



Spatial Distribution of Volcanoes on Mars

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Motivation

Scientific question

The heat flux of Mars likely decreased over time as the planet progressively lost heat and convection waned. The thermal evolution of the planet is seen in a compilation of elastic thickness estimates based on topography and gravity. The spacing between volcanoes of similar age may also reflect thermal evolution. My project presents a statistical analysis of volcanic spacing that shows that such a thermal evolution cannot be resolved in the available datasets.

Hypotheses

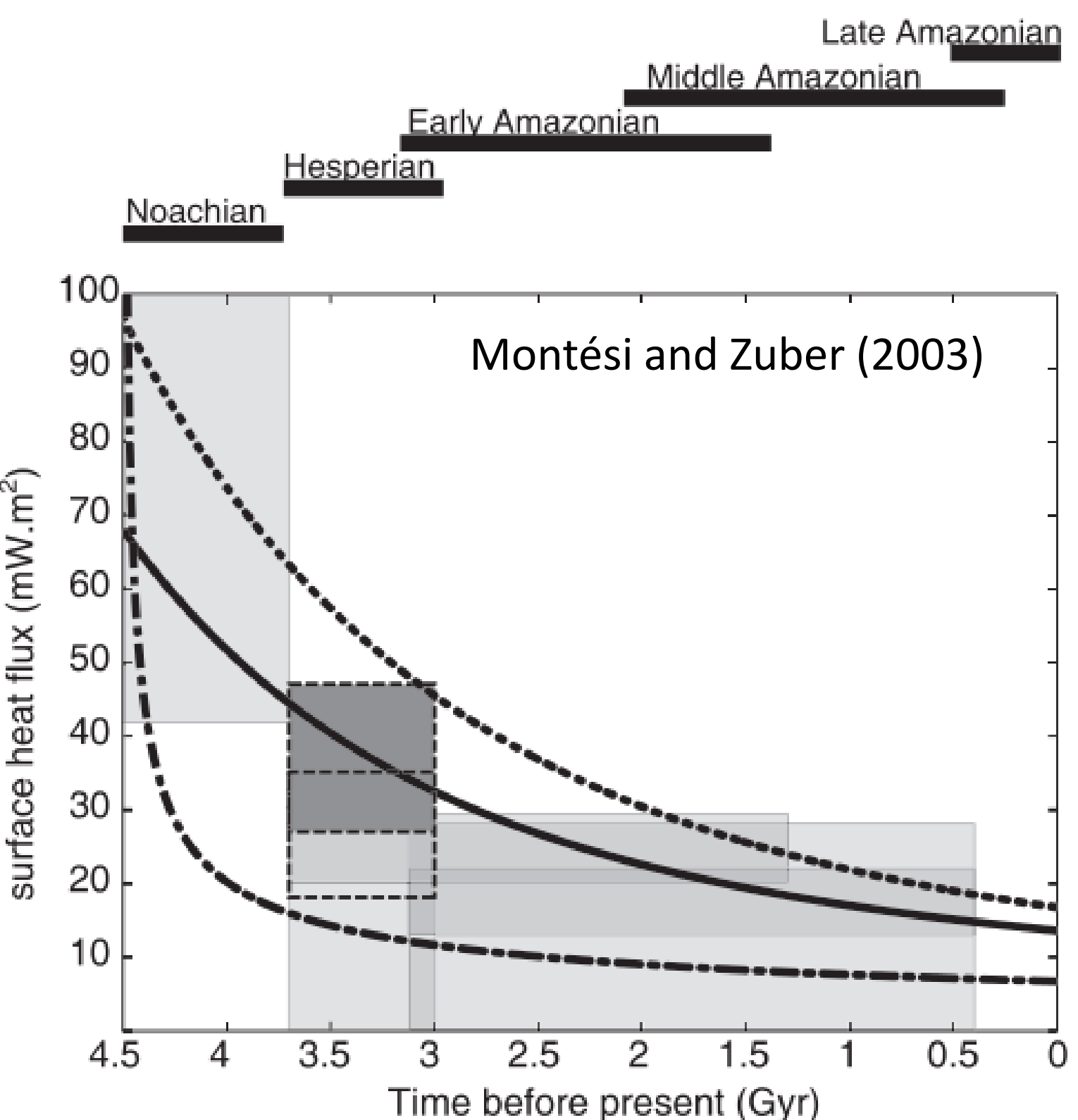
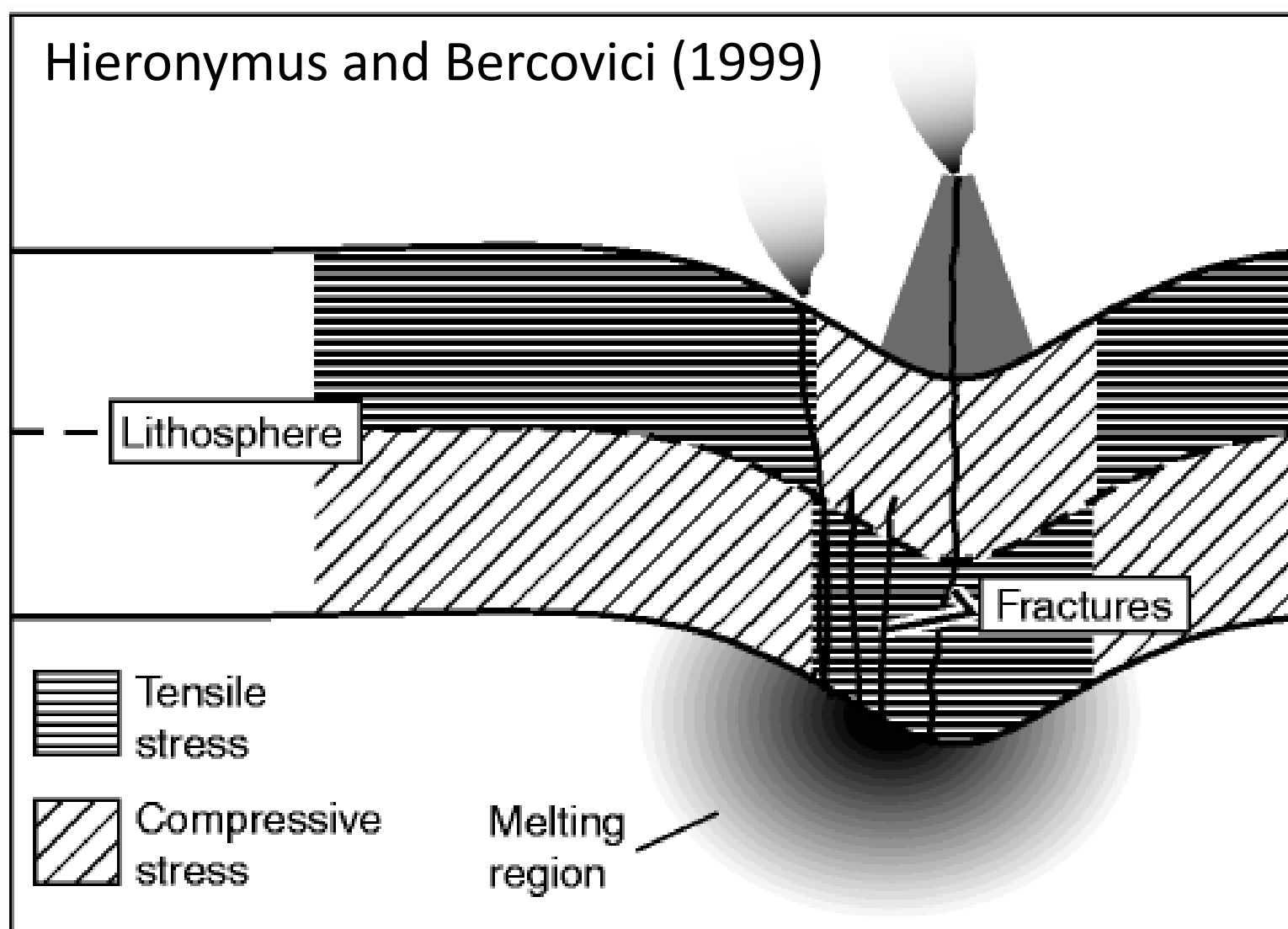
The spacing of volcanoes of the similar ages on Mars depends on the elastic thickness

Volcano spacing is different at different epochs following the thermal evolution of Mars.

Datasets

Three sets of volcanoes grouped by age

- Tharsis set: 12 volcanoes, 2 Ga
- Hellas set: 6 volcanoes, 3.6 Ga
- Noachian set: 36 volcanoes, 4 Ga
 - Three subsets: “tight”, “main” and “sparse” defined based on their grouping



Flexure of an elastic plate under the load of a volcanic edifice. The nearest possible magma path passes along the inflection point separating compressive and tensile domains. Therefore volcano spacing can be influenced by elastic thickness

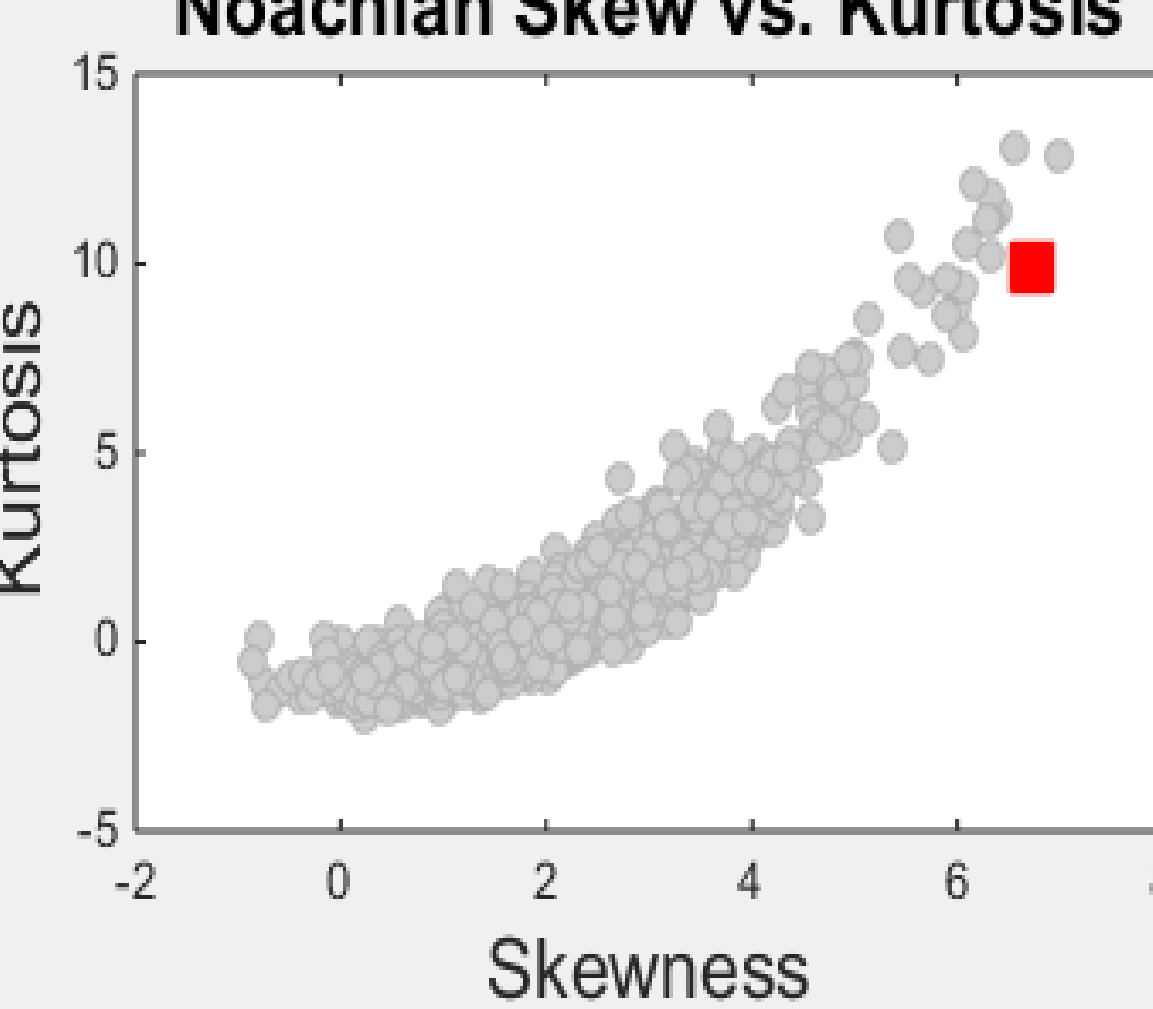
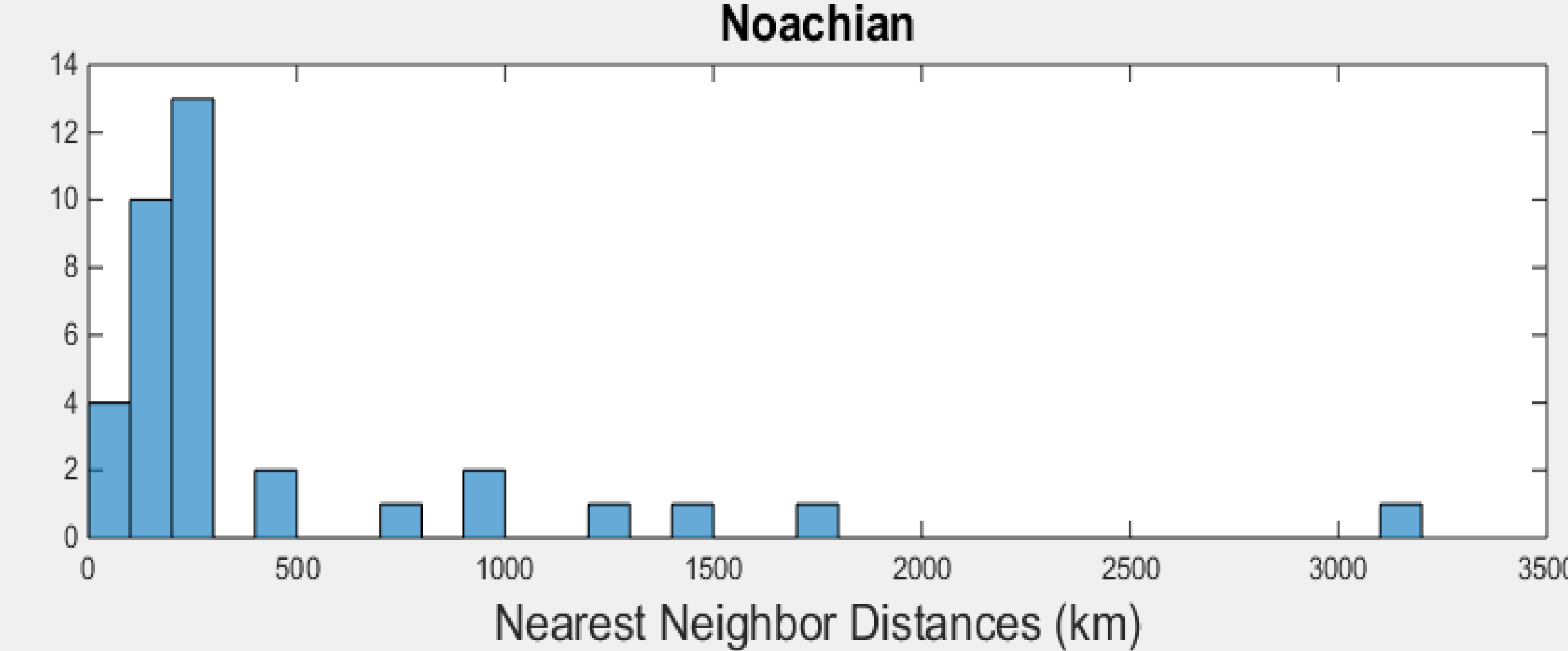
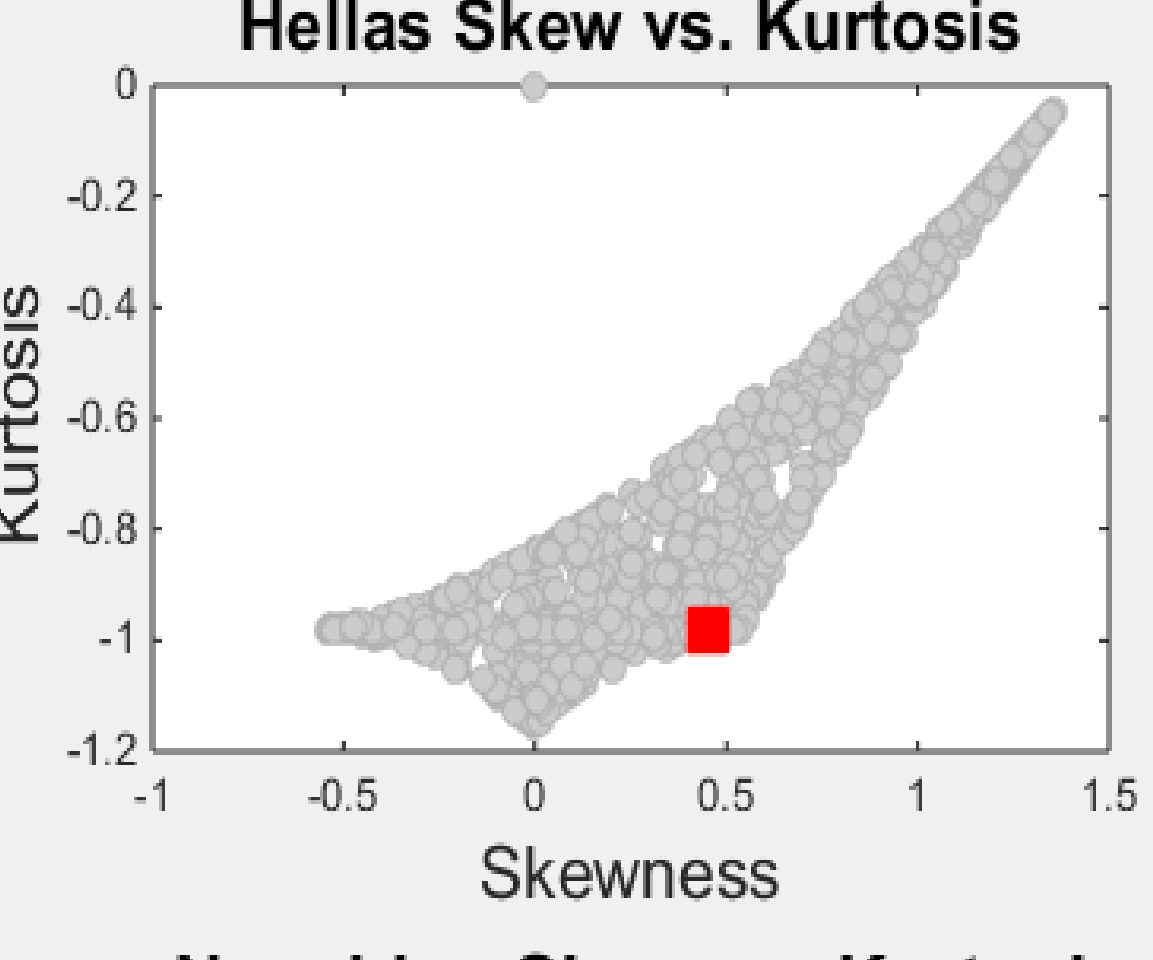
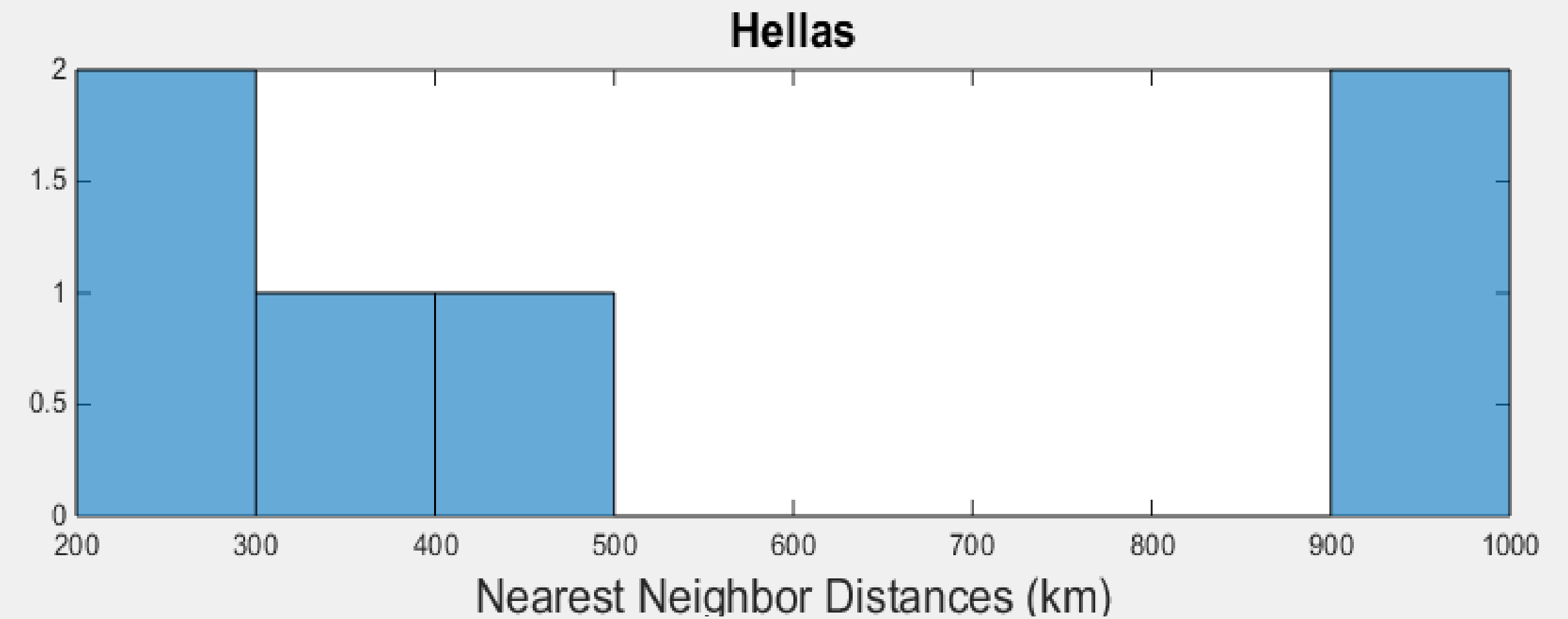
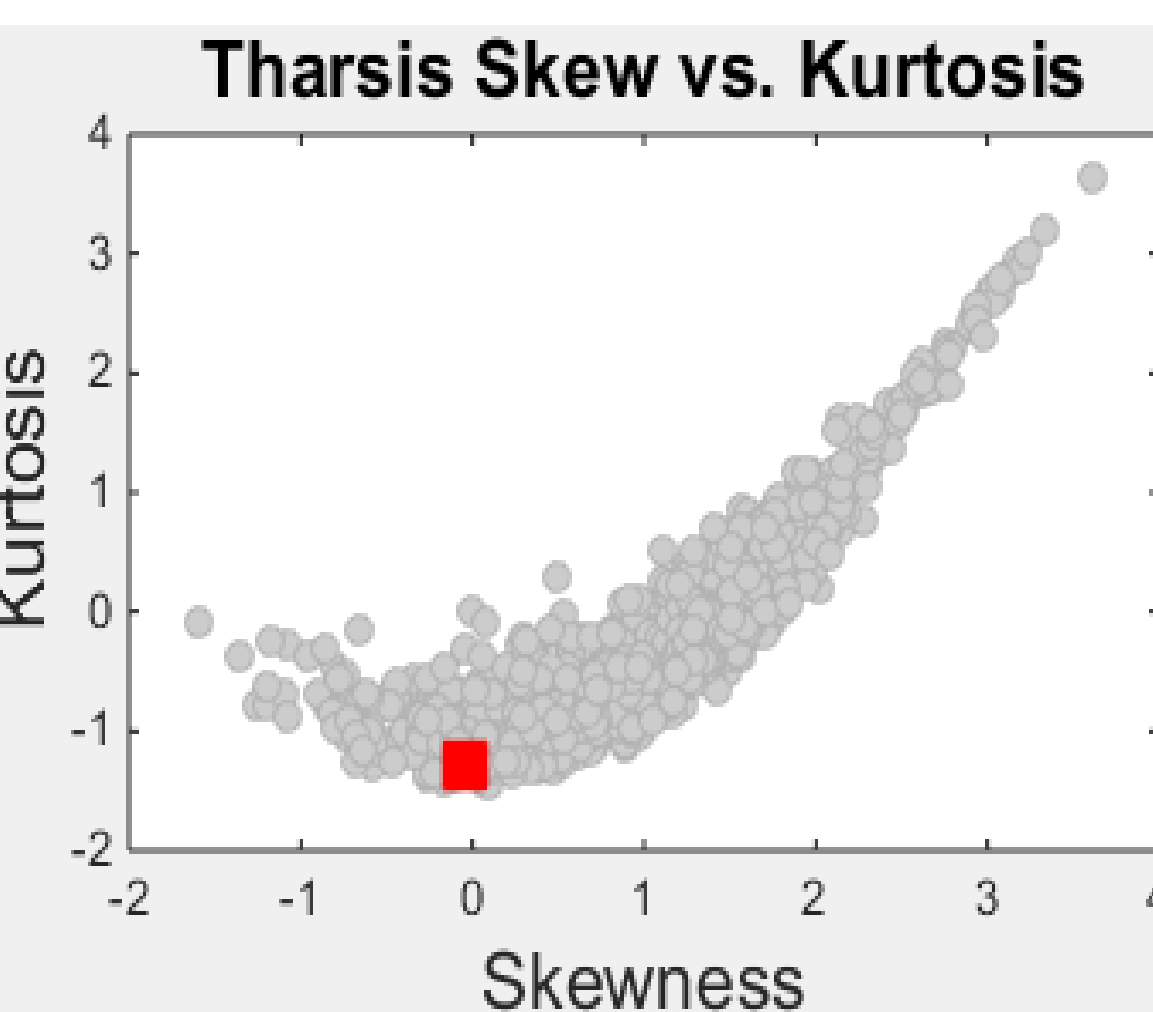
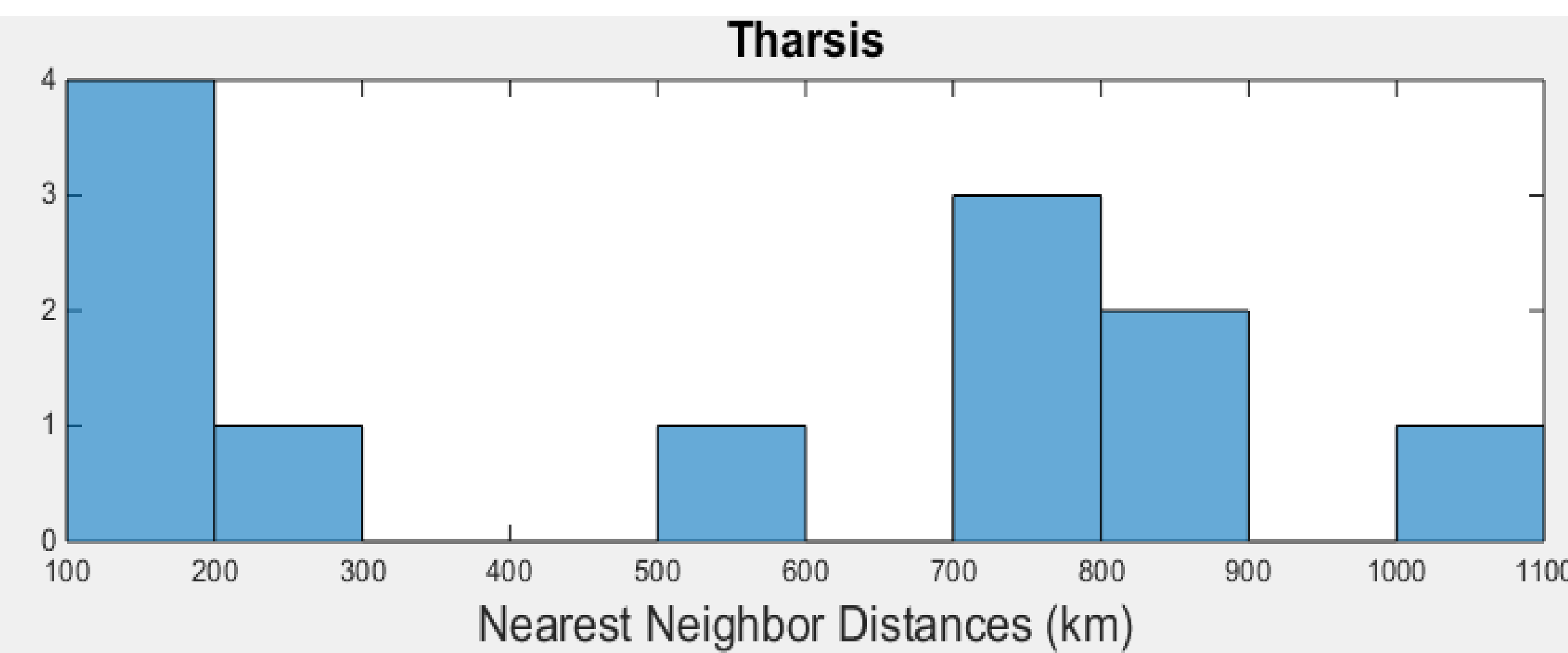
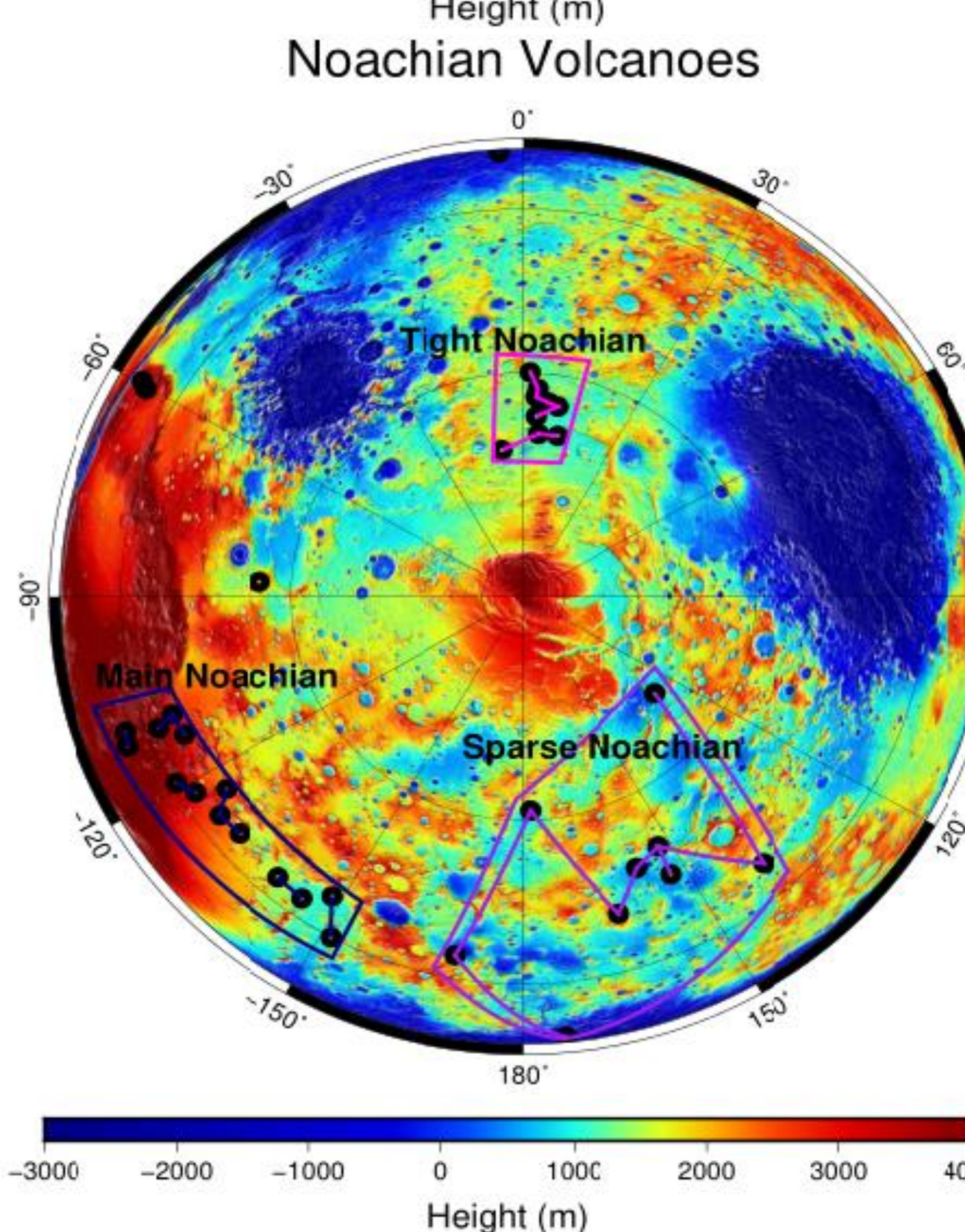
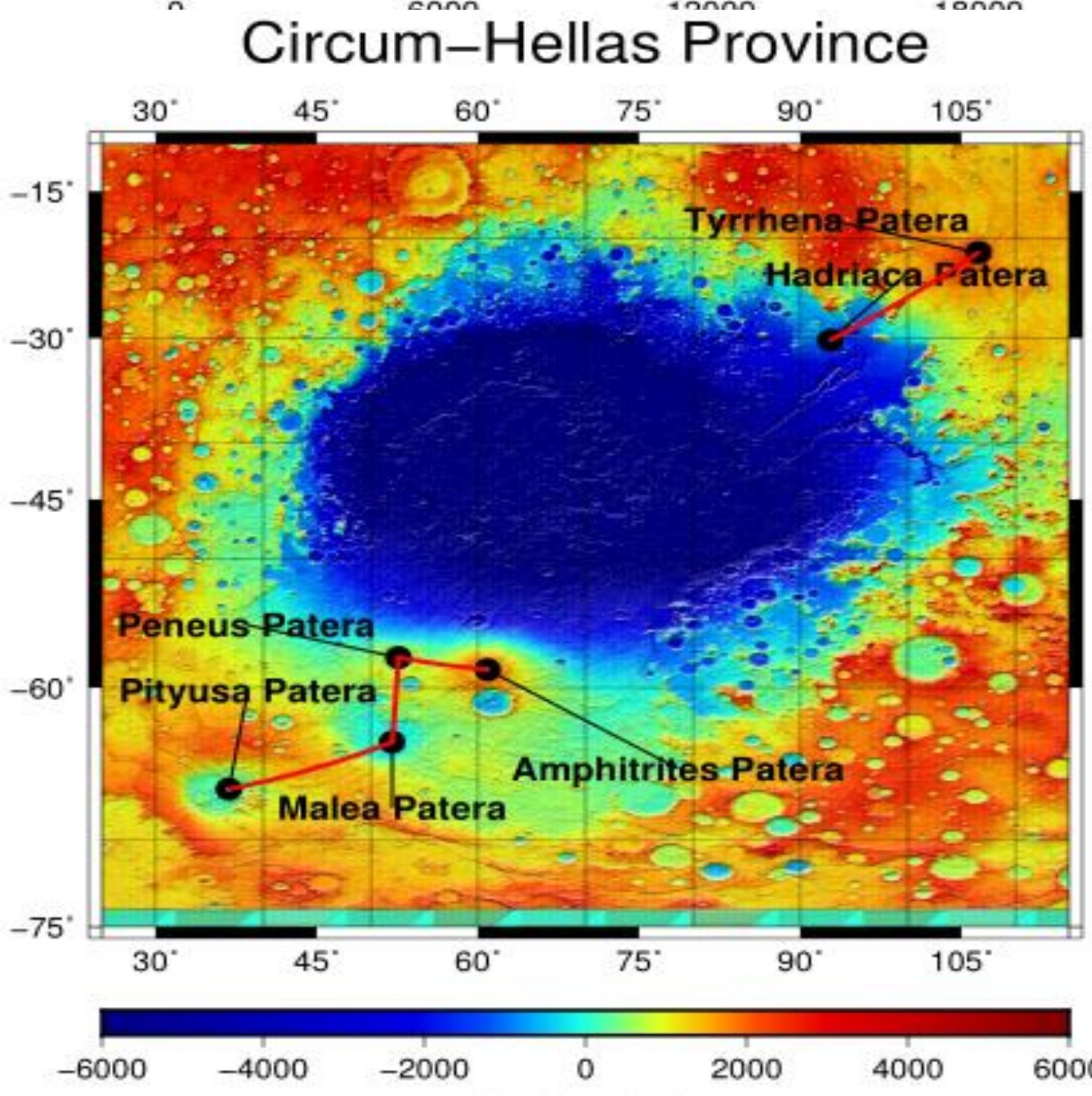
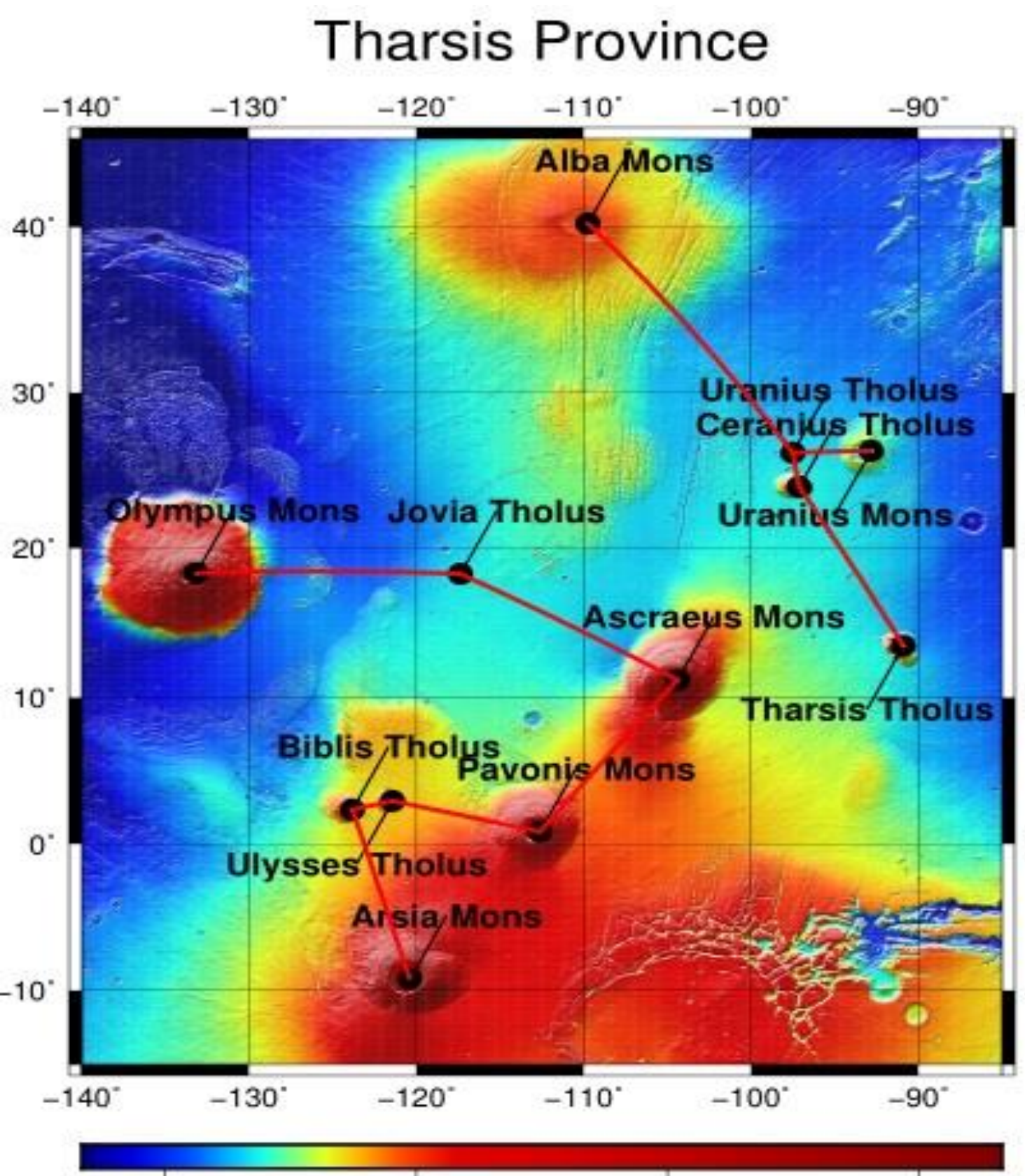
Martian Geologic Ages
Noachian: 4.5-3.7 Ga
Hesperian: 3.7-3.0 Ga
Amazonian: 3.2-0.0 Ga

Variation in Martian heat flux evidenced by gravity/topography analysis (light boxes), wrinkle ridge spacing (dark boxes) and compared with heat produced by radioactive decay (lines)

Results

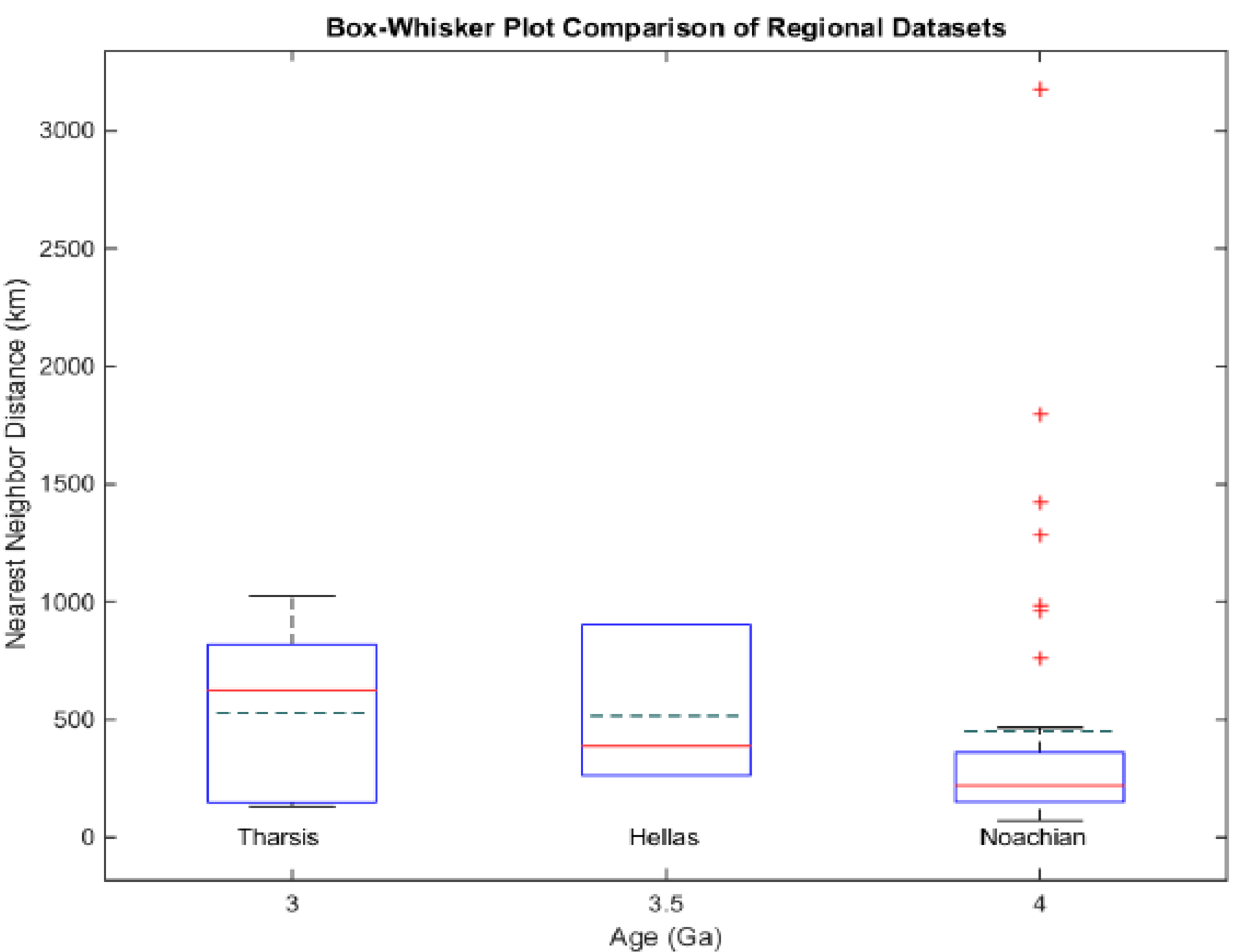
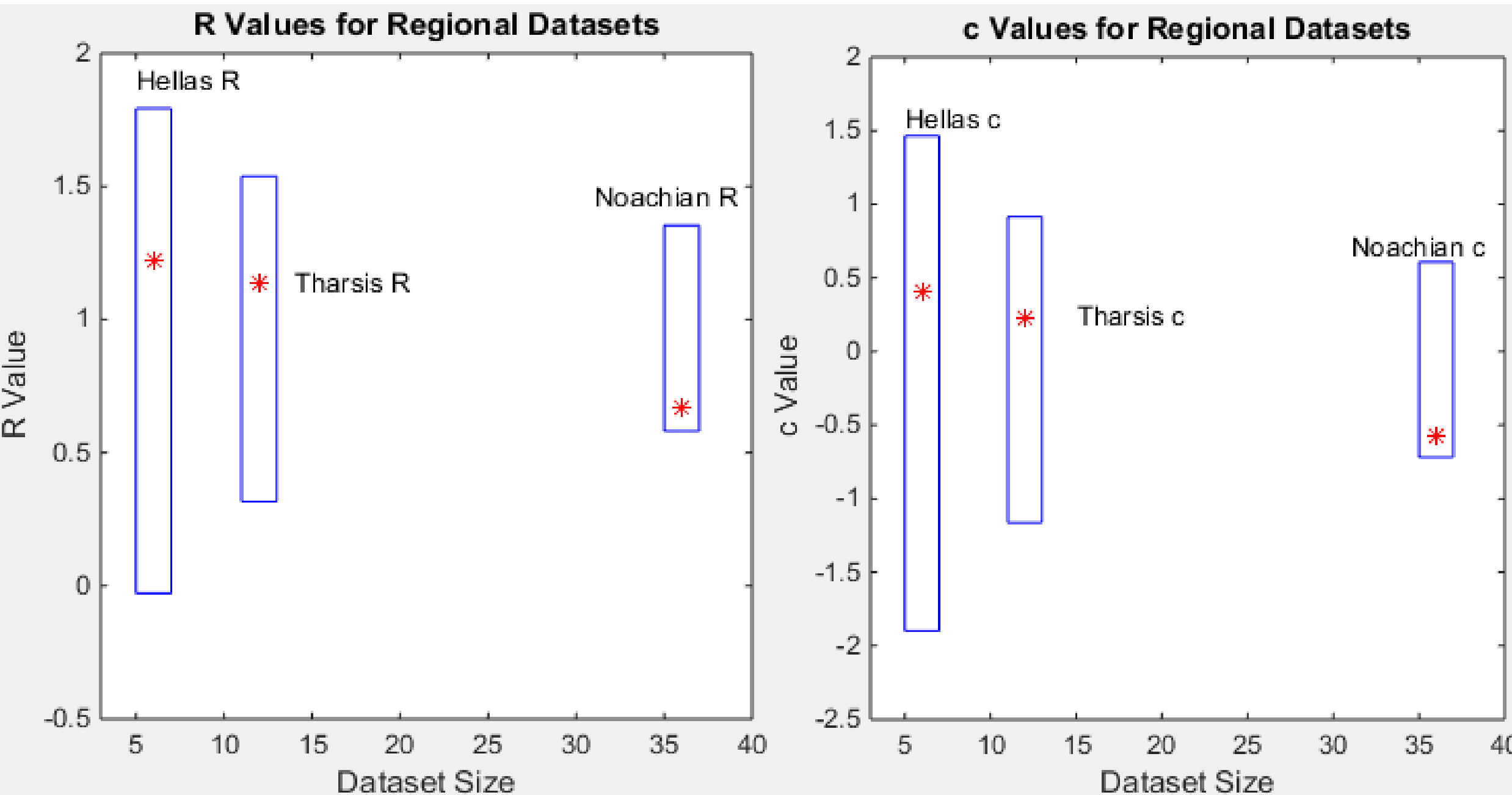
Methods – modelled after Richardson et al., (2012)

- For each edifice, identify nearest neighbor and distance.
- Compute nearest neighbor distance statistics for each volcano set.
 - Histogram generation to give an idea of the skewness of the dataset.
 - Median, mean r_a , standard deviation, interquartile scales, skew and kurtosis.
 - Compare with mean and standard deviation expected for a Poisson distribution, r_e and σ_e using the R and c statistics:
$$R = r_a / r_e \quad c = (r_a - r_e) / \sigma_e$$
- Evaluate significance of the spacing
 - Generate 1000 random sets of the same size and spatial extent as the dataset.
 - Calculate skew and kurtosis for each synthetic dataset.
 - Compute the R and c statistics of each synthetic dataset.
 - Evaluate the 2-sigma range of R and c values for synthetic sets.
- Repeat for each region



	Size	Mean $\pm 2\sigma$	Median	25 th %	75 th %	$R \pm 2\sigma$	$c \pm 2\sigma$	Skewness	Kurtosis	Reference
Tharsis	12	530 $\pm$ 340	620	150	820	1.1 $\pm$ 1.3	0.2 $\pm$ 1.3	-0.05	-1.30	Greeley and Spudis (1981)
Hellas	6	520 $\pm$ 300	390	260	900	1.2 $\pm$ 1.3	0.4 $\pm$ 1.2	0.45	-0.98	Williams et al. (2009)
Noachian	36	450 $\pm$ 620	220	150	360	0.7 $\pm$ 1.6	-0.6 $\pm$ 1.6	6.72	9.92	Xiao et al. (2012)
Tight	9	130 $\pm$ 170	141	71	140	0.2 $\pm$ 0.2	-1.0 $\pm$ 0.2	1.37	0.14	
Main	14	220 $\pm$ 90	200	180	240	0.9 $\pm$ 0.6	-0.2 $\pm$ 0.6	1.66	0.90	
Sparse	9	820 $\pm$ 560	760	260	1280	1.1 $\pm$ 1.4	0.2 $\pm$ 1.4	0.45	-0.90	

Summary



Both the R -values and the c -values for all three regional datasets fall within the expectation limits of a random distribution. The skewness versus kurtosis plot also plots within the range of the synthetic datasets. The box-and-whisker plots for the distributions of the regions display large error bars showing the characteristic spacing between the regions are statistically indistinguishable.

All regions’ datasets are indistinguishable from random sets. As such, nothing can be said about any underlying structural control on the emplacement of the volcanic edifices.

Conclusions

Because the regions’ volcanoes are all indistinguishable from random sets, there are no indications for structural control on the growth of the volcanic fields. Thus, the thickness of the lithosphere below the volcanic fields is not linked to the characteristic spacing between the volcanoes.

My hypothesis is therefore not born out by the data. There is a tantalizing increase of both the medians and the means of the datasets with decreasing age, but the ability to distinguish between different means and medians is not statistically significant and thus not scientifically relevant.