THE AGE OF SYRTIS MAJOR PLANUM AND IMPLICATIONS FOR THE CIRCUM-ISIDIS REGION.

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Introduction: Hesperian-aged volcanic plains cover ~30% of the surface of Mars [1]. In addition to defining the base of the Hesperian, these volcanic plains formed after the point in geological time when widespread valley network formation during the late Noachian had ceased.

Syrtis Major Planum, located on the western margin of Isidis Planitia is one such volcanic province, and is used as a key regional stratigraphic marker. Here, the Isidis impact event (~3.95 – 3.99 Ga) [2] and the formation of Syrtis Major Planum (~3.5Ga [3, 4]) bookend the most aqueously active period in the geological history of the circum-Isidis region. It is important to constrain what processes have affected this region, and when these processes occurred, because this location includes the landing site of the NASA 2020 rover mission, which will cache samples for future return to Earth [5]. However, Syrtis Major did not form instantly, different parts of the Planum formed at different times. Knowing the formation age of the component regions within Syrtis Major Planum is therefore vital, as this allows us to search for events that predate or interfinger with Syrtis Major volcanic units, and events that have modified the region subsequent to its formation.

Here we present new model crater retention ages (table 1), as well as collating previously published ages for the region, and combine this with detailed morphostratigraphic mapping for the major stages of formation of Syrtis Major Planum [3]. With these data, we assess whether Syrtis Major is a reliable stratigraphic marker, and what this means for our understanding of the geological history of the circum-Isidis region.

Method: Crater counts data (table 1) collated from [3] and the literature, were included if they had a well-defined: area, number of craters, crater size range, production and chronology function or N(x) value (number per size bin). Each count area was compared to our morphostratigraphic mapping to determine how it related to formation of the Planum.

For large areas, new crater retention model ages where determined by combining existing crater populations [4, 5] with our mapped unit areas. For smaller morpho-stratigraphic areas, manual counts where performed using a CTX base layer.

Observations: We have compiled a set of stratigraphically meaningful model ages for areas on, or associated with, Syrtis Major Planum with less meaningful dates, such as those which are published but violate superposition relationships excluded. The timing of events in the history of Syrtis Major Planum divides into phases of development. Phase 0 = Pre Syrtis Major, Phase 1 = Major phase of lava flow emplacement, Phase 1p = modification of Syrtis Major Planum at the boundary with the Isidis basin floor, Phase 2 = small scale volcanism in the central caldera complex and Phase 3= minor last stage events.

Location	Event	Date (Ga)	Error (Ga)	
Phase 3				
Nili Patera	Lava flow	0.51	+0.11/-0.11	[8]
East flank	Lava flow	1.02	+0.19/-0.19	[3*]
East flank	Lava flow	1.06	+0.20/-0.20	[3*]
Meroe Patera		1.20	+0.17/-0.17	[3**]
Phase 2				
Nili Patera	Erosion	1.55	+0.50/-0.50	[9]
Central	Lava flow	2.22	+0.26 /-0.26	[3**, 10]
Central	Lava flows	2.28	+0.11 /-0.11	[8, 3*]
NW flank	Lava flow	2.35	+0.25 /-0.25	[3*]
Lipany crater	Crater floor fill	2.42	unreported	[11]
Nili Patera		2.46		[8]
SMP Flanks, Nili Patera	Lava flow	2.48	+0.54 /-0.61	[8]
Nili Patera		2.71	+0.22 /-0.24	[8]
Phase 1p				
Isidis basin floor	Unknown	3.01	+0.07 /-0.09	[3*]
Isidis basin floor	Unknown	3.01	Minimum age	[12]
Phase 1				
Nili Patera, SE flank	Ignimbrites	3.08	+0.08 /-0.10	[8, 3*]
Cental		3.23	+0.08 /-0.13	[8, 3**]
Flanks	Volcanic plains	3.23	+0.05 /-0.06	[8]
Flanks	Volcanic	3.34	+0.03	[3*]

	plains		/-0.04	
Mereo Patera	Lava flows	3.39	+0.03 /-0.04	[3*, 3**]
Northern Flank	Lava flows	3.36	+0.02 /-0.02	[3*]
Northern flank	Lava flow	3.41		[13]
Isidis boundary	Volcanic plains	3.46		[14]
Flanks	Volcanic plains	3.48	+0.01 /-0.01	[3*]
Eastern Flank	Volcanic plains	3.50		[4]
Flanks	Volcanic plains	3.51	+0.01 /-0.01	[3*]
Flanks	Volcanic plains	3.54	+0.03 /-0.03	[3*]
Western Flank	Volcanic plains	3.60		[4]
Phase 0				
Antoniadi crater	Crater floor fill	3.70		[4]
Lipany crater	Crater floor fill	3.95		[11]
Circumferential Highlands	'Base-ment'	3.98	+0.01 /-0.01	[3*]

Table 1: Adapted from tables 2.4 and 7.1 in [3]. ([3*] = Chapter 4 and [3**] =Chapter 6 from [3])

Discussion: The dates pertaining to the formation of most of the areal extent of Syrtis Major Planum show a cluster of ages in the late Hesperian, plus some ages in the early Amazonian. These data also show localized activity in the central caldera complex and substantial resurfacing and erosional modification at the boundary where Syrtis Major Planum meets the floor of Isidis Plantia.

Of these dates, counts with the largest areas cluster in the Hesperian whilst dating of individual flows across the flanks mostly reported in [15] predominantly suggest much younger ages. As there is a link between count area, minimum crater size and model age [16], we have been critically selective in our interpretation of date for individual flows with small areas and do not feel they represent ages that inform about the formation of Syrtis Major Planum.

Geomorphology suggests only minor late stage flank activity after the major constructional phase in the history of Syrtis Major Planum. The majority of the lava shield appears to be very thin [3, 4] and kipukas to the highland terrain are common. This means that lava flows towards the edge of the Syrtis Major Planum are unlikely to be sufficiently thick to buried the largest craters formed if Syrtis Major Planum was emplaced over a long period of time. However, there is only one example of impact ejecta embayed by a lava flow, and that flow is not morphologically related to the lava flow that build the vast majority of Syrtis Major Planum [3], this suggests that Syrtis Major Planum was emplaced rapidly (<0,5 Ga) and perhaps on times scales comparable to terrestrial large igneous provinces [17].

Conclusion: Syrtis Major Planum is a reliable and useful stratigraphic maker in the Circum-Isidis region. It is likely that the areal extent of Syrtis Major Planum was established by ~3.3 Ga, and activity persisted for ~0.2 Ga. The only substantial, post-formation erosional modification is localized along the boundary with Isidis Planitia and probably finished before 3.0 Ga. This means that distributed erosional processes (pluvial, fluvial) ceased to be important before 3.5 Ga but large scale erosional process (glacial, thalassic) were operating within Isidis between 3.3 Ga and 3.0 Ga.

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