregularly shaped margins could result in deviations of equipotentiality of up to several hundreds of meters [15]. Also, different thermal histories among regions may have appreciably contributed to the deformation of the original large wavelength topography of putative paleoshorelines: variations in martian heat flow, similar in relative amplitude to those observed in terrestrial continental tectonothermally stable areas, could result in large wavelength elevation differences of kilometric scale

through differential thermal isostasy [16,17], an important amount of deformation for any possible paleoshoreline. (Diverse processes, including geomorphologic evolution, may affect small-scale topographic variations, and the rigidity of the Martian lithosphere could also prevent small-scale isostatic adjustment. Therefore, only large wavelength topographic variations, in which isostatic adjustment can work, are relevant for this note.)

Reasoning in reverse order, if the existence of paleoshorelines is accepted, then the total amplitude of elevation differences along these paleoshorelines, impose constraints to the differences in the evolution of the thermal structure of the lithosphere in shoreline-crossed regions. Thus, it is possible to make an approximate calculation of the amplitude of the ancient heat flow variations necessary to compensate present-day topography and transform the paleo-shorelines into equipotential surfaces [14]. Like other geological processes could have produced vertical movements, the results so obtained suppose an upper limit.

For the total elevation range of the Deuteronilus shoreline, ~ 1.1 km, the corresponding relative amplitude of heat flow variations (the ratio between maximum and minimum heat flow in shoreline regions) is ≤ 1.6 . This value is clearly lower than that presently observed on Earth. For instance, contoured maps of terrestrial heat flow show variations in continental areas that can be higher than a factor 2 or 3 [e.g., 18,19]. Those areas include terrains of different ages, and it is known for continental areas that an inverse relation exists between surface heat flow and age of the last tectonothermal stabilization [e.g., 19-21].

If surface heat flow variations on Mars are currently almost disappeared, then the upper limits to the heat flows variations deduced from the Deuteronilus shoreline topography must be mostly related to the time when this feature was formed. In this case, the present-day elevation range along Deuteronilus shoreline suggests that differences in the thermal state of the lithosphere in the "Deuteronilus shoreline regions" have been relatively small since the feature was formed, and therefore, that very large areas of the martian lithosphere have been tectonothermally stable since (at least) the latest Hesperian or earliest Amazonian (nominally ~ 3 Gyr ago [22]).

Dividing paleoshorelines?: Recently, the elevations along putative shorelines on northern Arabia Terra has been analyzed in higher resolution [10], finding a elevation of 3707 ± 21 m, for the Arabia shoreline, and two different elevations, 4000 ± 14 m

and 4200 ± 12 m, for two separate portions of the Deuteronilus shoreline, which could therefore represent two distinct shorelines. So, locally on northern Arabia Terra putative shorelines fit well equipotential surfaces, but they are suggesting a complex scenario for the possible evolution of martian oceans.

The original global mapping of the putative paleoshorelines [1-4] was limited by resolution of Viking images. Besides this, it is fairly evident that diverse degradational processes could have affected both the original morphology and topography. So, the proposition of considering the Deuteronilus shoreline as two distinct paleoshorelines should not surprise. Elevation difference between the two separate portions is difficultly due to post-formation processes, because elevation is nearly constant along distances of about 500 km, and to the clear bimodality in the elevation values [10].

Those reevaluations are of great interest to improve the knowledge the hydrogeological history, but also for the tectonothermal history of Mars, because they are affecting the elevation range attributed to a given paleoshoreline, and hence the information derived from elevation ranges.

Mixing paleoshorelines?: The possibility that the putative Meridiani shoreline could be the same feature as some portions of the Arabia shoreline was first suggested by [16], precisely related to preliminary work about thermal isostasy on Mars. Indeed, elevations in the Meridiani shoreline (-1.5 km as mean value, after [23]) are roughly similar to that of the Arabia shoreline in northeast Arabia, Utopia (not taken into account the Isidis basin), Elysium, and Amazonis regions.

The elevation range of this “mixed” Meridiani/Arabia shoreline, although not examined, would be mostly about 2 km (from -1 to -3 km; as a reference see the elevation profile along the Arabia shoreline in Figure 5 in [13]). This is still far of an equipotential surface, but a paleoshoreline through these regions and the Meridiani shoreline would be better candidate to represent a paleoequipotential surface than the Arabia shoreline *sensu stricto* (a similar conclusion can be deduced of [24]): for that reason, it was incorporated to the hypothesis for the martian hydrogeological history presented in [8], in order to represent the boundary of a putative Noachian ocean.

On the other hand, the elevation of the Arabia shoreline in northern Arabia Terra after [10] is intriguingly close to the mean elevation of the Deuteronilus shoreline, and it cannot be discarded a “mixed” Arabia/Deuteronilus shoreline, which would include the Arabia shoreline in northern Arabia Terra, and the Deuteronilus shoreline elsewhere.

Conclusions: The elevation range of paleoshorelines may inform about the thermal evolution of Mars. The elevation range of the Deuteronilus shoreline suggests the absence of global tectonothermal events by the latest ~ 3 Gyr, at least. The consistency of elevation differences between shorelines [24] could be indicative of a longer lithospheric stability. But it is clear that the lateral continuity of these features is poorly known, and diverse division and mixing of the originally proposed paleoshorelines could be required. Thus, it is necessary a careful reassessment of the diverse features interpreted as paleoshorelines, and of the relation among them.

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