College Heights Christian School
2012 MSIP Final Report

I. Introduction

Our science question was, can a rate of degradation be determined for small preserved craters on the Martian surface? This question is important and interesting because it could help us understand what has and is going to happen to the craters and other surface features on Mars. Determining the rate of degradation can help scientists know which geological areas have more sand and dust, and which areas see more dust storms. This could then tell researchers how quickly surface features on Mars can change, which will allow us to determine the harshness of the Martian surface. This type of data could play a role in determining where to land future missions to Mars. One hypothesis about our science question is that the preserved craters in the Plains regions will decay faster than the preserved craters in the Polar Regions. This is because there is more wind on the plains, which would cause more dust to full the craters. (Watt 1) We also suggested that the typical, slow rates of degradation seen planet-wide will be dramatically increased in some regions due to localized and global dust storms, which can last for months, could fill in the preserved craters or make measurable changes in the height of the rim at a faster rate.

II. Background

A crater is formed by meteorites hitting the surface of a planet. Craters are usually circular in shape, with a rim, floor, and walls. Some craters have central peaks. Material can slump down to the bottom of the crater because of gravity. A small preserved crater is defined as a crater 2 kilometers or less in diameter. (Watt 1) The rate of degradation of a crater can be defined as the amount of dust and wind erosion of the raised rim or the amount of infilling on the crater floor. (Decay 1) A dust storm is a storm of strong winds and dust-filled air over an extensive area during a period of drought. (Squyres 1) The Martian atmosphere has a general circulation so the wind pattern is carried over the entire surface. The sun heats the atmosphere more at low latitudes than high latitudes. (Squyres 1) Large dust storms begin when wind lifts dust into the atmosphere. The dust absorbs sunlight and warming the air around it. As warm air rises, more wind is prevalent and therefore stirs up more dust. These dust storms can blanket the entire planet. Dust storms are more common when Mars is closest to the sun because the sun is able to more extensively heat the atmosphere. (Themis 2)

The image below shows an example of a small, preserved craters on Mars. This type of crater is the focus of our study.

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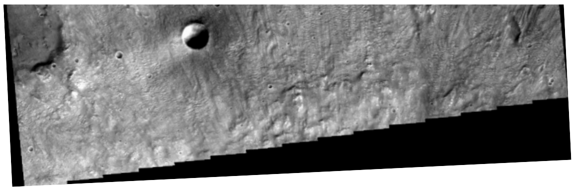


- V04645003

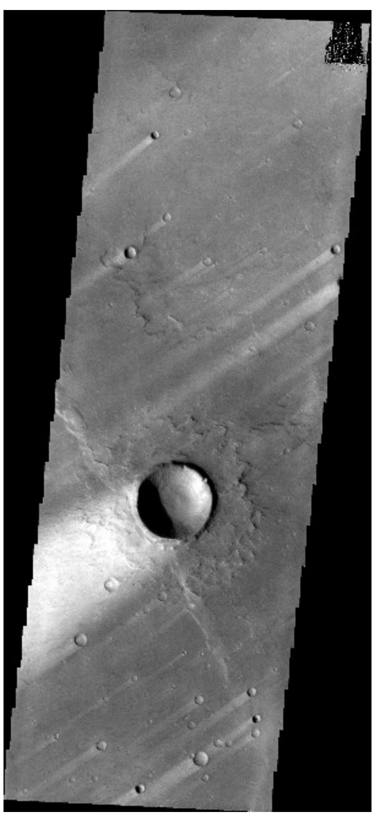
This photo shows the size of the craters we looked at for our data.

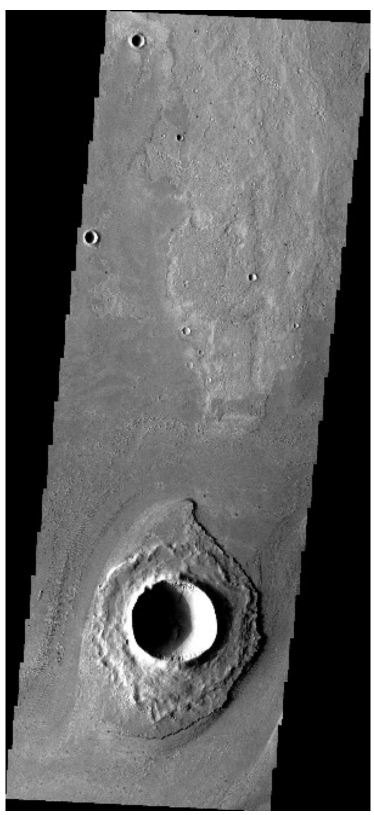
Small, distinct, and preserved craters

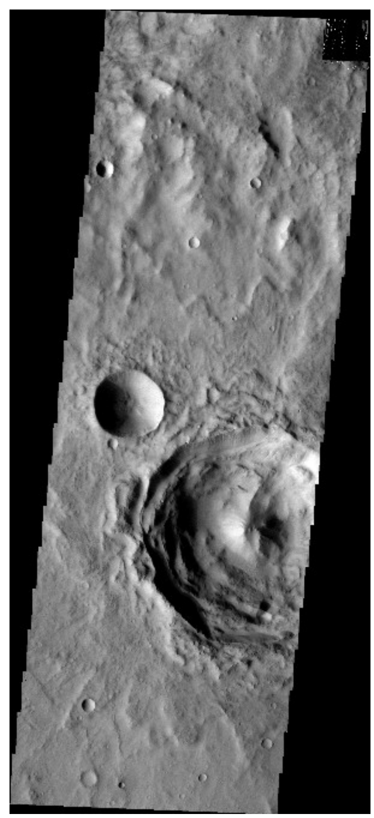
Location: 26.4°N/ 321.9°E

These are included to show the variety of craters seen on Mars.
As surface winds blow dust around, the craters become less and less distinct, showing in some cases (first image) wind streaks. The middle image shows the effect of an impact on ground that may have some subsurface ice, causes a splosh crater which ejects muddy material around the original impact site (Watt 1). The Third image shows an older large crater that has been somewhat degraded and a smaller, newer crater.

V16760012 V05899006 V31968004



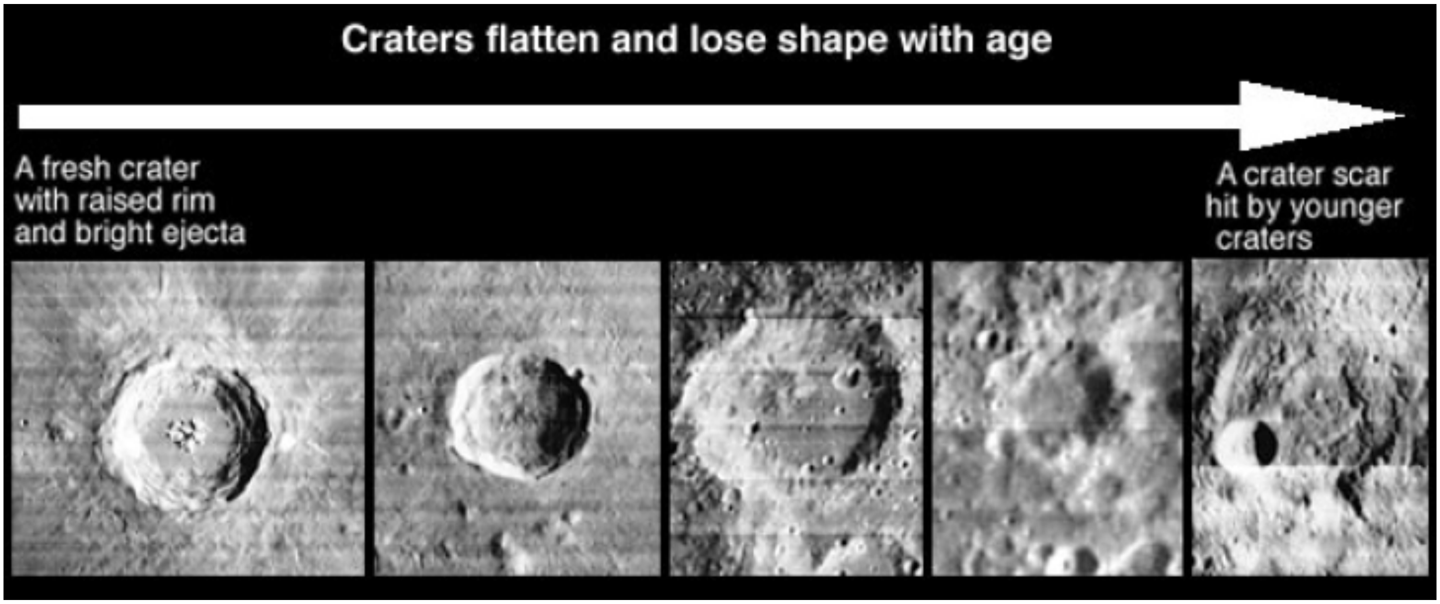




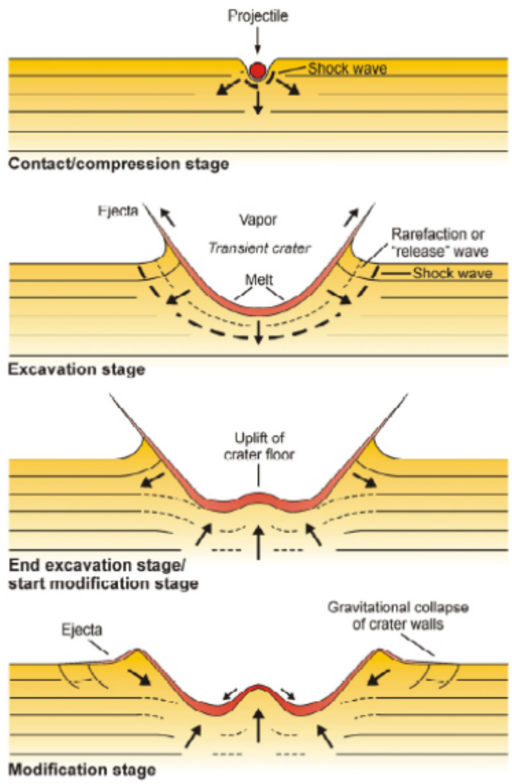
We used (themis.asu.edu) for these pictures.

It is our hypothesis that the degradation of craters which occurs after meteorite impact could be observed by comparing photos taken years apart of the same area.

This series of images was found in the Explorer's Guide and shows how craters are changed over time on Mars. (Explorer's guide.edu)



This is how craters are formed on Mars (the same as on Earth). (Explorer's Guide.edu)



We observed like these craters all over Mars. However, more craters are found in the Southern Hemisphere than in the Northern Hemisphere.

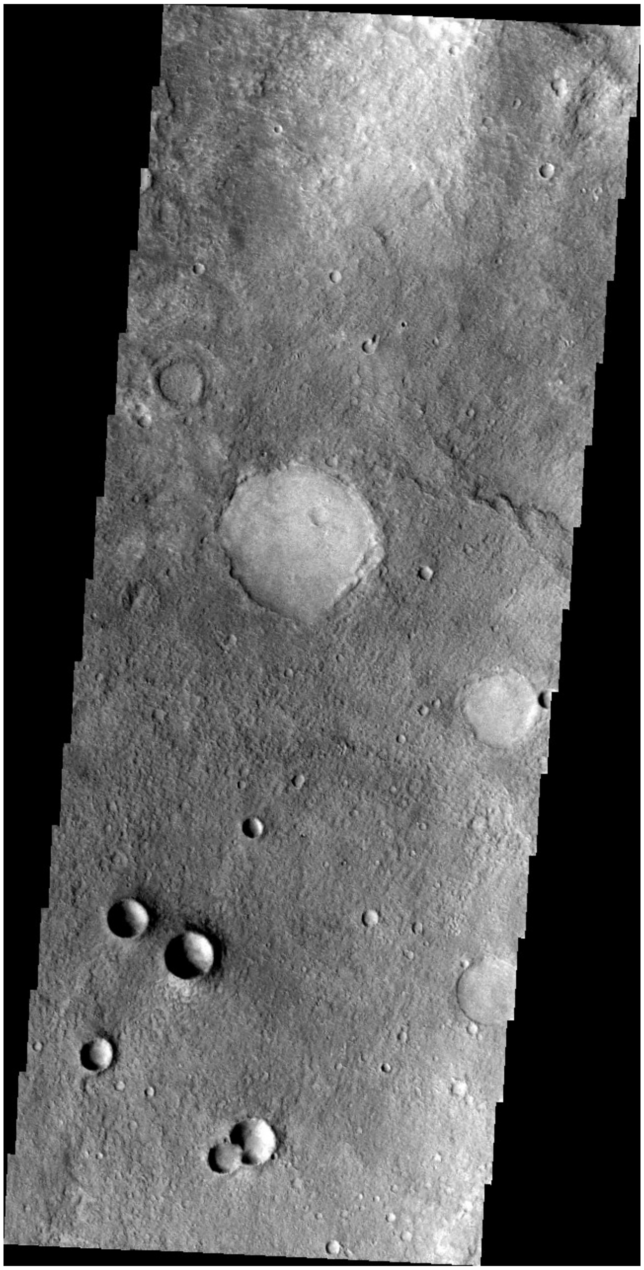
III. Methods

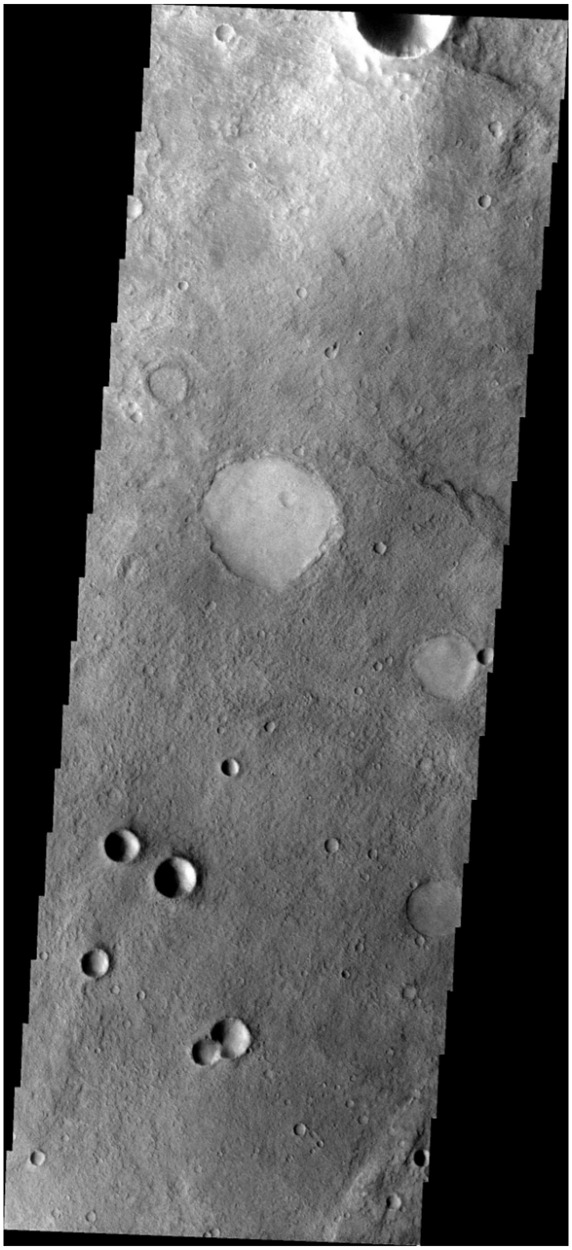
We used the images taken by the THEMIS camera aboard the Mars Odyssey spacecraft. First, we used wanted to find images of the same crater taken years apart. We used the program jmars to find craters that were preserved and less than 2km in diameter. By using the jmars program, we were able to quickly determine if a THEMIS image had been taken of a particular site, and if there were overlapping images several years apart. We only choose pairs of images that were more than 1 year apart, and that had full, clear craters in them. We began looking particularly at the geological regions of Chryse Planitia, Hellas Basin, and the Polar Regions. After spending several hours looking for craters in Hellas Basin, we found that many THEMIS images were unclear, or did not show preserved craters. It was suggested that this is because of large amounts of dust in that particular region (Manfredi 1) Craters were also scarce in the polar regions, so we modified our focus and began looking in multiple and varied regions in the Plains and mountainous areas. Because multiple groups worked along specific latitude lines, our compiled research is not focused on any specific region. Besides using jmars.asu.edu, we were also successfully able to locate craters with multiple images from the themis.asu.edu website. We chose a site by general latitude that we wanted to look at and tried to find images that fit our criteria. Then we looked for a duplicate image of the same crater. After we found duplicate images, we used jmars to get the year the images were taken and the central latitude/longitude of the specific crater we were looking at. Next, we used themis-data.mars.asu.edu to get search for the specific THEMIS images and it's corresponding data set, including the incidence angle and the line resolution. We were looking to record the diameter of the crater and the incidence angle of the sun in order to calculate the depth of the crater. The last step was measuring. We pasted the pictures into Gimp and used the measuring tool to measure the crater's diameter (East to West and North to South) and the length of the shadow. To calculate the depth we used a trigonometric function of $d=L/\tan\theta$ where d represents the depth and L is length of shadow and θ is the sun angle.

IV. Data

Initially while at ASU, we collected data on only a half dozen craters. Upon returning home, we had ten groups of students who collected measurements of craters over a week's time, and we have a total of 120 images to analyze. Included in this report is a sampling of that data, collected by specific groups.

An example of a pair of images we measured:





A pair of images like this (2 years apart) might generate as many as 6 measureable craters.

The following is the compiled master data table:

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Early Image													
												Creater Measurments	
Image Number	Yr of Image	Lat	Long	Geographic Region	Shadow length (pix)	Shadow length (m)	Sun Angle	Depth	Diameter (pix)	Diameter (m)	Resoultion (m/p)	Original Depth	Amount of infill
V15064001 (1)	27	-26.2	59.8	Sirtis Major Area	12	207.7	78.84	41	17	294.2	17.308	58.84	17.84
V15637001 (2)	27	-9.7	92.8	Sirtis Major Area	7.2	249.89	77.848	54	9.1	590	37.378	118	64
V15077007 (3)	27	-37.08	43.173	Terra	5.1	88.01	76.943	20.41095	32.5	160	35.06	32	12
V06222002 (4)	26	-6.271	227.602	Tharsis Region	5	87.61	15.06	88	9.1	160	17.522	32	16.94
V13595010 (5)	27	5.0219	291.12	Tharsis Region	2	71.62	82.38	72	3.5	720	35.81	144	72
V13595010 (6)	27	5.0219	291.12	Tharsis Region	4.1	146.81	82.38	19.64	7	260	35.81	52	32.36
V13595010 (7)	27	5.0219	291.12	Tharsis Region	11	196.35	82.38	55	18	640	35.81	128	73
V18203005 (8)		-26.76	229.234	Tharsis Region	16	273.008	66.5999	118.14	27	460	17.063	92	-26.14
V15069004 (9)		-23.36	275.99	Solis Planum	4.1	71.1719	79.3327	13	8	140	17.359	28	20
V08629003 (10)		-18.22	291.624	Thaumasia Planum	10	324.95	58.739	230	17.5	580	34.295	116	98.5
V14134008 (11)		32.97	226.59	Olympus Park	4.1	76.342	82.83	10	8	150	18.602	30	22
V14134008 (12)		32.97	226.59	Olympus Park	4	74.408	82.83	70	5.1	100	18.602	20	14.9
V13837015 (13)	27	5.3259	150.31	Elysium Planitia	10.2	362.65	82.71026	46.39	17.1	607.97	35.554	121.594	104.494
V13114005 (1)	27	26.947	129.575	Libya Planitia	11	202.543	74.064896	57.83008	16	294.608	18.413	58.9216	1.091521698
V14296013 (2)	27	14.077	230.722	Olympus Mons	18	654.624	84.37637	64.45903	33	1200.144	36.368	240.0288	207.0288
V14296013 (3)	27	14.077	230.722	Olympus Mons	10	363.68	84.37637	35.81057	17.5	636.44	36.368	127.288	109.788
V18168011 (4)	27	22.27	136.693	Libya Planitia	36	661.536	68.393906	262.002	70.5	1295.508	18.376	259.1016	188.6016
V08271001 (5)	26	-14.57	175.221	Amazonia Planitia	13	452.361	62.747677	233.0044	26	904.722	34.797	180.9444	154.9444
V12090006 (6)	27	25.747	148.817	Amenthes Mons	8	294.296	70.904945	101.8807	14	515.018	36.787	103.0036	89.0036
V15064001 (1)	27	-26.2	59.8	Sirtis Major Area	12	207.7	78.84	41	17	294.2	17.308	58.84	17.84
V15637001 (2)	27	-9.7	92.8	Sirtis Major Area	7.2	249.89	77.848	54	9.1	590	37.378	118	64
V15077007 (3)	27	-37.0817	43.173	Terra	5.1	88.01	76.943	20.410953	32.5	160	35.06	32	12
V06222002 (4)	26	-6.271	227.602	Tharsis Region	5	87.61	15.06	88	9.1	160	17.522	32	16.94
V13595010 (5)	27	5.0219	291.12	Tharsis Region	2	71.62	82.38	72	3.5	720	35.81	144	72
V13595010 (6)	27	5.0219	291.12	Tharsis Region	4.1	146.81	82.38	19.64	7	260	35.81	52	32.36
V13595010 (7)	27	5.0219	291.12	Tharsis Region	11	196.35	82.38	55	18	640	35.81	128	73
V18203005 (8)	27	-26.758	229.234	Tharsis Region	16	273.008	66.5999	118.14	27	460	17.063	92	-26.14
V15069004 (9)	27	-23.355	275.99	Solis Planum	4.1	71.1719	79.3327	13	8	140	17.359	28	20
V08629003 (10)	26	-18.22	291.624	Thaumasia Planum	10	324.95	58.739	230	17.5	580	34.295	116	98.5
V14134008 (11)	27	32.97	226.59	Olympus Park	4.1	76.342	82.83	10	8	150	18.602	30	22
V14134008 (12)	27	32.97	226.59	Olympus Park	4	74.408	82.83	70	5.1	100	18.602	20	14.9
V13837015 (13)	27	5.3259	150.31	Elysium Planitia	10.2	362.65	82.71026	46.39	17.1	607.97	35.554	121.594	104.494
V11990008 (1)	2004	23.27 N	154.56 E	Amazonis Planitia	26	971.828	69.19305	369.29773	45.4	1696.9612	37.378	339.39224	-29.90548608
V11990009 (2)	2004	31.18N	154.28 E	Elysium Mons	19	710.182	69.19305	276.85	38.5	1439.053	37.378	287.8106	249.3106
V12099014 (3)	M27	.7232S	245.611E	Tharsis Montes	21	736.26	80.02804	129.45101	32.5	1139.45	35.06	227.89	195.39
V19160009 (4)	M26	41.57N	323.77E	Acidalia Planitia	18	340.74	68.91337	131.38928	54	1027.2	18.93	205.44	151.44
V17742023 (5)	M27	22.01N	185.43E	Amazonis Planitia	31	570.276	69.94618	315.53	64	1174.208	18.93	234.8416	-80.6884
V13858009 (6)	M27	29.36N	267.91E	Tempe Terra	16	589.04	80.00748	160.85	23	846.745	36.815	169.349	8.499
V13023010 (7)	M27	27.08N	234.72E	Olympus Mons	22	807.46	73.902016	233.03058	39	1431.4117	36.703	286.28234	53.25176442
V17704026 (8)	M26	19.79N	201.32E	Amazonis Planitia	44	804.056	79.34483	261.29573	76	1388.824	18.274	277.7648	16.46907068
V121461010 (9)	M27	16.66N	245.31E	Tharsis Montes	10	365.14	74.06465	310.86	21	766.794	36.514	153.3588	124.406
V25490001 (10)	M28	2.486S	264.9E	Valles Marineres	34.9	613.1581	66.49007	266.735	80.3	1410.79	17.569	282.158	128.7992
V25490001 (11)	M28	2.486S	264.9E	Valles Marineres	41.8	734.3842	66.49007	319.47	93.1	1635.67	17.569	327.134	7.664
V17658007	2003	-28.77	110.48		11	190.311	60.05737	109.6222	49	847.749	17.301	169.5498	59.92762291
V17658007	2003	-28.77	110.48		13	224.913	60.05737	129.5535	79	1366.779	17.301	273.3558	194.3558
V17658007	2003	-28.77	110.48		32	553.632	60.05737	318.9009	120	2076.12	17.301	415.224	295.224
V07674003	2002	-21.85	111.38		13	446.875	66.728096	192.1951	36	1237.5	34.375	247.5	211.5
V07674003	2002	-21.85	111.38		21	721.875	66.728096	310.4689	34	1168.75	34.375	233.75	199.75
V07674003	2002	-21.85	111.38		9	309.375	66.728096	133.0581	31	1065.625	34.375	213.125	182.125
V07674003	2002	-21.85	111.38		30	1031.25	66.728096	443.5271	50	1718.75	34.375	343.75	293.75
V07674003	2002	-21.85	111.38		10	343.75	66.728096	147.8424	28	962.5	34.375	192.5	164.5
V08135024	2002	7	111.52		54	1930.014	74.37411	539.8098	100	3574.1	35.741	714.82	614.82
V08135024	2002	7	111.52		21	750.561	74.37411	209.926	41	1465.381	35.741	293.0762	252.0762
V05053003	2002	-11.12	99.66	Terra Tyrrhena	17.7	614.8626	75.59675	157.9071	22	764.236	34.738	152.8472	130.8472
V05053003	2002	-11.12	99.66	Terra Tyrrhena	22	764.236	75.59675	196.2687	32.5	1128.985	34.738	225.797	193.297
V05053003	2002	-11.12	99.66	Terra Tyrrhena	18.9	656.5482	75.59675	168.6126	31	1076.878	34.738	215.3756	184.3756
V05053003	2002	-11.12	99.66	Terra Tyrrhena	10.3	357.8014	75.59675	91.88942	19	660.022	34.738	132.0044	113.0044
V05053003	2002	-11.12	99.66	Terra Tyrrhena	18	625.284	75.59675	160.5835	23	798.974	34.738	159.7948	136.7948
V12695006	2003	28.16	336.59		40.9	1530.8461	72.05157	495.8792	65	2432.885	37.429	486.577	421.577
V12770011	2003	28.21	333.03		87	3253.104	72.64656	1016.559	87	3253.104	37.392	650.6208	563.6208
V12645009-1	2	7.0N	332.8E		10.8	396.39	81.1674	61.59538	16	587.2	36.7	117.44	55.84462346
I02460009	1	4.6N	331.4E		14	1402.88	59.6	823.0648	36	1321.2	100.2	264.24	64.2
I14808001	2	15.6S	246.0E		29	2934.13	84.01095	307.8226	18	1821.6	101.2	364.32	346.32
V12645009-2	2	17.7N	337.2E	Olympus Mons	62.8	2304.76	75.2	608.9439	27.2	998.24	36.7	199.648	172.448
V12645009-3	2	17.7N	337.2E		27.7	1016.67	75.2	268.6158	35.6	1306.6	36.7	261.32	225.72
V11990008 (1)	2004	23.2 N	154.5 E		22	822.316	69.19305	312.4827	45.4	1696.9612	37.378	339.39224	26.9095487
V11990009 (2)	2004	31.1N	154.2 E		19	710.182	69.19305	269.8714	38.5	1439.053	37.378	287.8106	17.93918479
V21328004	2006	58.6 N	68.3 E		50	967.9	69.62775	359.4253	102	1974.516	19.358	394.9032	35.47793838
V03229003	2002	14.3 N	114.4E		33	594.297	62.56435	308.5236	73	1314.657	18.009	262.9314	-45.59218854
V04702003	2003	14.0 N	116.2 E	"Elysium Planitia"	10	733.61	70.27972	262.9634	35.5	2604.3155	73.361	520.8631	257.899702
V05196001	26	-12.2	295.6		22.8	1579.812	79.96	279.701	33	2286.57	69.29	457.314	177.6131719
V05196001	26	-12.2	295.6		8.5	588.965	79.96	104.274	15.5	1073.995	69.29	214.799	110.5245685
V05196001	26	-12.2	295.6		10	692.9	79.96	122.676	15.6	1080.924	69.29	216.1848	93.50899821
V05082022	26	30.65	320.33		7.2	133.92	70.06	48.5841	11.5	213.9	18.60	42.78	-5.804135237
V05257020	26	28.47	313.29		4.1	75.85	79.09	14.6201	8.5	157.25	18.50	31.45	16.82986255
V05257020	26	28.47	313.29		6.4	118.4	79.09	22.8217	9.5	175.75	18.50	35.15	12.32832203
V05057010	26	26.52	320.68		5.1	187.629	70.30	67.1809	10.1	371.579	36.79	74.3158	7.134891801
V05057010	26	26.52	320.68		8.1	297.999	70.30	106.699	15.2	559.208	36.79	111.8416	5.142510508
V03334003	26	25.02	327.89		2.8	205.632	61.03	113.843	6	440.64	73.44	88.128	-25.71496892
V03334003	26	25.02	327.89		1.4	102.816	61.03	56.9215	3.8	279.072	73.44	55.8144	-1.107084458
V03359003	26	19.28	326.1		8	290.4	62.13	153.564	17	617.1	36.30	123.42	-30.14425928
V02610007	26	19.31	326.76		8.9	322.981	57.97	202.056	18.6	674.994	36.29	134.9988	-67.05734952
V05918016	26	18.73	329.22		2.2	40.15	79.56	7.39788	5.1	93.075	18.25	18.615	11.21711817
V05918016	26	18.73	329.22		2	36.5	79.56	6.72535	4.1	74.825	18.25	14.965	8.239652885
V05918016	26	18.73	329.22		3	54.75	79.56	10.088	6.5	118.625	18.25	23.725	13.63697933
V03309005	26	17.26	327.74		3.6	260.856	62.67	134.811	8.1	586.926	72.46	117.3852	-17.42563777
V05319014	26	18.37	323.82		6.4	116.48	73.79	33.8626	11	200.2	18.20	40.04	6.177385078

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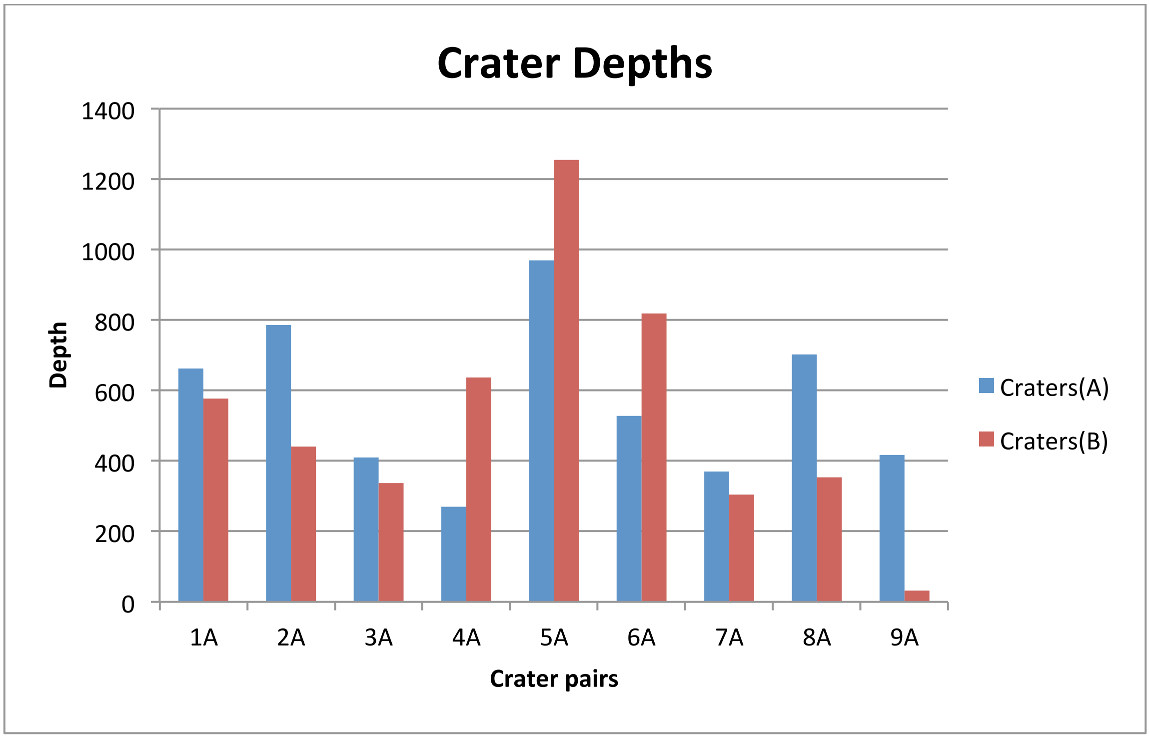
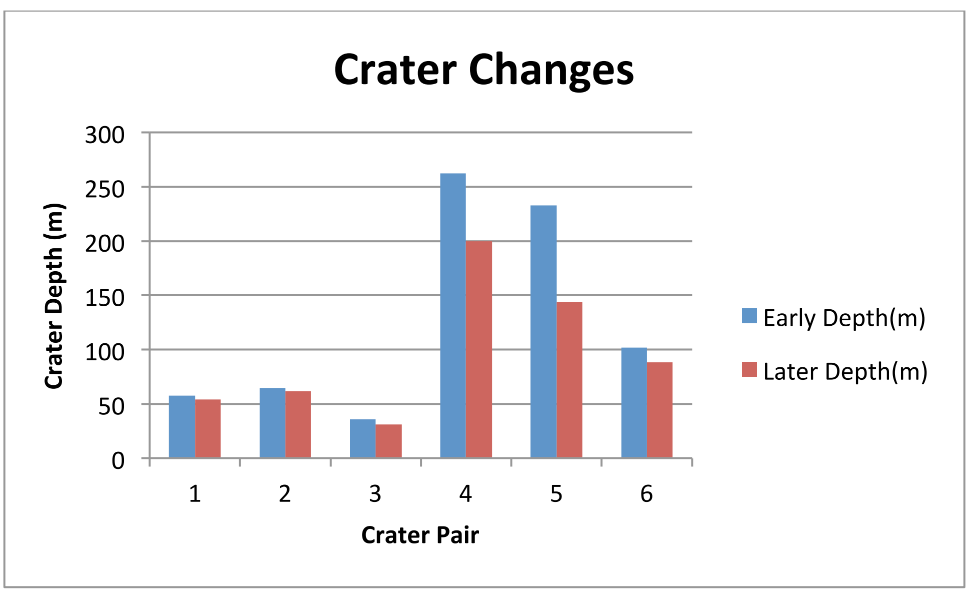
Later Image																	
												Creater Measurments		Observations			
Image Number	Yr of Image	Lat	Long	Geographic Region	Shadow length (pix)	Shadow length (m)	Sun Angle	Depth	Diameter (pix)	Diameter (m)	Resoultion	Oringinal Depth	Amount of infill	Ejecta	Central Peak	Rim Def	Other changes
V36527003 (1)	30	-25.14	60.016	Sirtis Major Area	7	241.58	73.07688	40	10	350	34.504	70	30				
V42703001 (2)	30	-9.7	92.8	Sirtis Major Area	15	265.5	43.14	61	30.5	350	17.7	70	9				
V36540005(3)	30	-36.49	43.265	Terra	2.2	75.4622	79.639	19	4.1	540	34.301	108	89				
V31181001 (4)	29	-6.271	227.6	Tharsis Region	3	106.146	80.246	18.24685	5.5	190	35.382	38	19.75315209				
V401002010 (5)	30	5.021	291.12	Tharsis Region	5.1	91.035	68.83	12	10	180	17.85	36	24				
V401002010 (6)	30	5.021	291.12	Tharsis Region	7.1	126.735	68.83	130	14.5	260	17.85	52	-78				
V401002010 (7)	30	5.021	291.12	Tharsis Region	19	339.15	68.83	131.3	34	610	17.85	122	-9.3				
V3659006 (8)		-26.76	229.304	Tharsis Region	10.5	273.008	74.022	100	15.5	530	34.4	106	6				
V26101003 (9)		-23.36	275.906	Solis Planum	3	51.3	63.486	13	7	140	17.1	28	15				
V26088004 (10)		-18.03	291.67	Thaumasia Planum	10	324.95	63.6	39	16	280	17.27	56	17				
V39166005 (11)		33.17	226.59	Olympus Park	5.1	95.375	68.25	40	8	150	18.701	30	-10				
V39166005 (12)		33.17	226.59	Olympus Park	3	56.103	68.25	20	5.1	100	18.701	20	0				
V27265033 (13)	29	5.556	150.28	Elysium Planitia	21	374.28	72.96	114.7147	34.1	607.76	17.823	121.5	6.78				
V27877007 (1)	29	27.084	129.622	Libya Planitia	9	167.94	72.11121	54.20686	16	298.56	18.66	59.712	5.505141211	NA	no	N/A	N/A
V27699029 (2)	29	14.164	230.685	Olympus Mons	12	218.244	74.16306	61.90883	66	1200.342	18.187	240.0684	178.1595711	NA	no	N/A	N/A
V27699029 (3)	29	14.164	230.685	Olympus Mons	6	109.122	74.16306	30.95441	34	618.358	18.187	123.6716	92.71718553	NA	no	N/A	N/A
V27877007 (4)	29	22.456	136.581	Libya Planitia	36	661.536	73.1895	199.8618	70.5	1295.508	18.376	259.1016	59.23981499	NA	no	N/A	N/A
V35637004 (5)	30	-14.43	175.286	Amazonia Planitia	12	213.564	56.091232	143.5565	51	907.647	17.797	181.5294	37.97290364	NA	no	N/A	N/A
V26479022 (6)	28	27.539	149.107	Amenthes Mons	15	277.455	72.39311	88.05063	28	517.916	18.497	103.5832	15.53256591	NA	no	N/A	N/A
V36527003 (1)	30	-25.14	60.016	Sirtis Major Area	7	241.58	73.07688	40	10	350	34.504	70	30				
V42703001 (2)	30	-9.7	92.8	Sirtis Major Area	15	265.5	43.14	61	30.5	350	17.7	70	9				
V36540005(3)	30	-36.49	43.265	Terra	2.2	75.4622	79.639	19	4.1	540	34.301	108	89				
V31181001 (4)	29	-6.271	227.6	Tharsis Region	3	106.146	80.246	18.246848	5.5	190	35.382	38	19.75315209				
V401002010 (5)	30	5.021	291.12	Tharsis Region	5.1	91.035	68.83	12	10	180	17.85	36	24				
V401002010 (6)	30	5.021	291.12	Tharsis Region	7.1	126.735	68.83	130	14.5	260	17.85	52	-78				
V401002010 (7)	30	5.021	291.12	Tharsis Region	19	339.15	68.83	131.3	34	610	17.85	122	-9.3				
V3659006 (8)	30	-26.758	229.3043	Tharsis Region	10.5	273.008	74.022	100	15.5	530	34.4	106	6				
V26101003 (9)	28	-23.355	275.906	Solis Planum	3	51.3	63.486	13	7	140	17.1	28	15				
V26088004 (10)	28	-18.032	291.67	Thaumasia Planum	10	324.95	63.6	39	16	280	17.27	56	17				
V39166005 (11)	30	33.17	226.59	Olympus Park	5.1	95.375	68.25	40	8	150	18.701	30	-10				
V39166005 (12)	30	33.17	226.59	Olympus Park	3	56.103	68.25	20	5.1	100	18.701	20	0				
V27265033 (13)	29	5.556	150.28	Elysium Planitia	21	374.28	72.96	114.71466	34.1	607.76	17.823	121.5	6.78				
V28700011 (1)	2008	23.27 N	154.56 E	Amazonis Planitia	59	1106.486	74.42651	308.38465	89.1	1670.9814	18.754	334.19628	25.81163281				
V29274011 (2)	2008	31.18N	154.28 E	Elysium Mons	47	881.25	72.55884	269.87	75.7	1419.375	18.75	283.875	14.005				
V39265012 (3)	M29	.7232S	245.611E	Tharsis Montes	35	619.08	80.02804	108.84814	65.5	1139.45	17.688	227.89	119.0418574				
V39562005 (4)	M30	41.57N	323.77E	Acidalia Planitia	20	378.6	75.79	95.87084	55	1027.2	18.93	205.44	109.5691599				
V37645006 (5)	M30	31.34N	268.11E	Amazonis Planitia	27	495.369	57.504277	208.17	64	1174.208	18.347	234.8416	170.8416				
V27286025 (6)	M30	29.36N	267.91E	Tempe Terra	26	481.13	71.51386	103.68	46	846.745	18.505	169.349	123.349				
V26788020 (7)	M30	27.08E	234.72E	Olympus Mons	41	764.281	71.76825	251.75219	77	1435.357	18.641	287.0714	35.31920514				
V35136007 (8)	M30	19.79N	201.32E	Amazonis Planitia	35	681.31	67.027084	288.81893	78	1388.824	18.274	277.7648	11.05412647				
V35434014 (9)	M30	16.66N	245.31E	Tharsis Montes	6.1	219.92	48.071648	104.26	12	432.648	36.054	86.5296	191.2352				
V27836001 (10)	M29	1.9916S	264.95E	Valles Marineres	24.1	848.657	79.33149	159.87	38.6	1410.79	35.214	282.158	122.288				
V27836001 (11)	M30	1.9916S	264.95E	Valles Marineres	32.8	1155.0192	79.33149	217.5857	47.8	1635.67	35.214	327.134	109.5483				
V36363004	2006	-29.54	110.38		6	207.588	73.95765	59.69099	25	864.95	34.598	5	-54.69099053	NA	none	good	NA
V36363004	2006	-29.54	110.38		8	276.784	73.95765	79.58799	40	1383.92	34.598	8	-71.58798737	NA	none	good	NA
V36363004	2006	-29.54	110.38		17	588.166	73.95765	169.1245	60	2075.88	34.598	12	-157.1244732	NA	none	good	NA
V27105008	2005	-21.44	111.36		36	619.848	76.05586	153.9037	71	1222.478	17.218	14.2	-139.7037376	NA	none	good	NA
V27105008	2005	-21.44	111.36		49	843.682	76.05586	209.4801	71	1222.478	17.218	14.2	-195.2800873	NA	none	good	NA
V27105008	2005	-21.44	111.36		22	378.796	76.05586	94.05228	64	1101.952	17.218	12.8	-81.25228408	NA	none	good	NA
V27105008	2005	-21.44	111.36		69	1188.042	76.05586	294.9822	105	1807.89	17.218	21	-273.9821637	NA	none	good	NA
V27105008	2005	-21.44	111.36		30	516.54	76.05586	128.2531	55	946.99	17.218	11	-117.2531147	NA	none	good	NA
V27105008	2005	-21.44	111.36		95	1635.71	76.05586	406.1349	203	3495.254	17.218	40.6	-365.5348631	NA	none	good	NA
V27105008	2005	-21.44	111.36		38	654.284	76.05586	162.4539	70	1205.26	17.218	14	-148.4539452	NA	none	good	NA
V18557003	2004	-9.48	99.74	Terra Tyrrhena	16.2	284.1804	68.54208	111.7006	44.5	780.619	17.542	8.9	-102.8006094	NA	none	good	NA
V18557003	2004	-9.48	99.74	Terra Tyrrhena	20.9	366.6278	68.54208	144.1076	64.5	1131.459	17.542	12.9	-131.2075764	NA	none	good	NA
V18557003	2004	-9.48	99.74	Terra Tyrrhena	14.3	250.8506	68.54208	98.59992	61.5	1078.833	17.542	12.3	-86.29992067	NA	none	good	NA
V18557003	2004	-9.48	99.74	Terra Tyrrhena	7.2	126.3024	68.54208	49.64472	36.5	640.283	17.542	7.3	-42.3447153	NA	none	good	NA
V18557003	2004	-9.48	99.74	Terra Tyrrhena	16.5	289.443	68.54208	113.7691	46.5	815.703	17.542	9.3	-104.4691392	NA	none	good	NA
V27633033	2005	27.83	336.68		83.5	1561.784	71.85041	511.9663	130.5	2440.872	18.704	26.1	-485.8662657	NA	none	good	NA
V27633033	2005	27.83	336.68		97.1	1791.3979	71.85041	587.2357	173.5	3200.9015	18.449	34.7	-552.5356825	NA	none	good	NA
V27296031-1	5	6.5N	333E		8.2	149.06	71.2	50.74416	15.1	274.5	18.2	54.9	4.155836818	NA	No	Round	
V31401009	4	3.6N	330.5E		9.1	327.29	81.1674	50.85787	16	570.2	36	114.04	63.18213076	NA	Yes	Round	
I32514013	4	15.6S	246.0E		27.7	697.46	67.82001	284.344	48	1208.6	25.2	241.72	-42.62404717	NA	No	Round	
V27296031-2	5	17.7N	337.2E	Olympus Mons	113.2	2057.75	71.2	700.5152	243.3	4428.06	18.2	885.612	185.0967592	NA	Yes	Round	
V27296031-3	4	17.7N	337.2E		40.5	736.21	71.2	250.6263	80.9	1470.6	18.2	294.12	43.49367251	NA	Yes	Round	
V28700011 (1)	2008	23.27 N	154.56 E		59	1106.486	74.42651	308.3846	89.1	1670.9814	18.754	334.19628	25.81163281	NA	none	clear/ mostly u	NA
V29274011 (2)	2008	31.18N	154.28 E		47	881.25	72.55884	276.8624	75.7	1419.375	18.75	283.875	7.012590981	NA	none	clear/ mostly u	NA
V29664005	2008	58.6 N	68.3 E		50	972.45	71.272964	329.6677	102.2	1987.6878	19.449	397.53756	67.86987351	NA	none	clear/ mostly u	NA
V38758008	2010	14.3 N	114.4E		17	617.032	63.776886	303.9266	35.3	1281.2488	36.296	256.24976	-47.67687561	NA	none	clear/ mostly u	NA
V27104034	2008	14.0 N	116.2 E	"Elysium Planitia"	36	648.684	71.30736	219.4746	150.5	2711.8595	18.019	542.3719	322.8973499	NA	none	clear/ mostly u	NA
V36157001	30	-9.73	295.91		13.9	968.691	61.86	518.102	34.1	2376.429	69.69	475.2858	-42.81642999				
V36157001	30	-9.73	295.91		11.4	794.466	61.86	424.918	15.2	1059.288	69.69	211.8576	-213.0607757				
V36157001	30	-9.73	295.95		5.7	397.233	61.86	212.459	14	975.66	69.69	195.132	-17.32718784				
V26810012	29	31.00	320.42		4.2	157.92	72.36	50.2165	7	263.2	37.60	52.64	2.423455217				
V30566012	29	29.25	313.57		3.6	133.92	81.71	19.5129	6	223.2	37.20	44.64	25.12705512				
V30566012	29	29.25	313.57		3.6	133.92	81.71	19.5129	7	260.4	37.20	52.08	32.56705512				
V38414009	30	26.56	320.68		4.1	76.055	60.50	43.0298	9.8	181.79	18.55	36.358	-6.671848645				
V38414009	30	26.56	320.68		9.4	174.37	60.50	98.6538	15	278.25	18.55	55.65	-43.00379933				
V28956007	29	26.38	328.06		5	92.15	74.82	25.0021	10.5	193.515	18.43	38.703	13.70093672				
V28956007	29	26.38	328.06		3.6	66.348	74.82	18.0015	7.1	130.853	18.43	26.1706	8.169114435				
V31264011	29	20.36	326.42		3.6	132.84	83.62	14.8534	9	332.1	36.90	66.42	51.56655807				
V35893016	30	19.13	326.88		9.4	171.738	52.14	133.502	17.5	319.725	18.27	63.945	-69.55693383				
V27471028	29	18.79	329.02		2.8	51.408	72.45	16.2582	6.5	119.34	18.36	23.868	7.609784456				
V27471028	29	18.79	329.02		1.4	25.704	72.45	8.12911	4.1	75.276	18.36	15.0552	6.926092228				
V27471028	29	18.79	329.02		3	55.08	72.45	17.4195	8.1	148.716	18.36	29.7432	12.32368335				
V27783021	29	18.50	327.88		7.1	130.214	73.65	38.2006	13.5	247.59	18.34	49.518	11.31738028				
V27284029	29	18.16	323.85		7.2	130.896	71.83	42.9605	11	199.98	18.18	39.996	-2.964482387				
V27284029	29	18.16	323.85		4	72.72	71.83	23.8669	8.5	154.53	18.18	30.906	7.039065341				
V27284029	29	18.16	323.85		3.2	58.176	71.83	19.0935	6	109.08	18.18	21.816	2.722452273				
V27284029	29	18.16	323.85		4.1	74.538	71.83	24.4636	9	163.62	18.18	32.724	8.260391974				
V38988048	30	16.97	319.41		3.6	65.736	65.08	30.5415	7.5	136.95	18.26	27.39	-3.151530139				
V35419011	30	28.38	319.35		5	99.8	49.95	83.8907	12	239.52	19.96	47.904	-35.98666431				
V35893016 (1)	5	19	327	Chryse Planitia		657.72	52.137894	511.32		1388.52	18.27	277.704	-233.616				
V37855005 (2)	5	-17.31	270.43	Valles Mosaic		692.8	72.988205	211.97		1299	17.32	259.8	47.83				
V37855005 (3)	5	-17.31	270.43	Valles Mosaic		467.64	72.988205	143.1		1247	17.32	249.4	106.3				
V37855005 (4)	5	-17.31	270.43	Valles Mosaic		311.76	72.988205	95.38		831.36	17.32	166.272	70.892				
V40024013 (5)	5	22.66	312.22	Chryse Planitia		1142.66	74.45318	317.89		1874.76	18.43	374.952	57.062				
V42286083 (6)	5	-9.08	241.08	Arsis Mons		216	43.51228	227.52		612	17.76	122.4	-105.12				
V36020019 (7)	5	13.82	262.57	Tharsis Mons		180	53.205364	134.63		360	17.99	72	-62.63				
V22929010	2007	9.8	316	Terra	15	539.1	87.94112	19.37941	40	1437.5	35.938	287.504	268.1245899				
V13832013	2005	15.3	296.6	Temple Terra	47	1690.6	81.47538	253.4031	62.35	2242.7	35.97	448.5459	195.1428116				
V13832013	2005	15	296	Temple Terra	11	395.7	81.47538	59.30711	15.55	559.3	35.97	111.8667	52.55959421				
V13832013	2005	15.4	295.8	Temple Terra	9.8	352.5	81.47538	52.83724	14.45	519.8	35.97	103.9533	51.1160603				
V13832013	2005	15.6	295.8	Temple Terra	10	359.7	81.47538	53.91555	15	539.6	35.97	107.91	53.99444928				
V20395002	2005	40.4	341.3	Chryse Planitia	7	132.1	81.82567	18.97506	20	377.4	18.871	75.484	56.50893947				
V20395002	2005	36.4	338.3	Chryse Planitia	15.3	288.7	81.82567	41.47406	31	585.0	18.871	117.0002	75.52613912				
V29213009	2008	30.2	114.1	Acidalia Planitia	145.1	2708.0	74.61447	745.1721	219	4087.2	18.663	817.4394	72.26730978				
V29213009	2008	29.7	114.3	Acidalia Planitia	28.6	533.8	74.61447	146.8775	43.55	812.8	18.663	162.55473	15.67725391				
V20047005	2006	16.6	293.5	Temple Terra	28	1006.0	73.305626	301.702	47.5	1706.6	35.928	341.316	39.61400382				
V20047005	2006	15	292.1	Temple Terra	14	503.0	73.305626	150.851	22.5	808.4	35.928	161.676	10.82500191				
V20047005	2006	13	293.1	Temple Terra	33	1185.6	73.305626	355.5774	53	1904.2	35.928	380.8368	25.25944735				

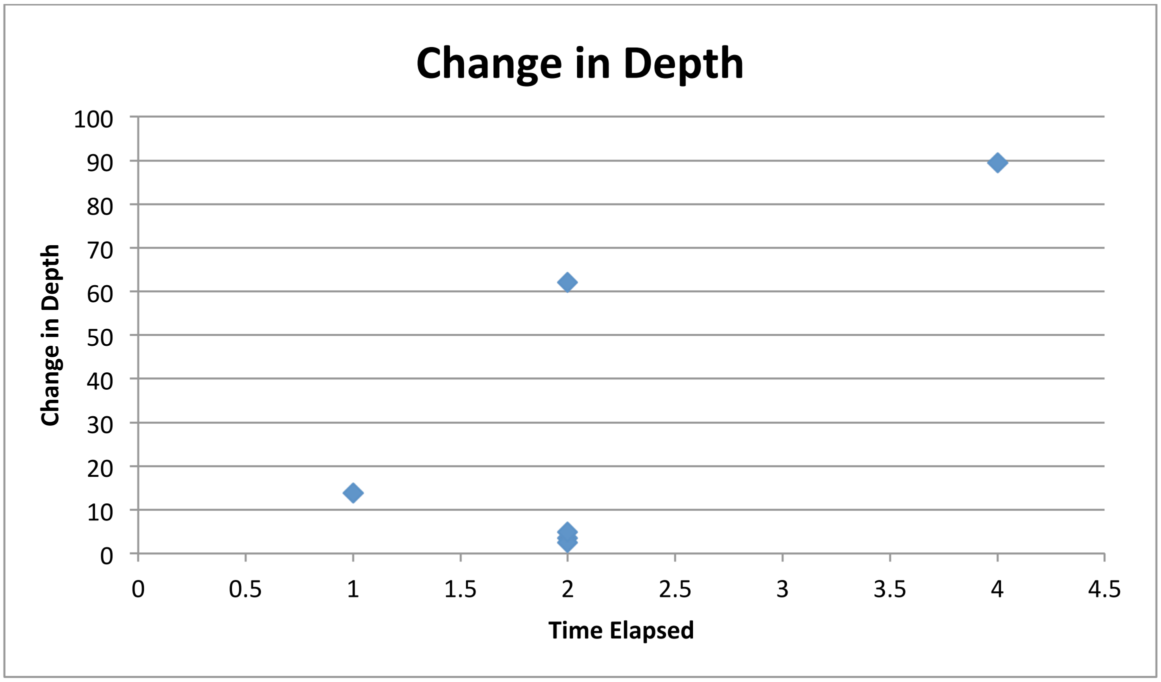
In order to better understand the data we collected, the following are some of the graphs generated by subsets of the above data:



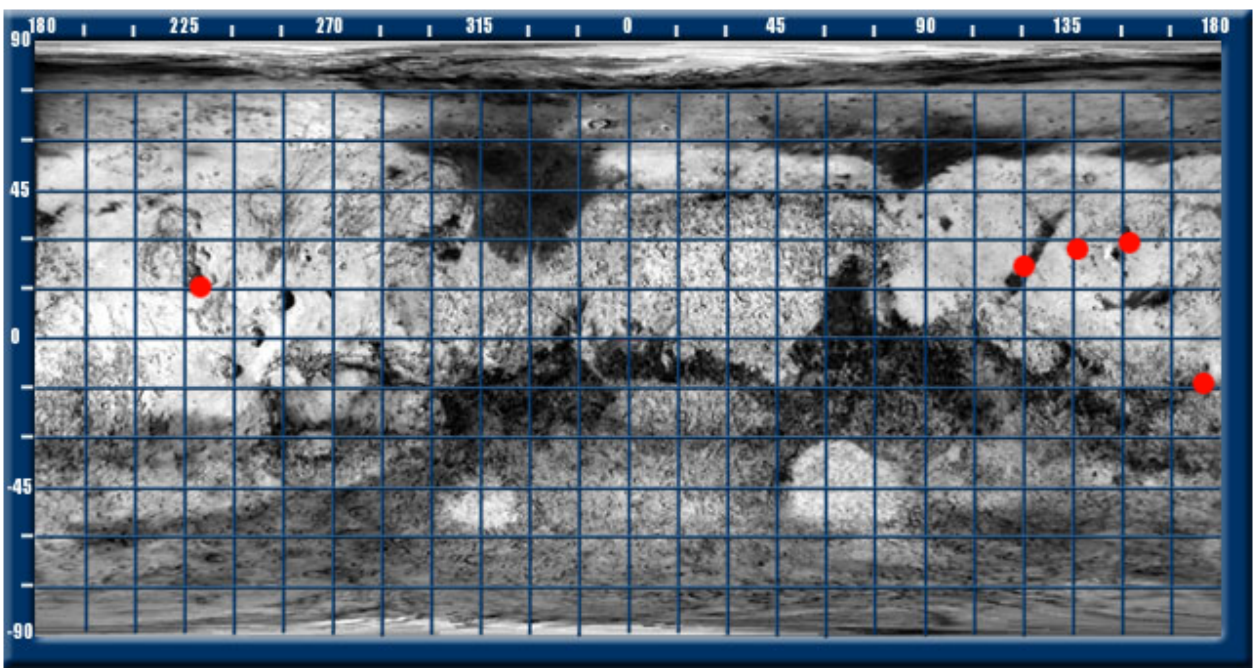
Data Compiled by William and Cole



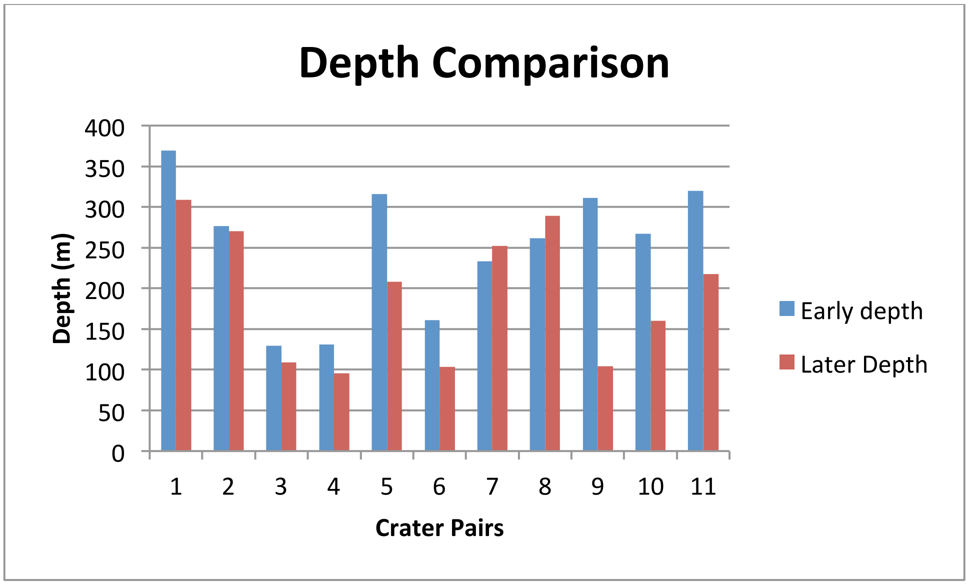
Data Compiled by Ryan and Dagen



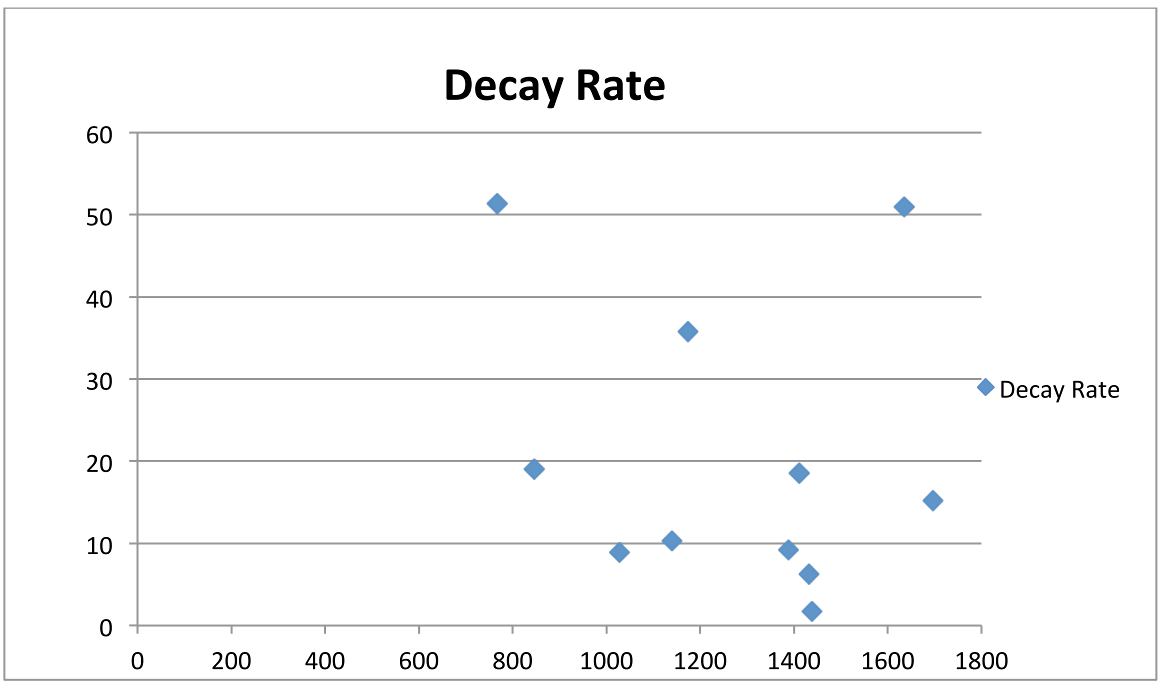
Compiled by Ryan and Dagen



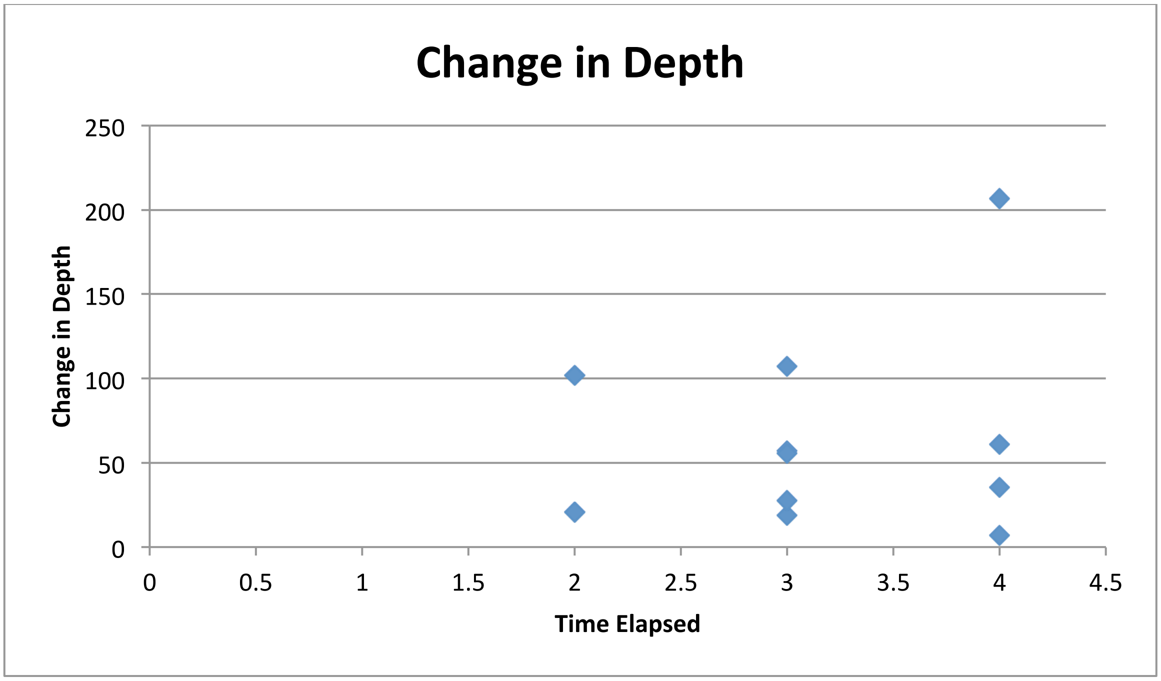
Shows locations on Mars of craters measured by Ryan and Dagen



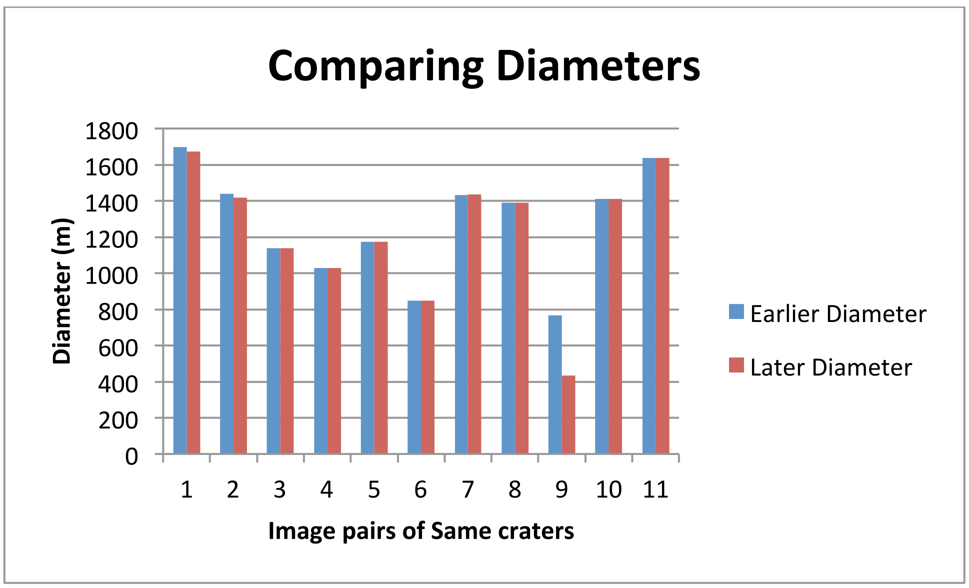
Data Compiled by Athen and Patrick



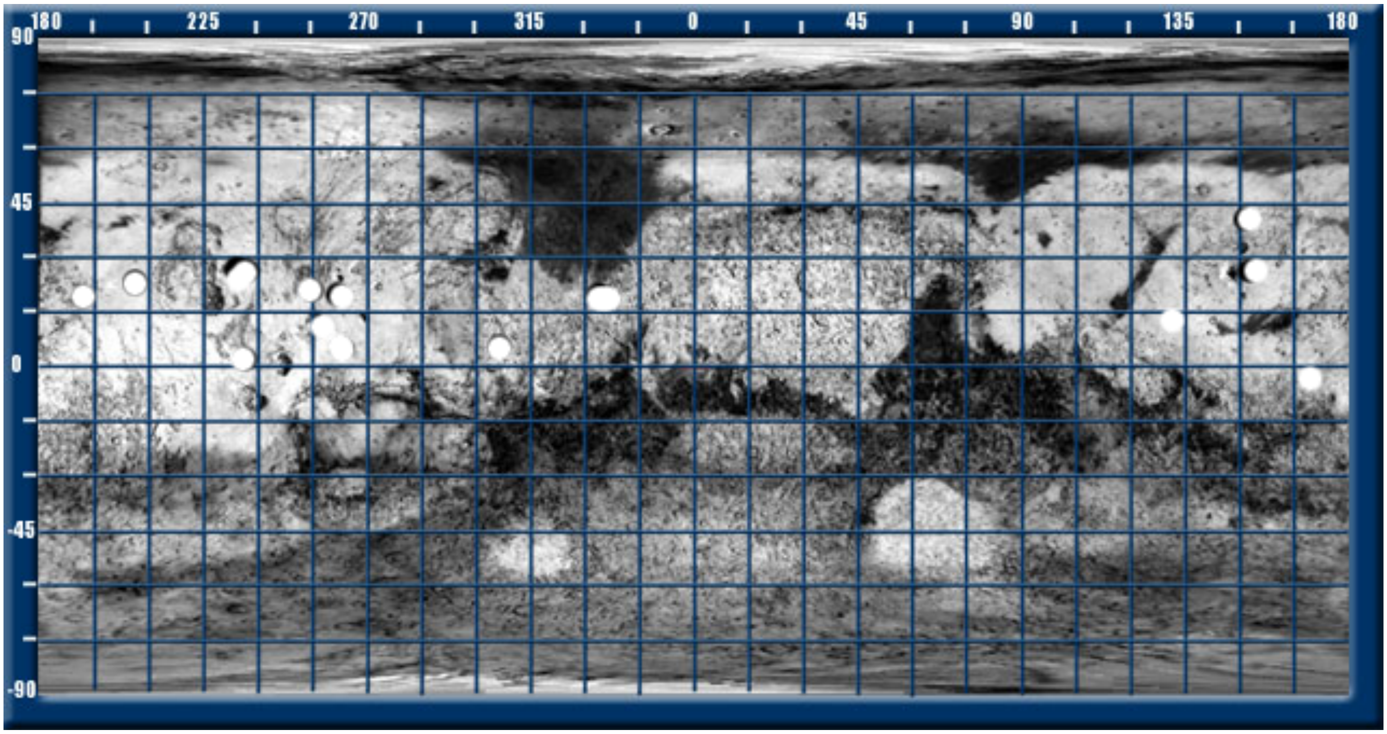
Compiled by Athen and Patrick



Compiled by Athen and Patrick

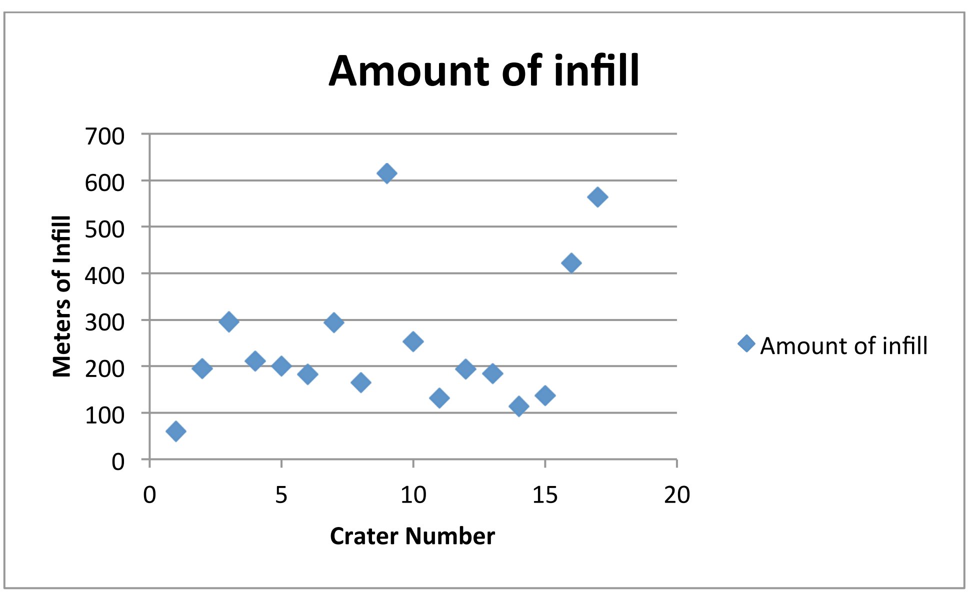


Compiled from Athen and Patrick Data



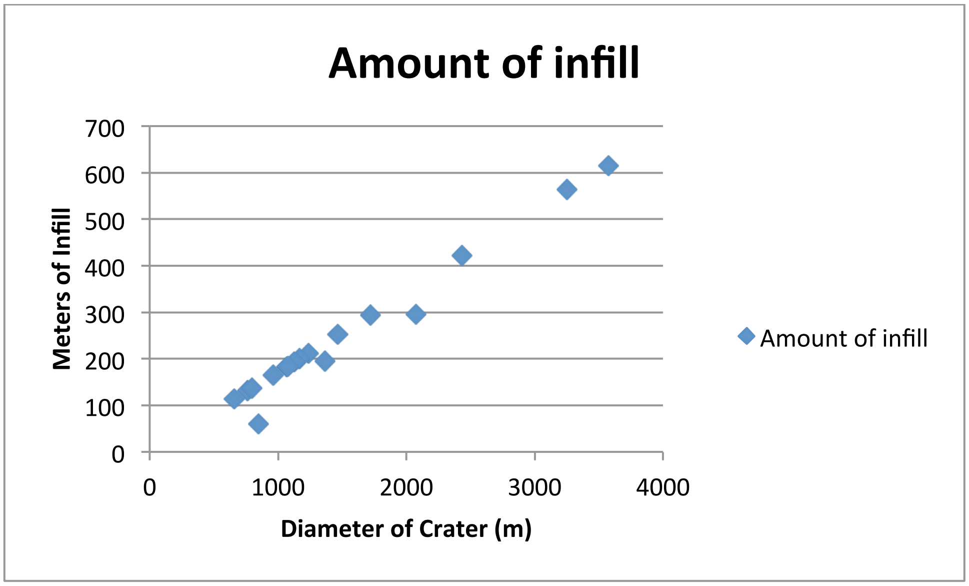
White dots are locations of craters analyzed by Athen and Patrick

After quite a bit of time analyzing craters and their possible decay rates, we were also intrigued to look at the amount of infill the craters had accumulated. The original depth of the craters can be calculated by using the formula: Diam X 0.2. (Manfredi 1) This allowed us to calculate the amount of material that has accumulated in the craters. An example of this is:



Data collected by Eric and Josh

A plot of the amount of infill of a crater as a function of diameter:



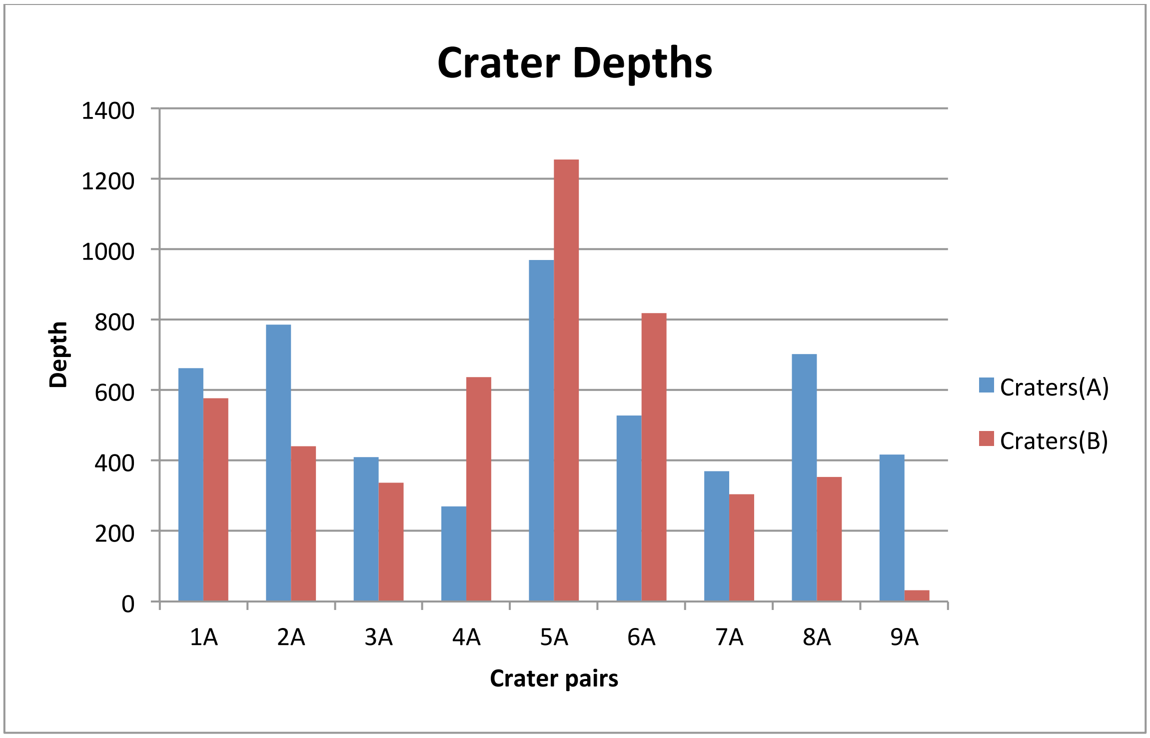
Data collected by Eric and Josh

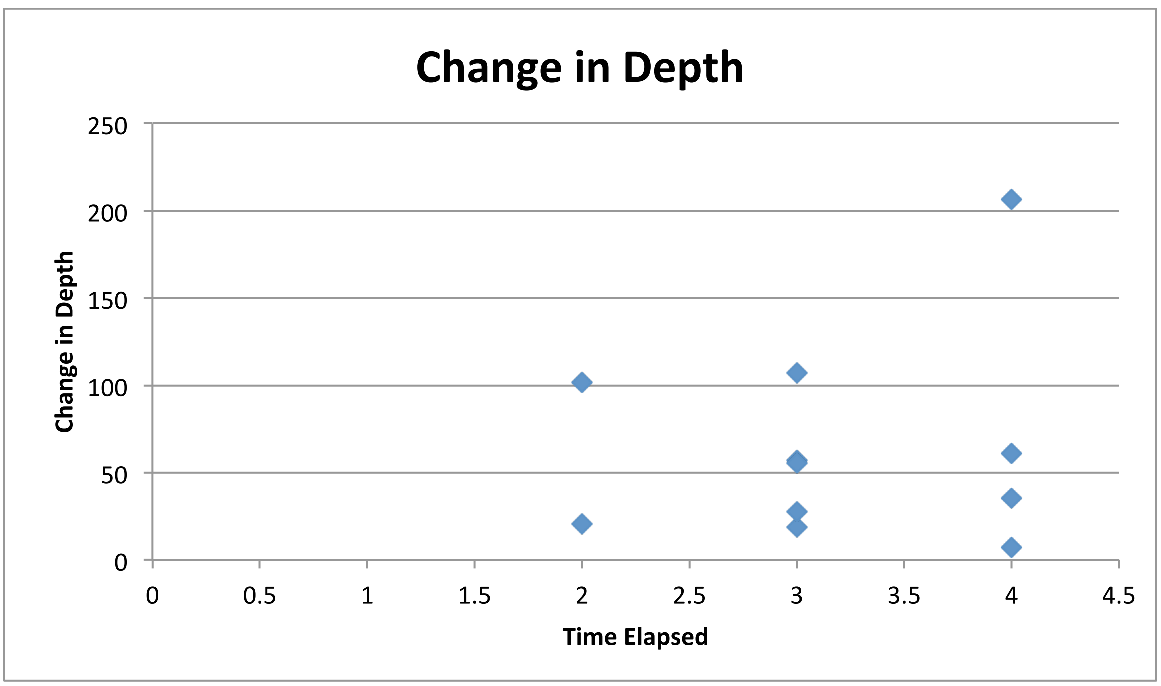
V. Discussion

Our data shows that a rate of decay is not as simple to calculate from THEMIS images as we had hoped. Although we were able to measure quite a number of crater depths, we found such wide variations in the changes to those depths that one begins to question the validity of the data or the methods. The biggest issue is the size of a pixel of data. When using the program gimp to measure the length of the shadow of a crater, even a slight variation of one pixel can generate a difference in depth of 18 to 75 m, depending on the resolution of the image used. The shadows appear in the craters as shades of gray – where one called the shadow to end can have a significant effect on the supposed depth of the crater. The edges of shadows are not the clearest things and lead to a margin of error.

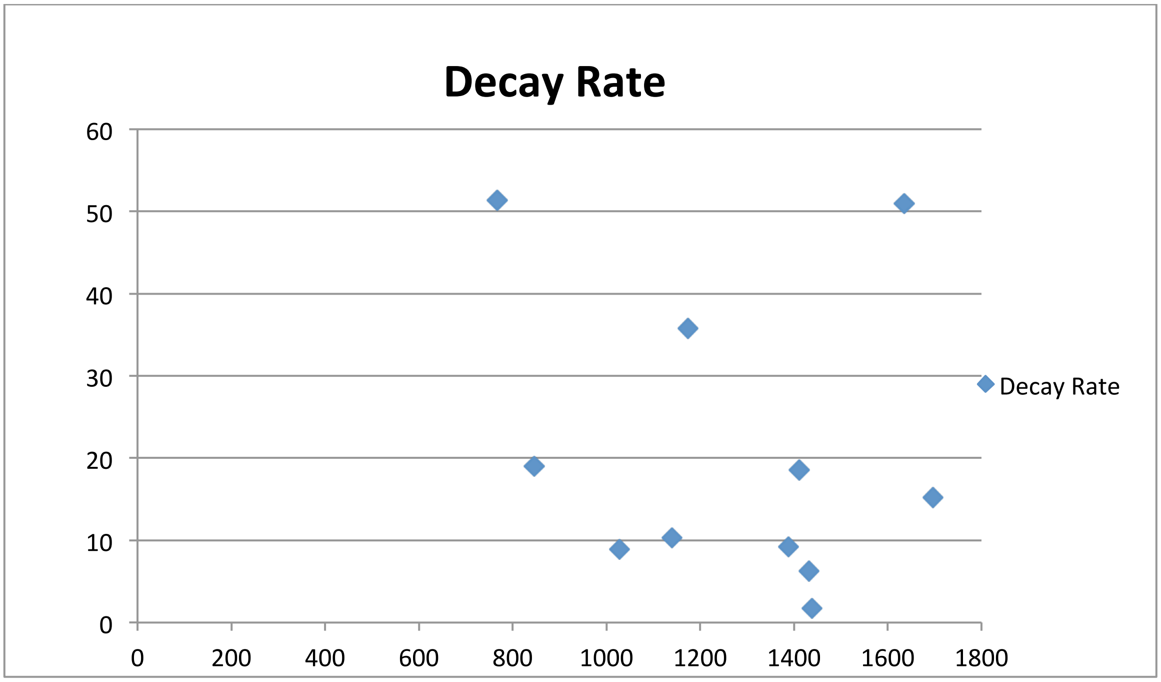
Also, when examining the graphs of crater depths, we found some craters appeared to fill in while other appeared to become deeper. There might be a plausible explanation for the in-filling of a crater over time (our proposal), but for a crater to become deeper makes one wonder. Could a dust storm really remove 250 m of dust in a span of 2 years? Information provided by the research scientists at ASU indicated this would be unlikely (Manfredi,1)

As a typical subset of data, the graph below shows craters 1A, 2A, 3A, 7A, 8A, and 9A getting filled in in the period of time that passed between photos. Yet, craters 4A, 5A and 6A appear to be getting deeper.

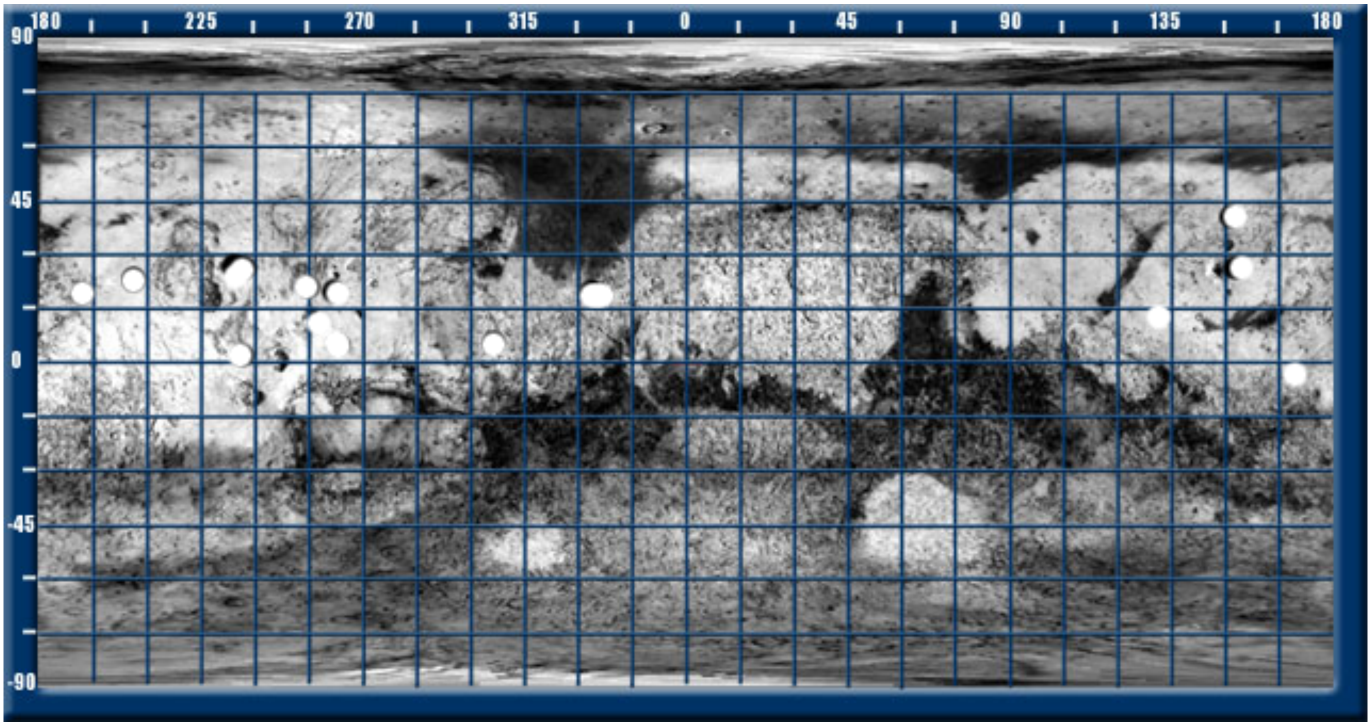




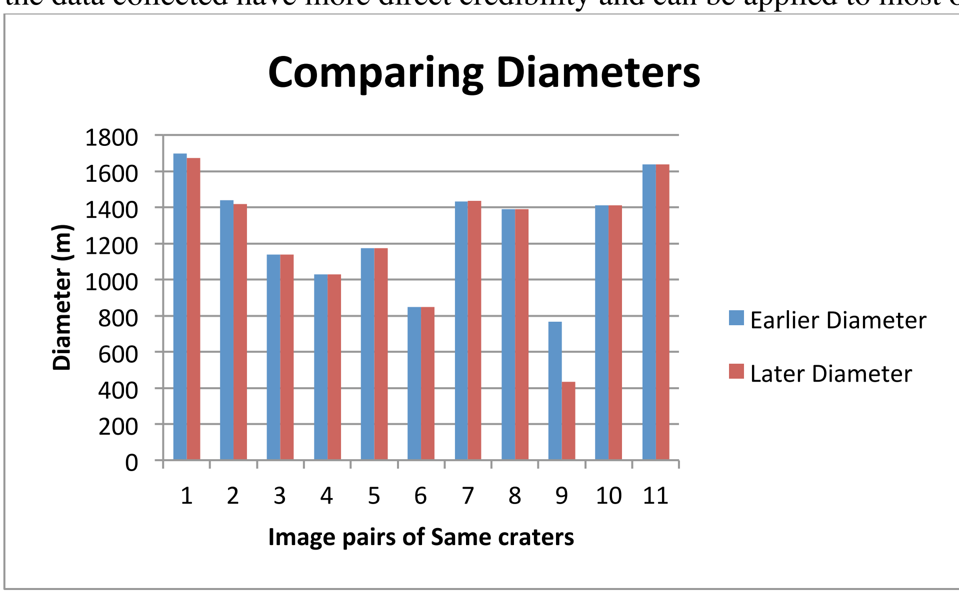
For us to determine a rate of decay we needed to find the change in depth and then divide it by the time elapsed. This graph displays the change in depth of 10 craters over a certain number of Mars years. These values are then used to find the rate of decay by taking Change in depth divided by the number of years elapsed. This type of analysis shows randomness to the depth changes over time. We would expect greater depth changes as more time passes.



This graph shows the decay rate compared to the diameter of the crater. This is important because our question focused on small craters (2 kilometers or less) and we can see how that value varies with size of the crater. It could be interpreted that smaller diameters have a higher rate of decay. But because of the randomness, an average rate of decay for small craters cannot be determined.

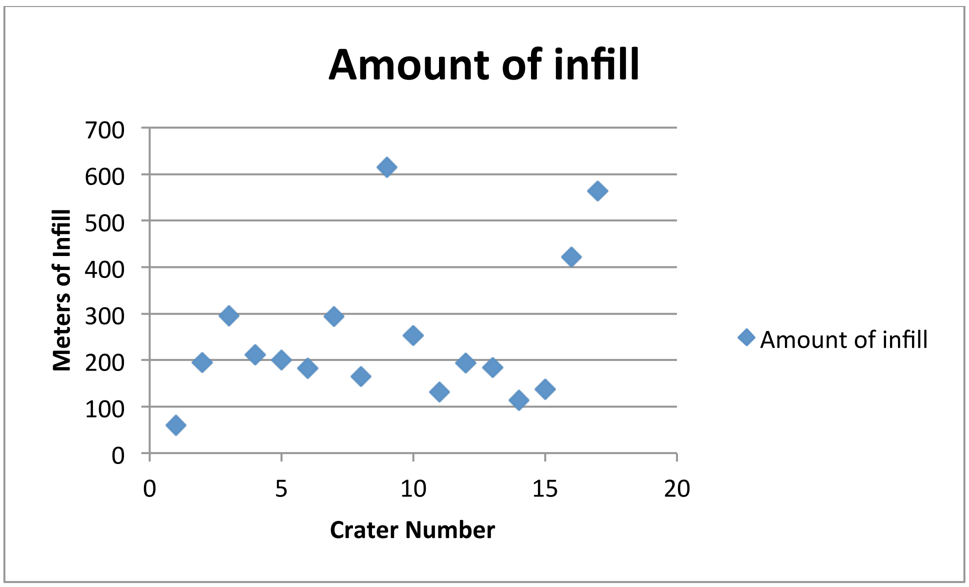


The importance of displaying our data on a geographic map of Mars is that it helps visualize where our data is located. Because part of our original question was to focus on specific regions on Mars we can see perhaps some trends for each specific region. Since our data comes from more parts of the planet it makes the data collected have more direct credibility and can be applied to most of the surface.

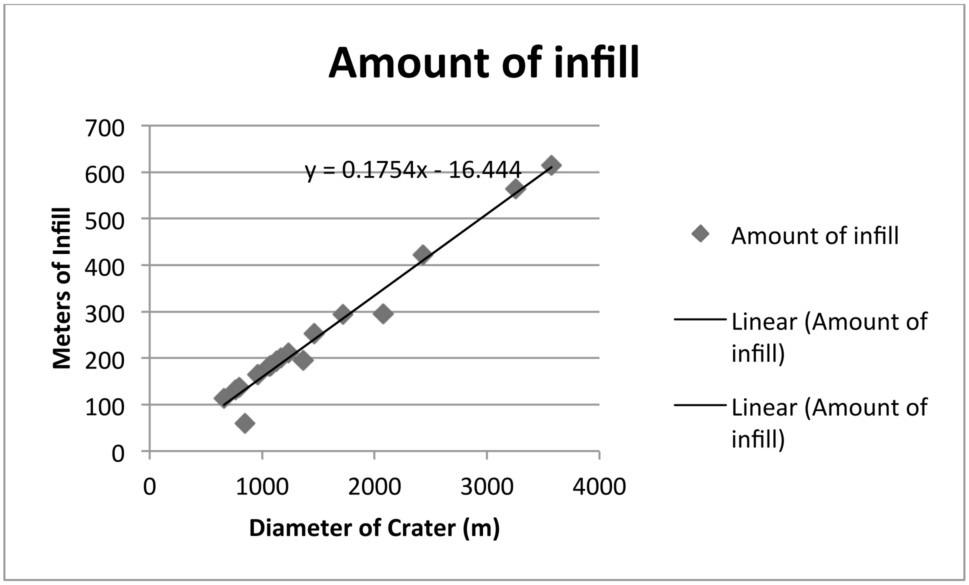


This graph was done as a type of control. Since we were concerned about measurement errors, we thought comparing diameters, which were measured from two difference images of the same craters, would give a bit of an indication of consistency in measurement. This data set does indicate that most of our measurements of crater's diameters are fairly close, with one exception (set 9). The differences between diameters for all except pair nine seem to be within tens of meters, and could be due to different sun angles for the two images. The fact that our diameter measurements were fairly consistent of the same crater over a period of years does seem to suggest we are able to use the gimp program effectively, and suggests that our measurements of the depths of these craters are not in error because of our understanding of the gimp program.

The original depth of the craters can be calculated by using the formula: Diam X 0.2. (Manfredi 1) This allowed us to calculate the amount of material that has accumulated in the craters. An example of this is:



When the infill is plotted as a function of crater diameter, a nice linear relationship is demonstrated reflecting the formula y = 0.1754 x – 16.44. We calculated the original depth from the formula 0.2 x diameter. We then measured the current depth from shadows on THEMIS images, this data, allowing us to determine the amount of infill. The trend –line shows a consistent rate of infill for craters ranging in size from 800 m to 3600 m.



There are many potential errors that could have been made. The first being that when we measured the pixels being off by just one pixel could hugely alter our data (18 to 75 m). Second, determining where the edge of a shadow ends to calculate depths of the craters was subjective. There could also be errors with the calculations by mis-entering a number in a calculator or recording the wrong answer.

VI. Conclusions

Our science question was, can the rate of degradation be determined in small preserved craters on the Martian surface? From our research it can be seen that a rate of degradation can be determined in some small preserved craters. However there does not seem to be any pattern in the rate of decay. As discussed earlier, there is room for many errors so that also must be taken into account here. One hypothesis we had was that the preserved craters would decay faster in the plains regions than in the Polar Regions. We also thought that the craters would decay faster in the Northern Hemisphere because it is windier there. Unfortunately, since throughout our research we discarded looking at specific regions, our hypotheses cannot be supported or disproven. In order to further our research, a number of thing could be done. It seems the best way to determine how much a crater fills in over time might be to send small devices specifically to Mars to measure dust infilling small preserved craters. A rain-gauge type of device that would be able to use light to measure the depth of the collected dust would seem feasible. Without dust-gauge devices, this question could use further researched with HiRise or CTX- high resolution satellite images on Mars. The higher resolution images would significantly lower the margin of error generated by camera resolution and shadow definition. Continued research could easily benefit further rover missions, helping them avoid potentially disastrous dust storms; landing missions, giving us an idea of where the best sites would be; and give us a general idea of Martian weather, so we could better prepare our equipment to survive exposure.

Regarding subsequent findings, we did see that craters show a consistent rate of in-filling over time and that larger craters have become more filled in than smaller craters.

We need to give a special thanks to Mrs. Miller for making this project possible! Without her, we wouldn't have been able to learn or experience any of this. Many people have contributed to helping with our project. We thank Mr. Clouse and Mrs. Green for taking time out of their schedules to travel with us to Arizona and be sponsors. We thank ASU staff, especially Mr. Leon Manfredi and all workers with the Mars Student Imaging Project for allowing us to participate in the program and working with us to answer our question. We also thank supporters of our trips for their donations so that we could go to ASU: Leggett and Platt, Tri-State Engineering, Joplin Greenhouse, McAllister's, and, of course, our parents. And of course, none of this would be possible without NASA, the ASU Mars Education Program, the Mars Odyssey spacecraft or the THEMIS camera. We also give thanks to the Lord God for giving us curious minds with which to explore the vast Universe He created.

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