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Phobos: Close Encounter Imaging From the Viking Orbiters

Thomas C. Duxbury,
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and Adriana C. Ocampo

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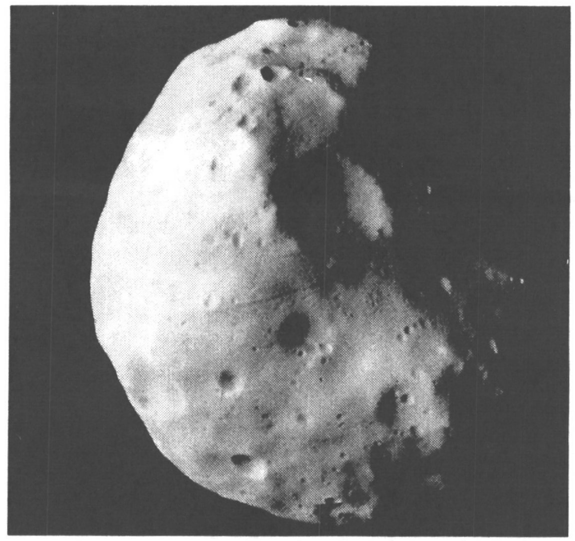
Phobos: Close Encounter Imaging From the Viking Orbiters



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Pasadena, California

NASA
National Aeronautics
and Space Administration
Scientific and Technical
Information Branch

1984

FOREWORD

The Viking plan to explore Mars was extremely bold in concept and amazingly successful in execution. Two spacecraft, launched at different times and placed in different orbits, delivered a soft lander, each, to the surface and then continued to encircle the planet, acquiring and relaying to Earth vast quantities of photographic and other information. The target of this exploration was the world of Mars, but its two small moons, Phobos and Deimos, were also photographed. Thus, some 100 years after their discovery by Asaph Hall (1877), characteristics of the surfaces of these tiny worlds were revealed for all to see.

Phobos, the larger and innermost of these two irregular moons is the subject of this volume. The shape and orbital characteristics of Phobos are discussed and illustrated, but the real treasure of the book is the host of close-up photographs. As you examine them, it will become obvious that the wealth of information provided by Viking is just the beginning of our quest. There is much to do to understand the dramatic events of Mars' history, including how and where Phobos formed and how its surface was shaped. This volume can help us in this quest by making available an organized set of information that includes the best photographs of Phobos ever obtained.

Geoffrey A. Briggs
Director
Solar System Exploration Division
OSSA

December 1983

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ACKNOWLEDGEMENTS

Late on a Saturday evening in February of 1977, a group of scientists were anxiously awaiting the return of data obtained from the first close encounter of Phobos by Viking Orbiter-1 (VO-1). As the initial data came in it became evident that Phobos was less massive than predicted and that the change in the orbit of VO-1 was two seconds different than predicted. This two second difference made all of the remaining commands which were stored on VO-1 for additional close encounter Phobos pictures incorrect. Project management and the Flight Team immediately responded to the possible loss of hundreds of high resolution pictures. By Sunday afternoon, all close encounter sequences were recalculated and transmitted to VO-1. Only a few pictures were lost on that Sunday before the new commands were sent. This book is a testimony to the responsiveness and dedication of the Viking Management and Flight Operations Team without which these pictures could not have been taken.

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Orbiter Scientist
C. W. Synder

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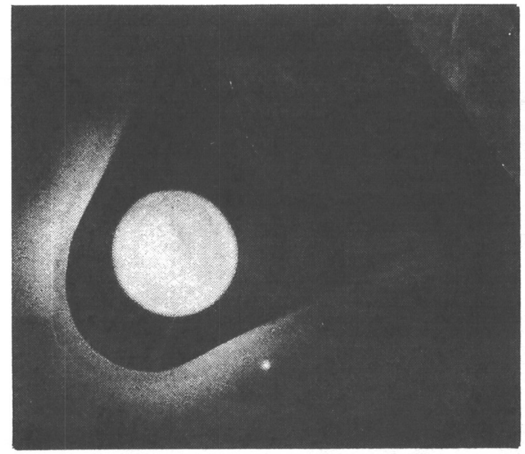
INTRODUCTION

In 1877, Asaph Hall of the U.S. Naval Observatory set out to discover two moons of Mars. The Earth had one moon and at that time Jupiter was thought to have 4 moons (the Galilean satellites); therefore, following a mathematical progression Mars should have two moons. Indeed, in 1877 Asaph Hall did discover two moons, Phobos and Deimos. It seems fitting that in 1977 the Viking Orbiters performed the most exhausting exploration of these two Martian moons as part of the centennial commemoration of their discovery. Viking Orbiter-1 had three close encounters with Phobos while Viking Orbiter-2 had one close encounter with Deimos in 1977. This book presents the high resolution pictures of Phobos that were obtained during these close flybys.

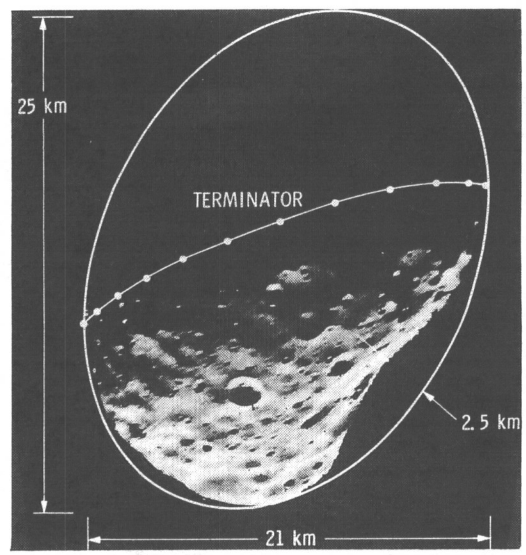
Prior to the close encounters, significant information on Phobos had been accrued from Earth-based, Mariner 9 and Viking. The orbit of Phobos is nearly circular and inclined about one deg to the Mars equatorial plane. Phobos orbits Mars in 7 hours and 39 minutes. Since a day on Mars is 24 hours and 40 minutes, Phobos would rise in the west and set in the east (opposite of our Moon) three times within a Martian day. With a mean radius of 11.1 km and an orbital radius of 9377 km (~ 2.8 Mars radius), Phobos would appear slightly smaller than the Sun when viewed from the surface of Mars.

The general shape of Phobos is somewhat ellipsoidal with the longest axis pointing toward Mars maintaining a synchronous rotation as our Moon. Topographic variation from an ellipsoidal surface are as large as 20% of the local radius. Depressions and elevations of 1 or 2 km are common on the surface of Phobos. The surface is covered with a fine grained material (regolith) uniformly grey in color. The reflectivity is similar to Carbonaceous Chondritic material of Type I Asteroids which suggests the possibility that Phobos may be a captured asteroid.

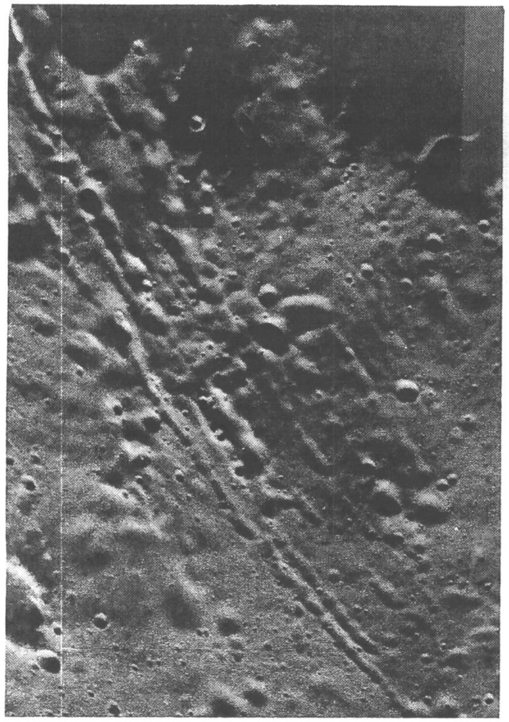
The high resolution pictures from the close encounters gave rise to new discoveries on the surface of Phobos as well as a refinement to the lower resolution Mariner 9 and Viking data. Linear grooves, apparently fractures, cover a significant portion of the surface of Phobos. These grooves radiate from the large crater Stickney and from the antipodal point of Stickney. The



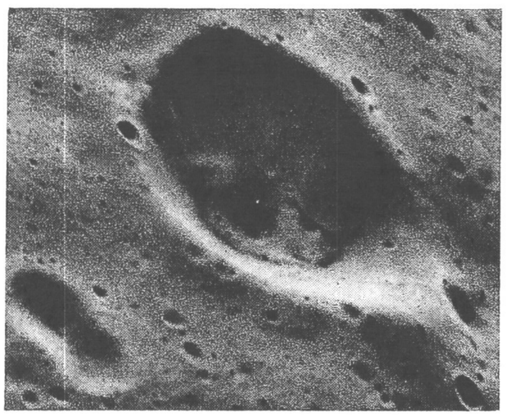
Earth-based photograph of Mars, Phobos and Deimos by D. Pascu (U.S. Naval Observatory) from the same telescope used by Asaph Hall



Phobos is somewhat ellipsoidal in shape but has large topographic variations



Long, linear grooves dominate the surface of Phobos



Large, flat-bottomed craters give evidence of a thick regolith, pool melting and wall slumping

grooves are up to 10 km long, a few hundred meters across and tens of meters deep.

Large, flatbottomed craters indicate that the surface of Phobos is covered with a regolith up to a few hundred meters thick. Wall slumping on some of these large craters gives evidence of the small gravity of Phobos. Dark material lines the bottom of these large craters possibly the result of pool melting during the impact that formed the crater. The regolith is saturated with craters as small as ten meters (our limiting resolution). Halo craters with light ejecta and craters with dark ejecta are very small (tens of meters) and are very sparse. A few hummocks, probably large debris from crater ejecta, about a few hundred meters in size were also found.

The orbit of Phobos has brought it dangerously close to Mars. Phobos is within the Roche Limit where tidal forces from Mars would have torn a more fluid satellite apart. These same tidal forces are accelerating Phobos in its orbit and drawing it even closer. We may not know the origin of this tiny Martian moon, but Phobos is destined to become a ring around Mars during the next 50 million years when these tidal forces tear it apart and Phobos will be no more.

FIRST ENCOUNTER

During the last two weeks of February 1977, Viking Orbiter-1 (VO-1) had multiple close encounters with Phobos. The orbit of VO-1 was inclined about 40 deg to the orbit of Phobos with the encounters occurring at the descending node of the VO-1 orbit on the orbit of Phobos. VO-1 passed through the descending node approximately one hour after Mars periapsis. VO-1 flew by Phobos at 1.8 km/sec passing from the northern to the southern hemisphere. Multiple encounters were achieved by changing the orbital period of VO-1 to 22.95 hours — 3 times the orbital period of Phobos. By phasing the passage of VO-1 through the descending node with the passage of Phobos, the 3 to 1 orbital commensurability gave a close flyby every VO-1 orbit.

Lighting conditions varied little during this two week period since all of the encounters occurred at the same orbital position and since Mars orbital motion about the sun was about 0.5 deg/VO-1 revolution. The sub-solar point was approximately at 11 deg South latitude and 252 deg West longitude. The sun illuminated the trailing side of Phobos, a side not seen well by Mariner 9.

Specific geometries of the flybys are depicted in Figures 1 and 2. Figure 1 shows the Phobos flyby geometry as viewed from the approach to Phobos. The flyby point for each revolution (REV) of VO-1 about Mars, numbered 242A through 252A, is indicated by a circle. The circles completely filled indicate those revolutions on which imaging data were taken. It is seen that all flybys were within 300 km of Phobos and the closest flyby, 89 km, occurred on revolution 243A (Feb 20, 1977).

The ground tracks of VO-1 on Phobos and the imaging coverage are shown in Figure 2 for each revolution on which data were taken. The large white area was illuminated by the Sun. The sub VO-1 point on Phobos is shown from 56 min to 63 min past Mars closest approach. The heavy lines on the ground tracks indicate when the imaging sequences were taken. It can be seen that the flyby period only lasted a few minutes each revolution during which the imaging sequences and other instrument (Infra Red Thermal Mapper and Mars Atmospheric Water Detector) sequences (not indicated) had to be taken.

The following figures are comprised of the high resolution pictures from each sequence. There are two figures for each sequence except for the closest sequences on REV's 243A and 244A which could not be mosaicked. The first figure for each sequence shows: a) the planned placement of pictures on the surface of Phobos; b) all of the pictures in the sequence that contained an image of Phobos with the specific Picture Numbers given; and c) a mosaic of a few of the pictures to show total surface coverage. The second figure for each sequence contains two mosaics: a) the raw data on the right which shows lighting variations from the sub-solar point to the terminator; and b) a high pass filtered version (left) which suppresses lighting changes and enhances surface detail. An approximate Planetocentric latitude and longitude grid is superimposed on the raw data mosaics. The sub-spacecraft point is indicated by a small plus sign and the sub-solar point is indicated by a larger asterisk. These grids were drawn assuming: a) the surface is ellipsoidal with no topographic variations; b) all pictures in the mosaic were taken at the same sub-spacecraft point; c) Phobos was perfectly locked in synchronous rotation with no rotational librations; and d) the mosaic was taken as one picture from a wide angle, distortionless TV camera. These assumptions give errors of up to tens of degrees as is evident when locating the same feature in different sequences. Additional geometry information is listed in Section VII.

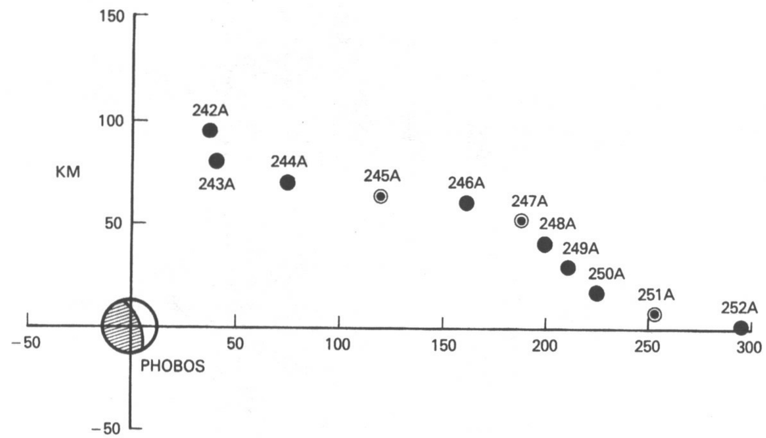


Figure 1. VO-1 flyby distances from Phobos

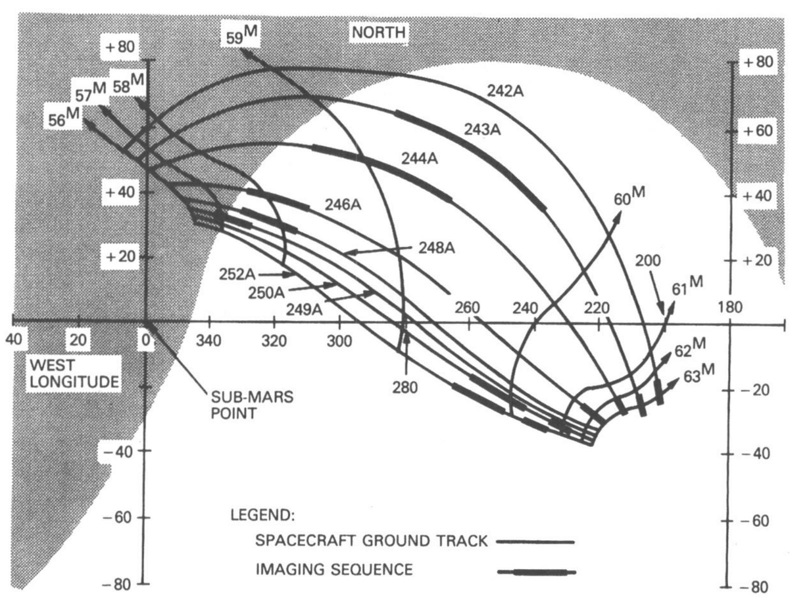
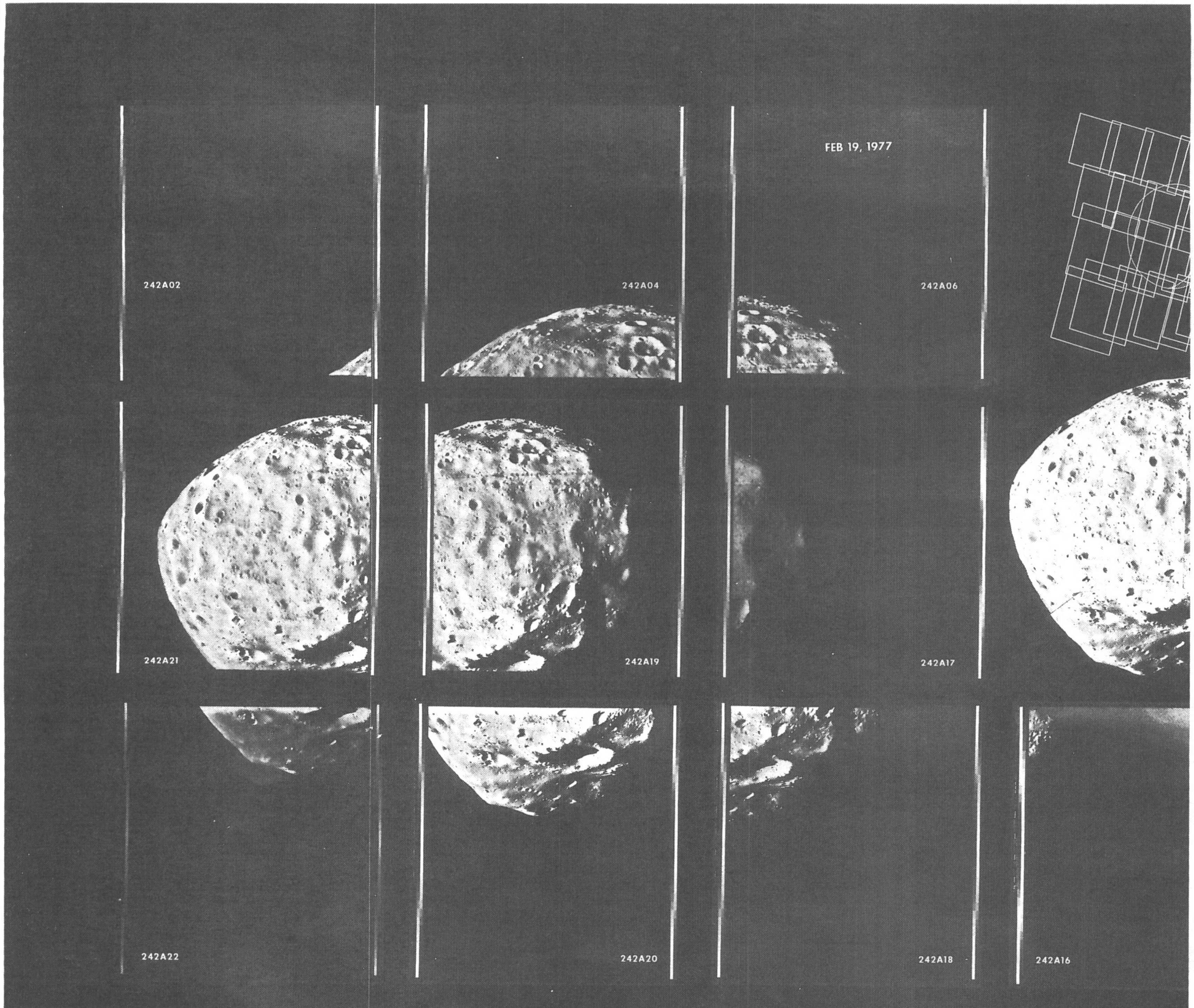


Figure 2. Ground track of VO-1 on Phobos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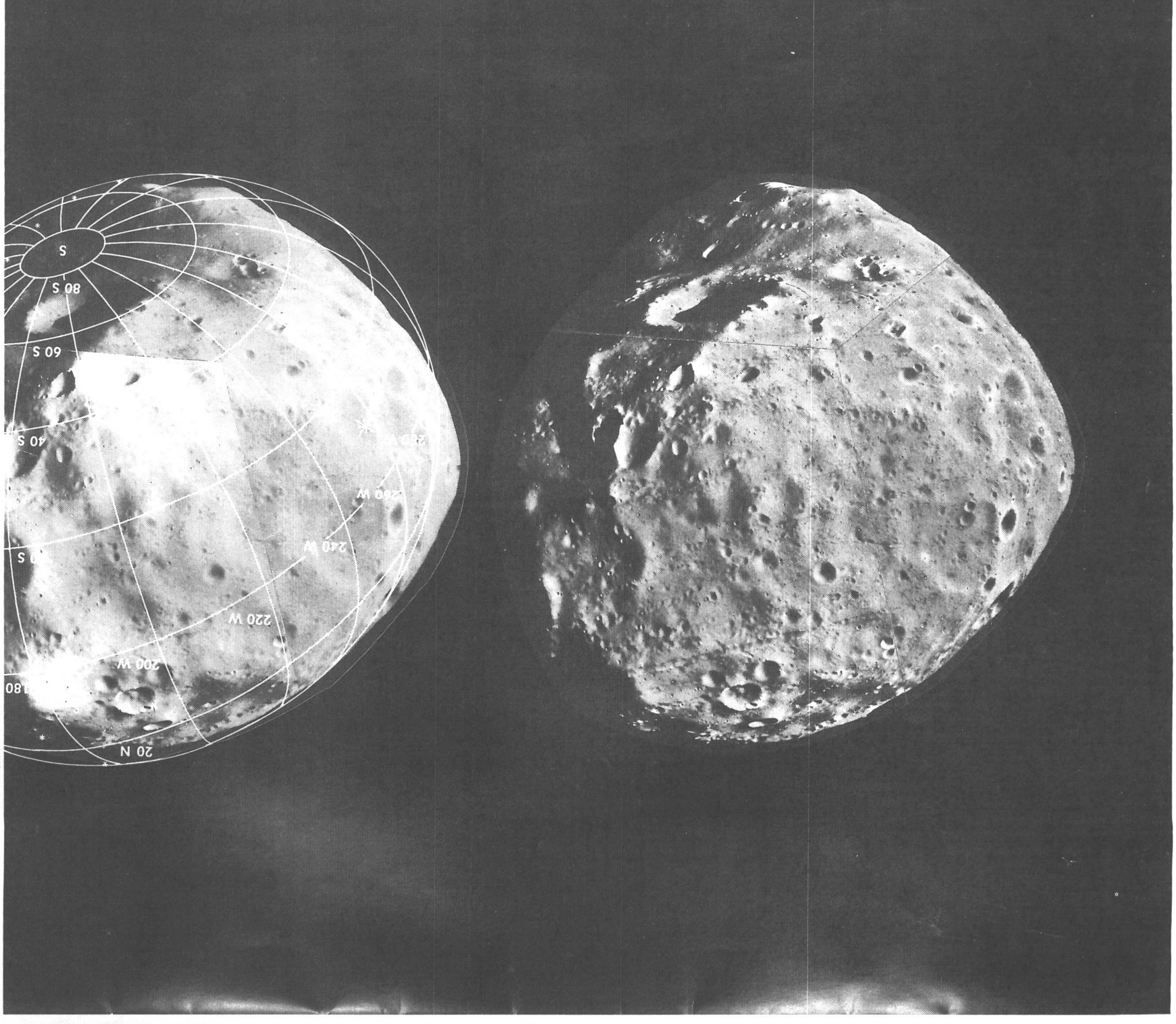
242A04
242A06
242A21
242A19
242A17
242A22
242A20
242A18
242A16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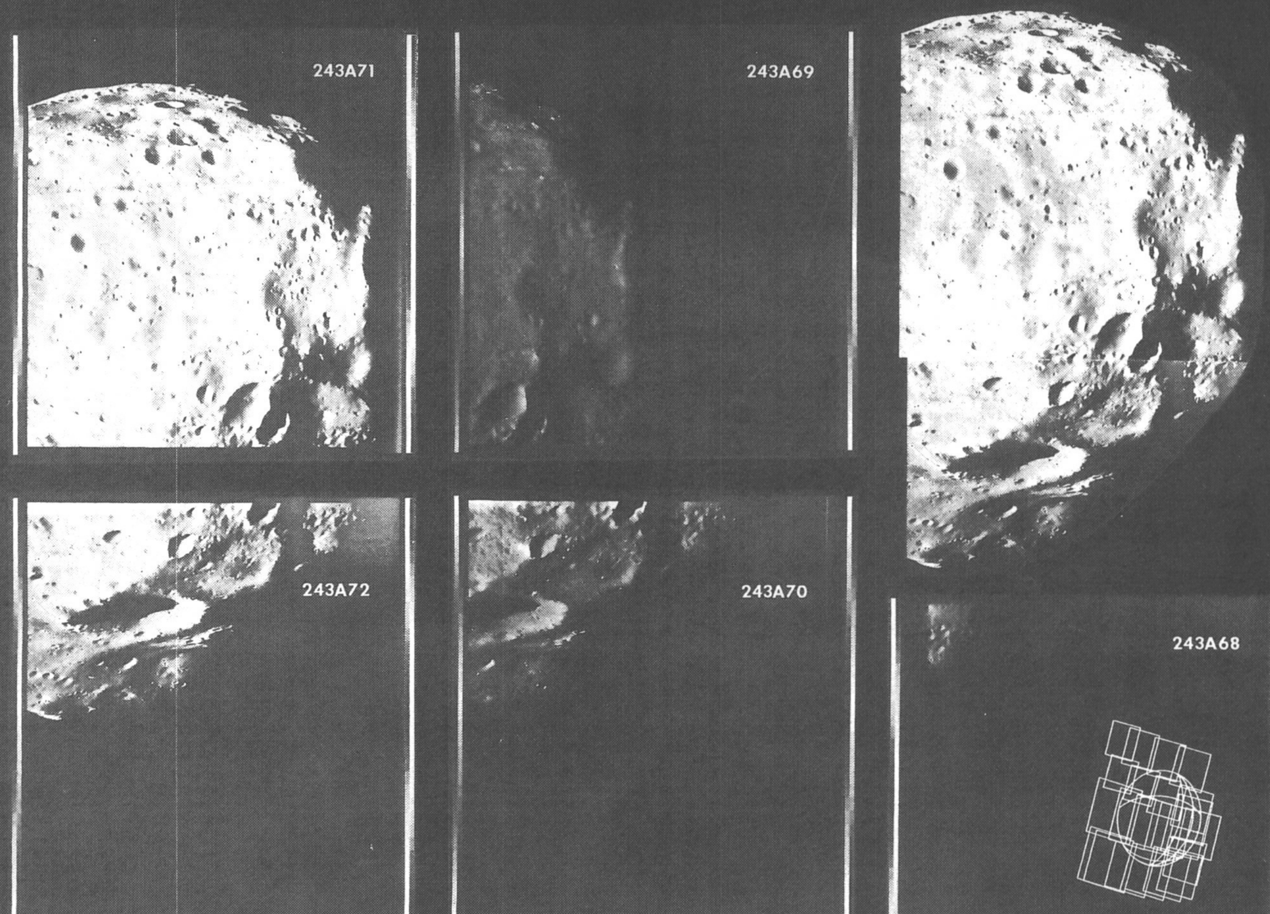
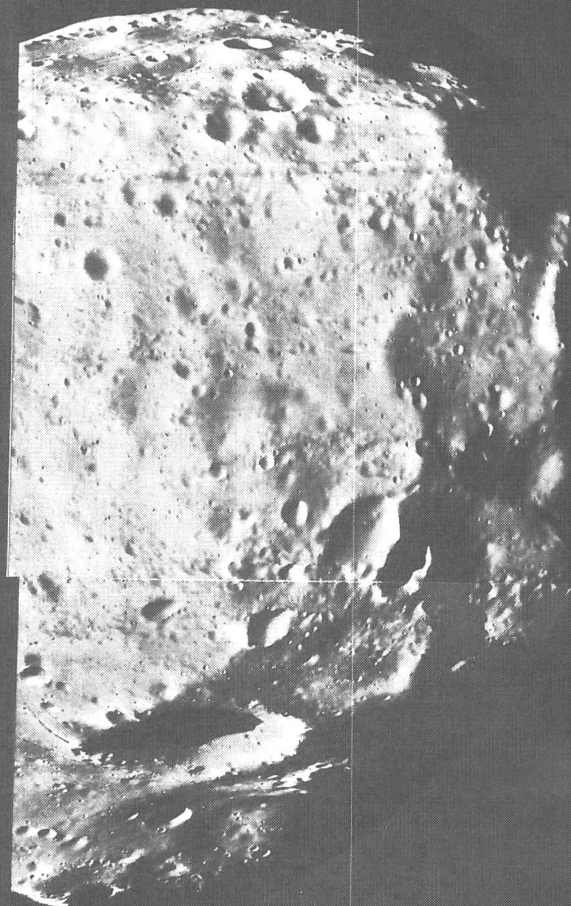
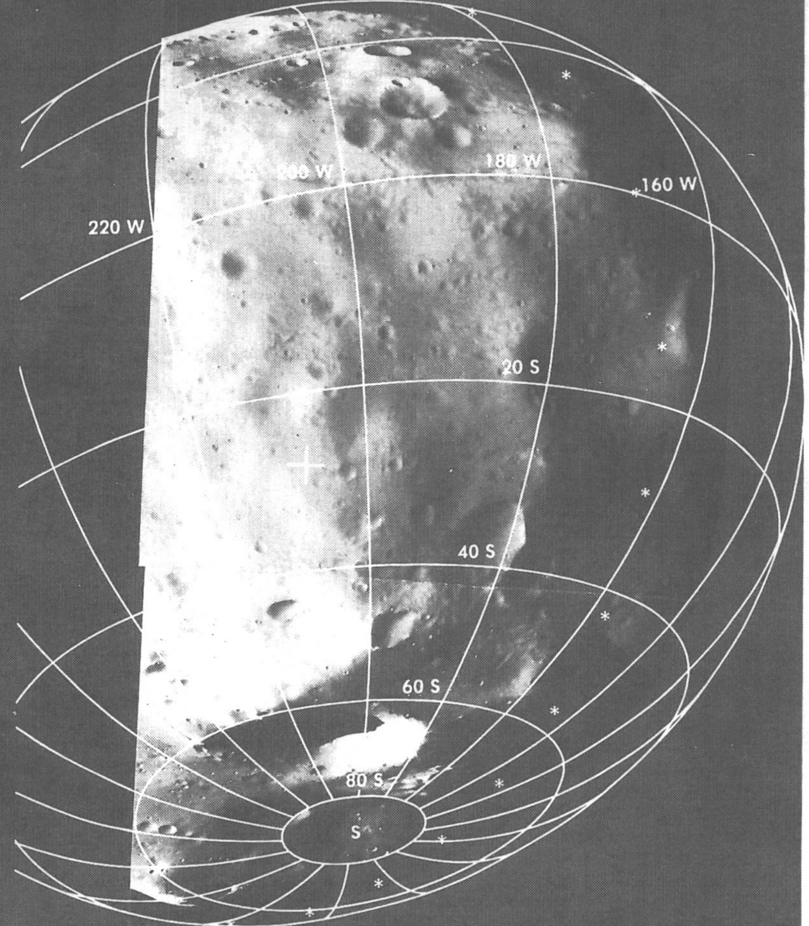
200 W
220 W
240 W
260 W
180
40 S
60 S
80 S
S

REV 243A   February 20, 1977







220 W
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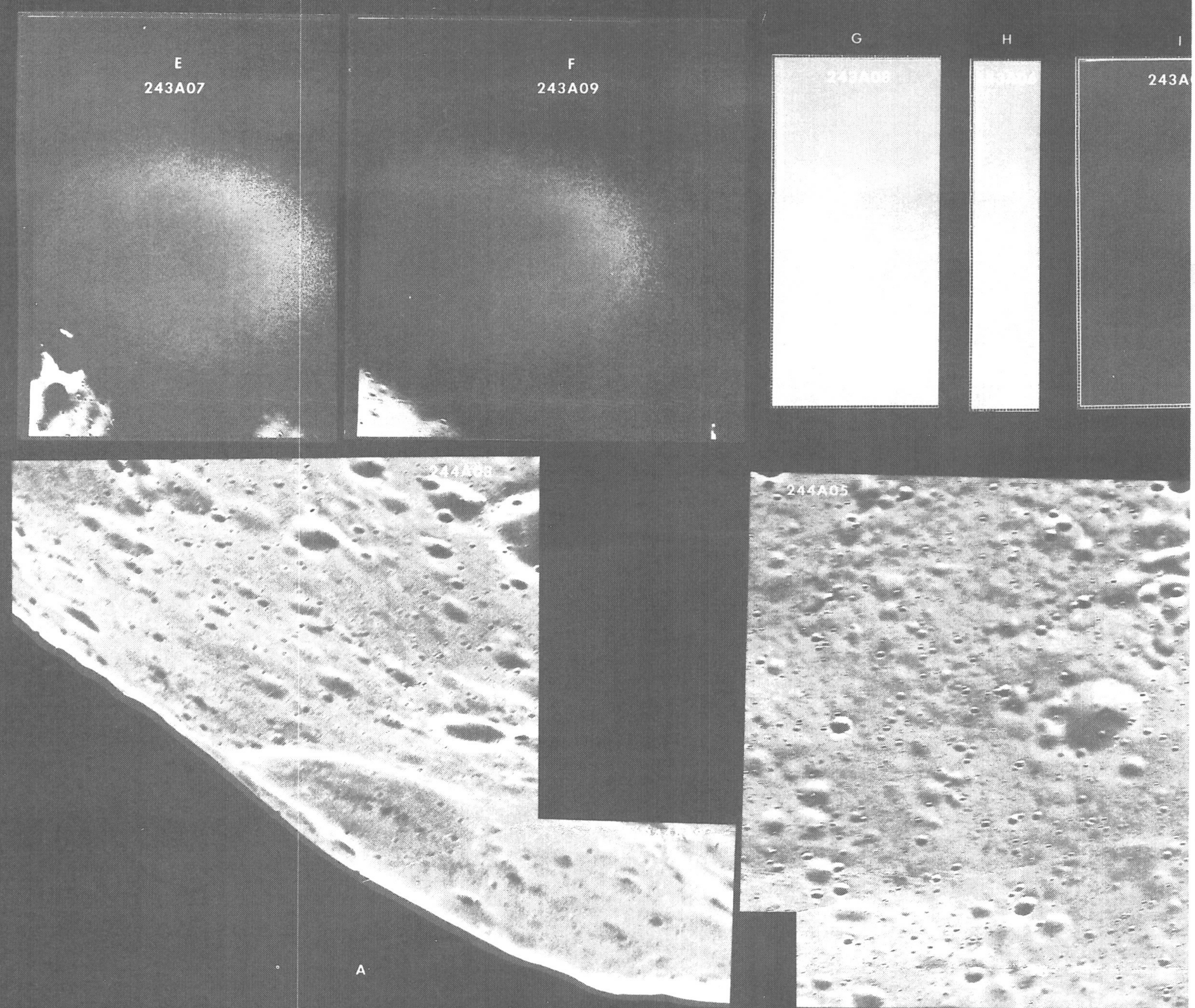
180 W
160 W
20 S
40 S
60 S
80 S
S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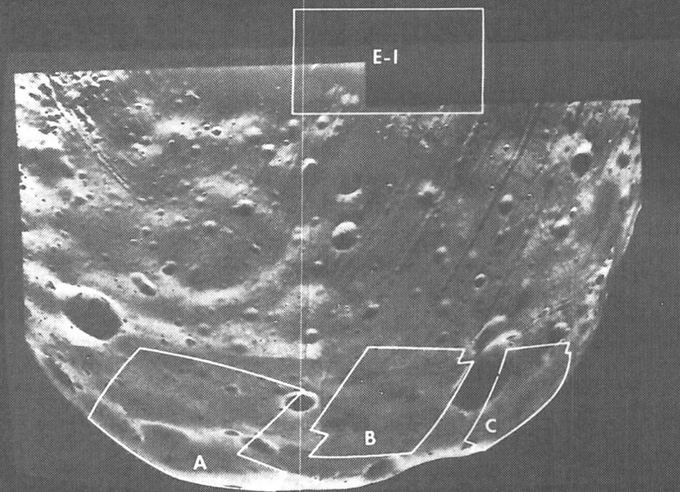
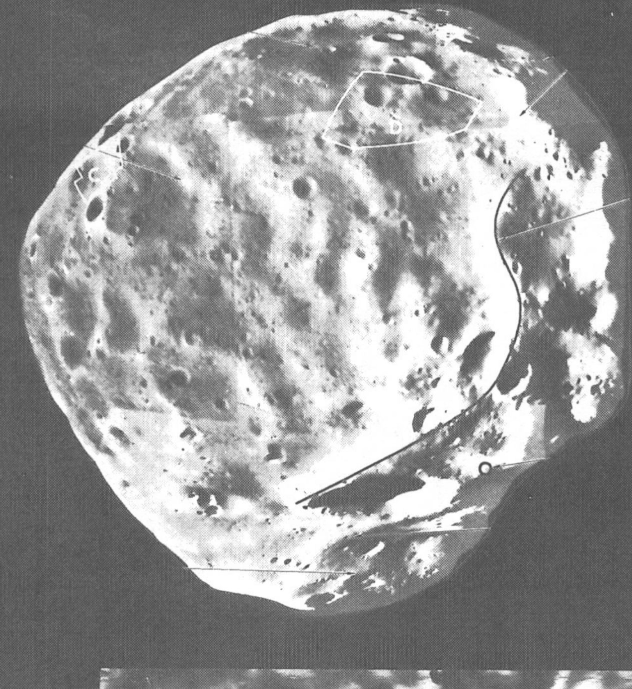
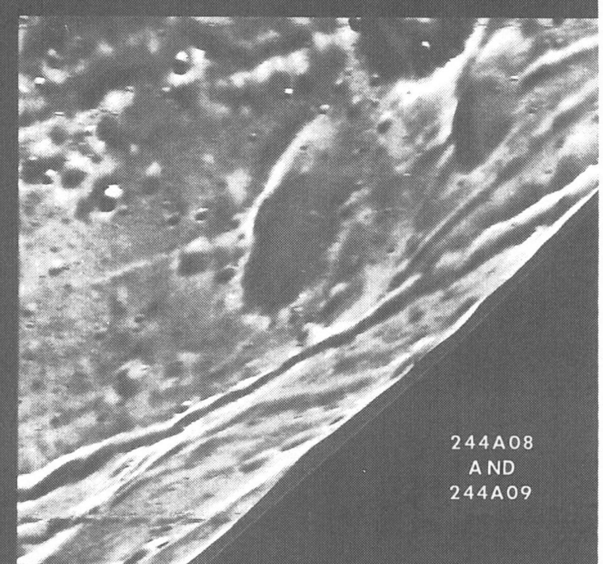
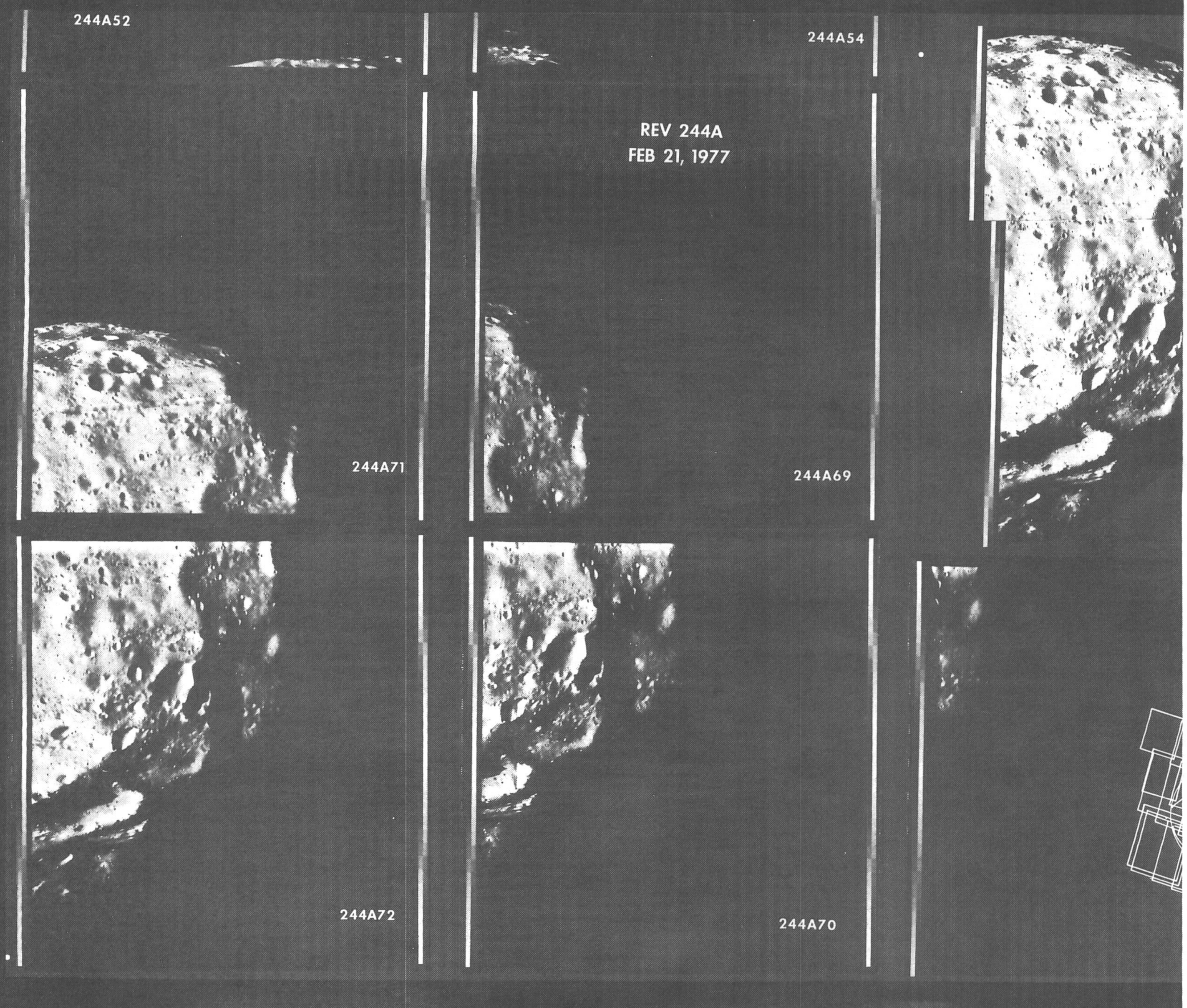
F
243A09
G
243A08
H
I
244A05
A







244A08
AND
244A09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FEB 21, 1977
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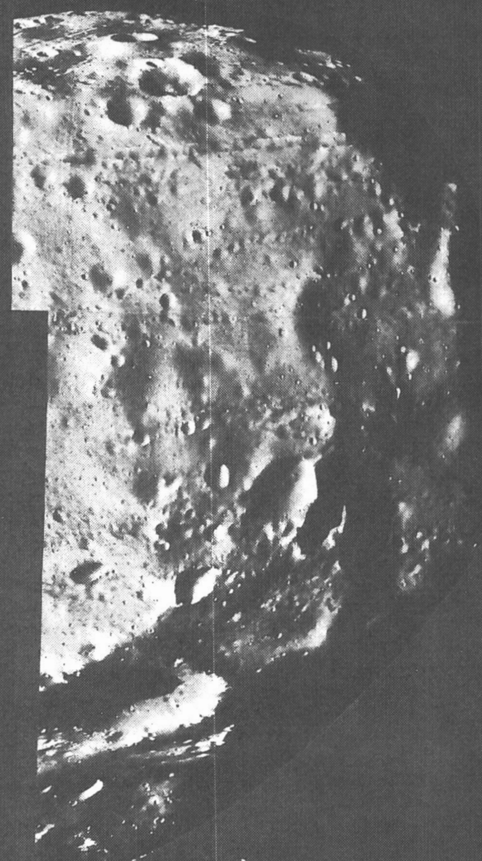
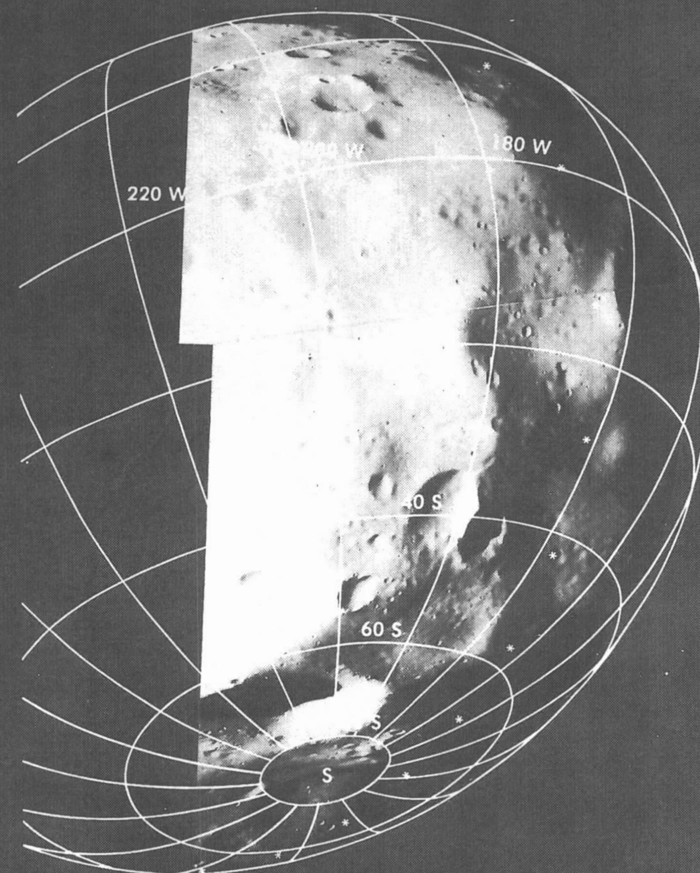
244A69
244A72
244A70

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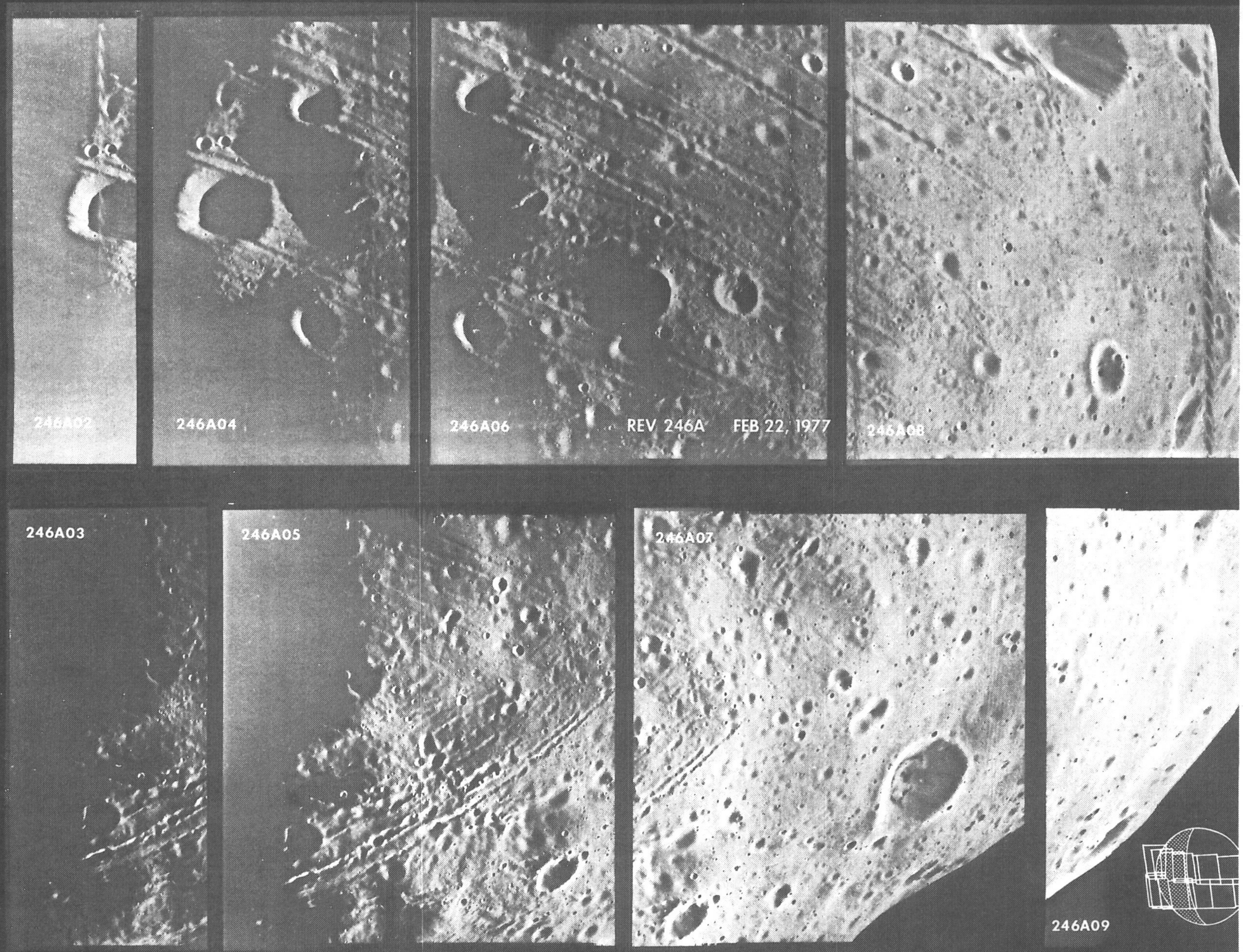
S
S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246A06
REV 246A FEB 22, 1977
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246A03
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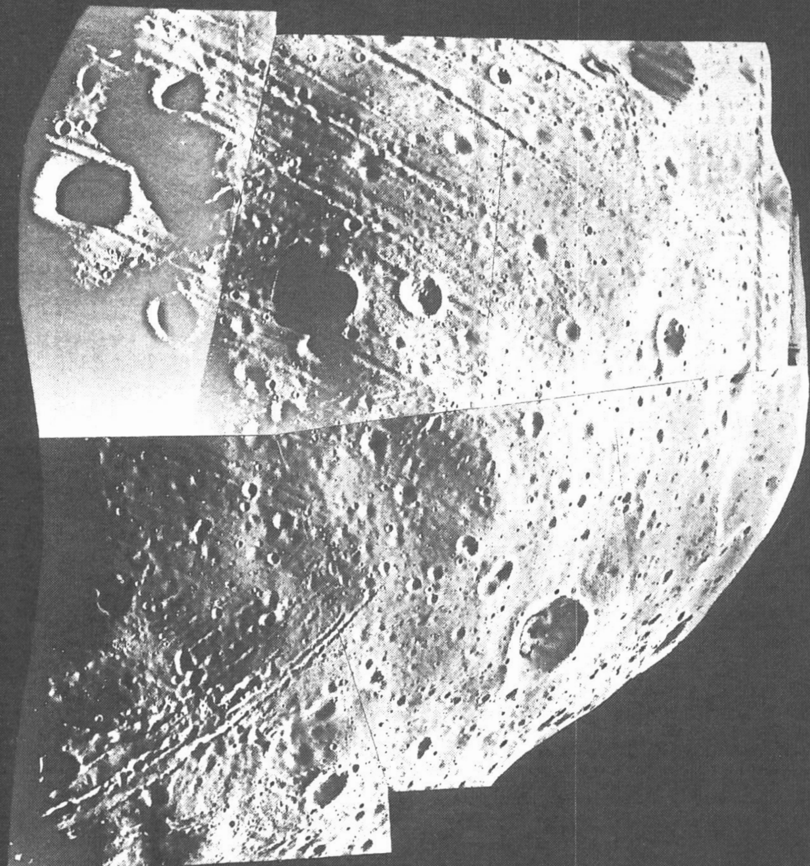

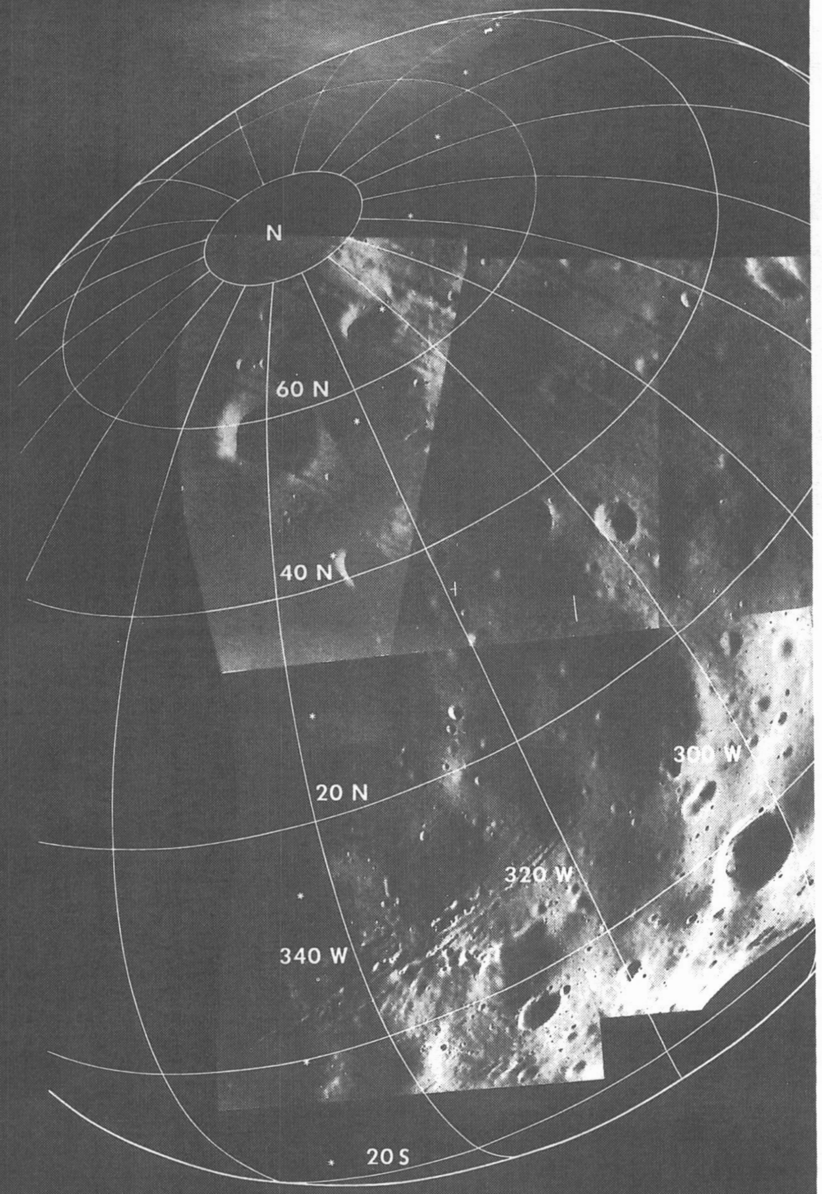
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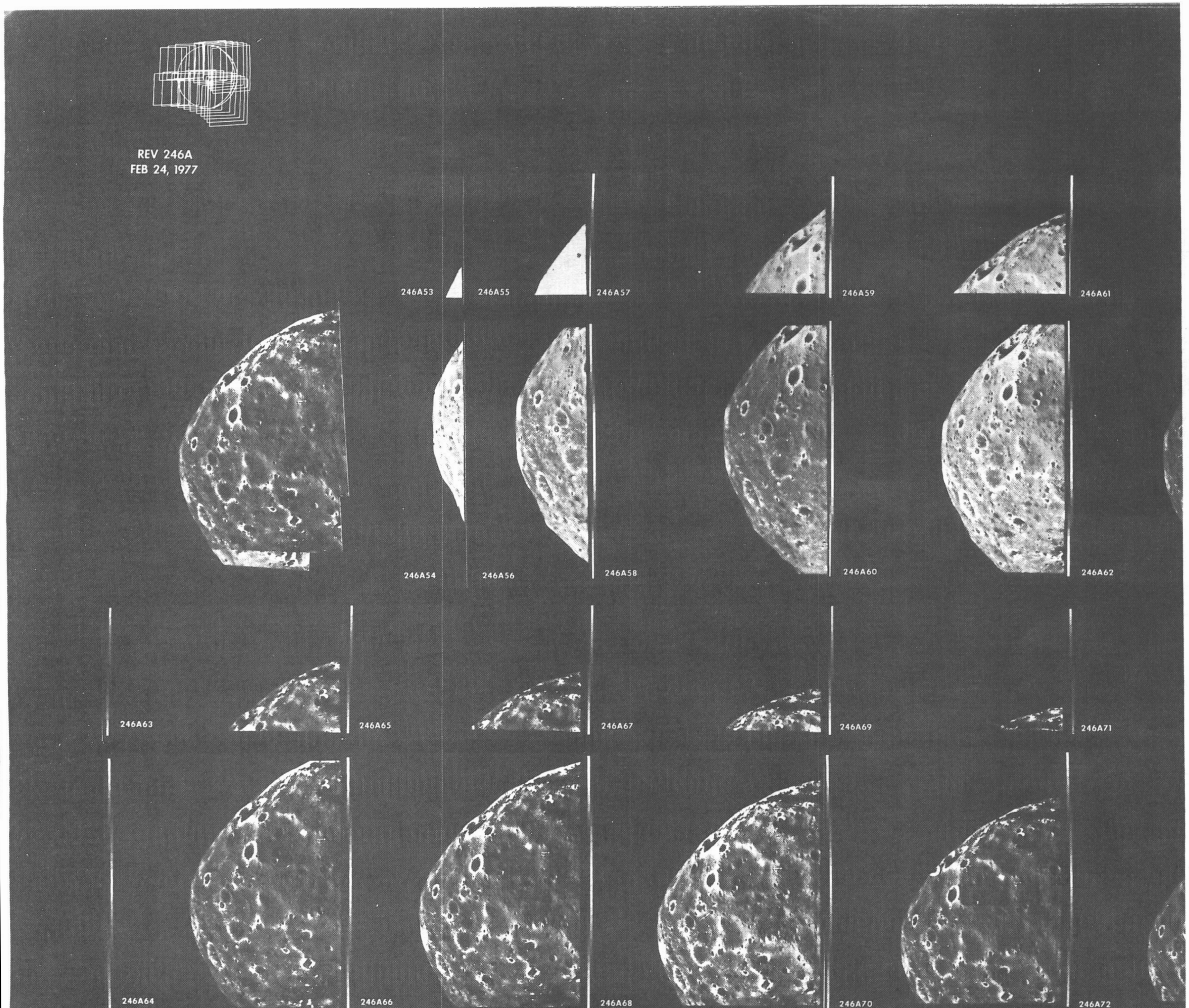
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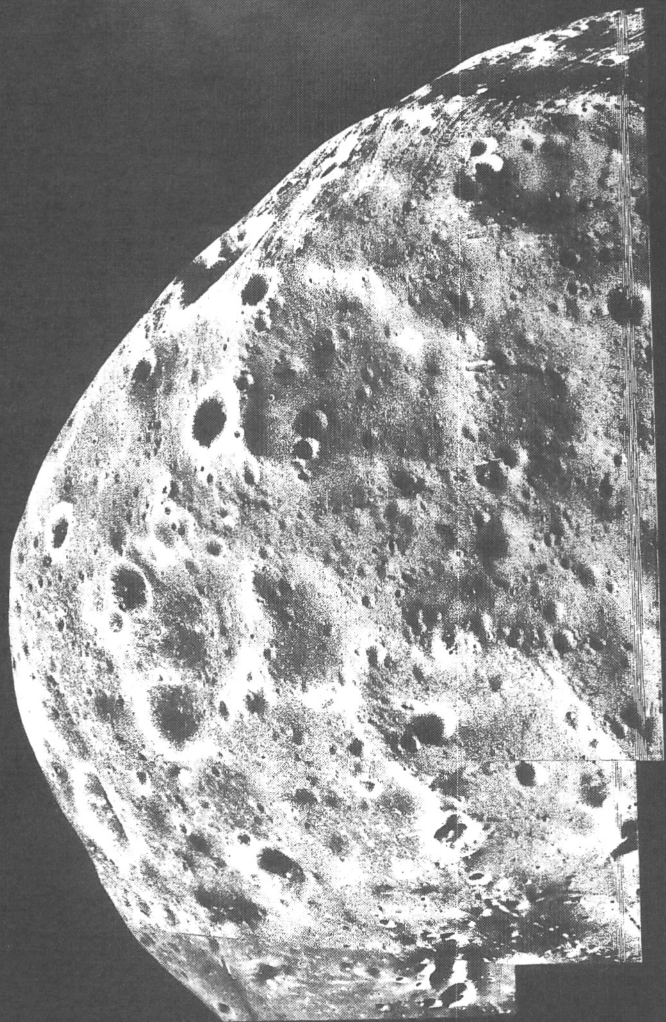

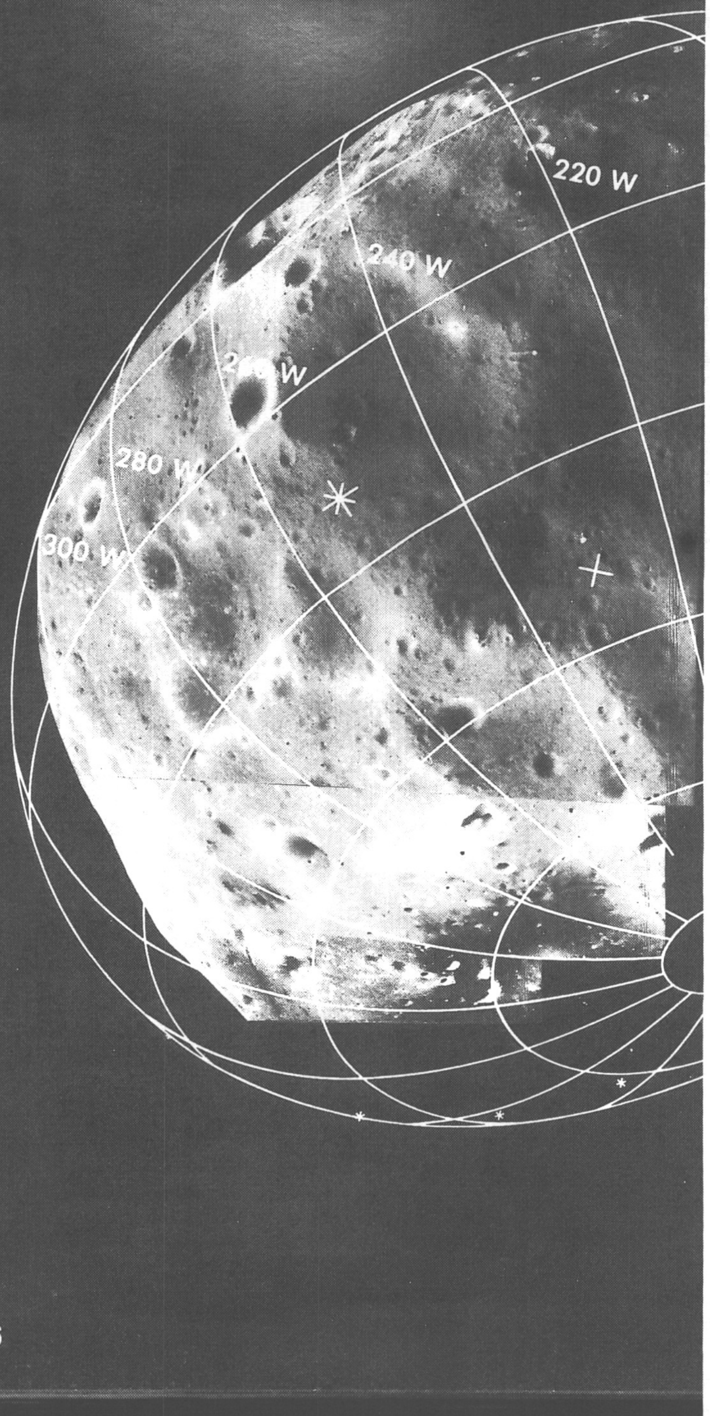

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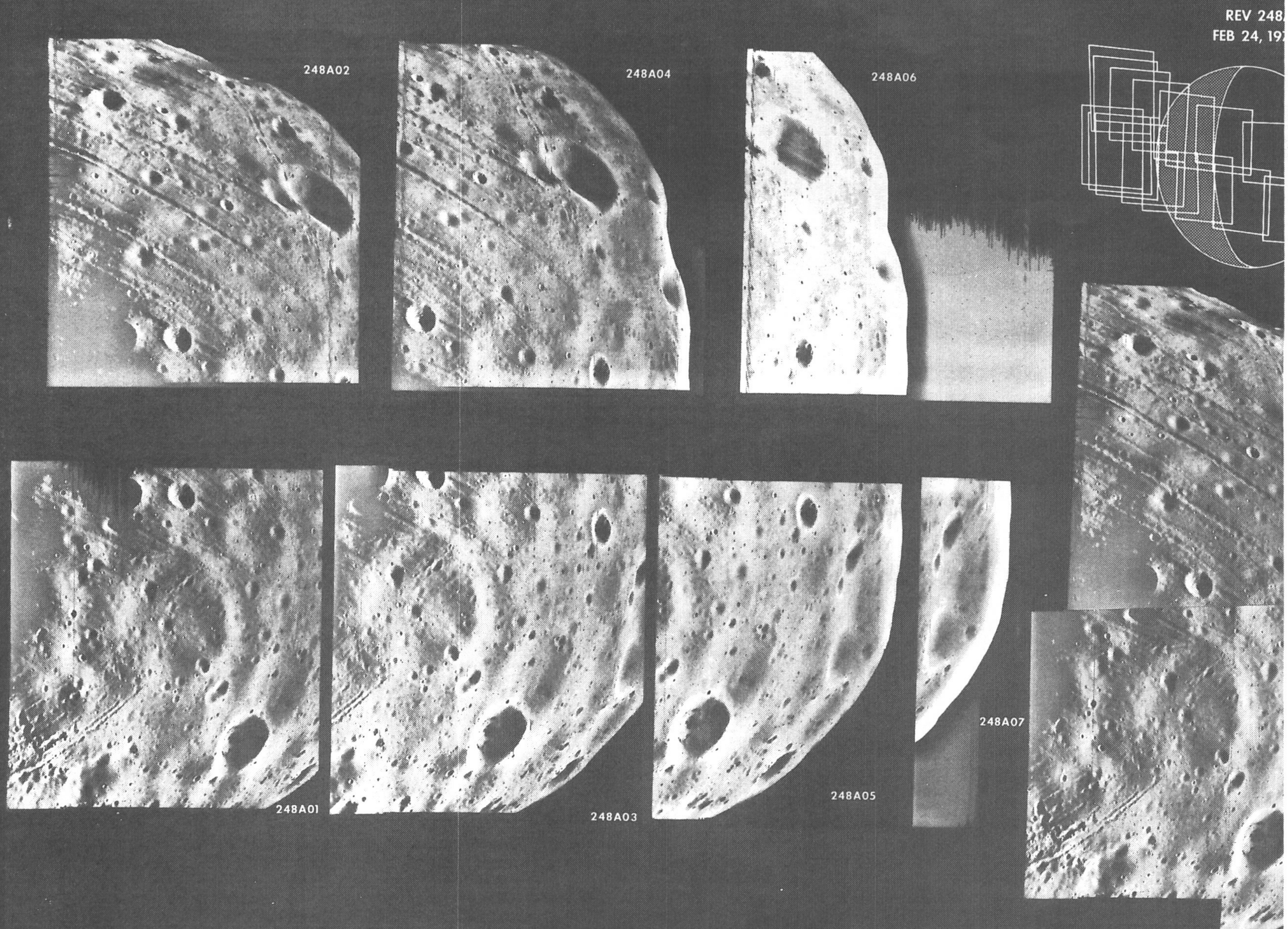
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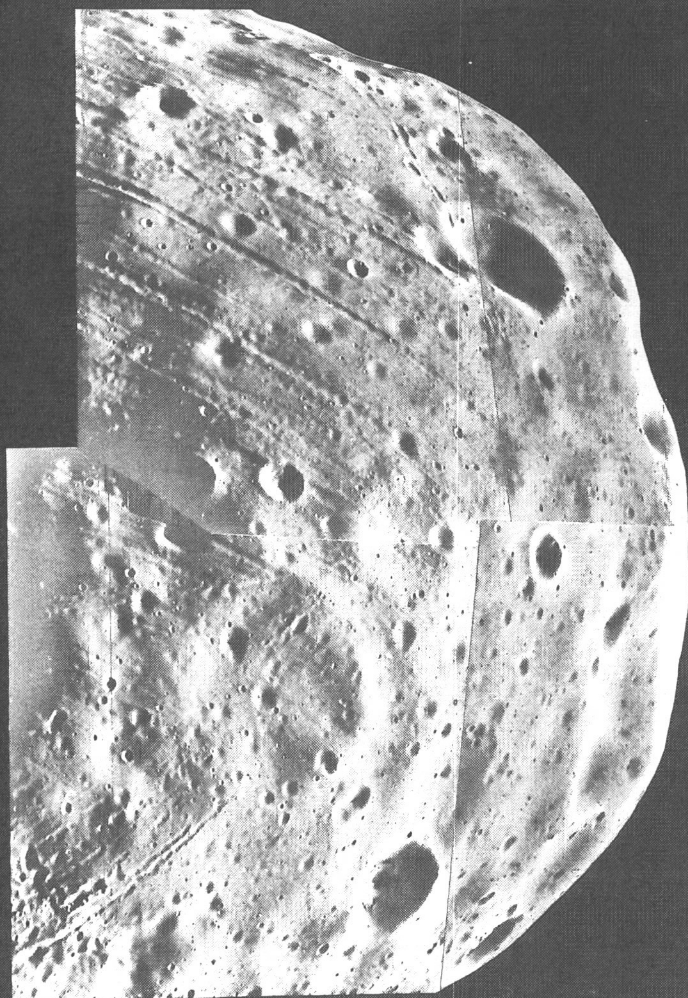

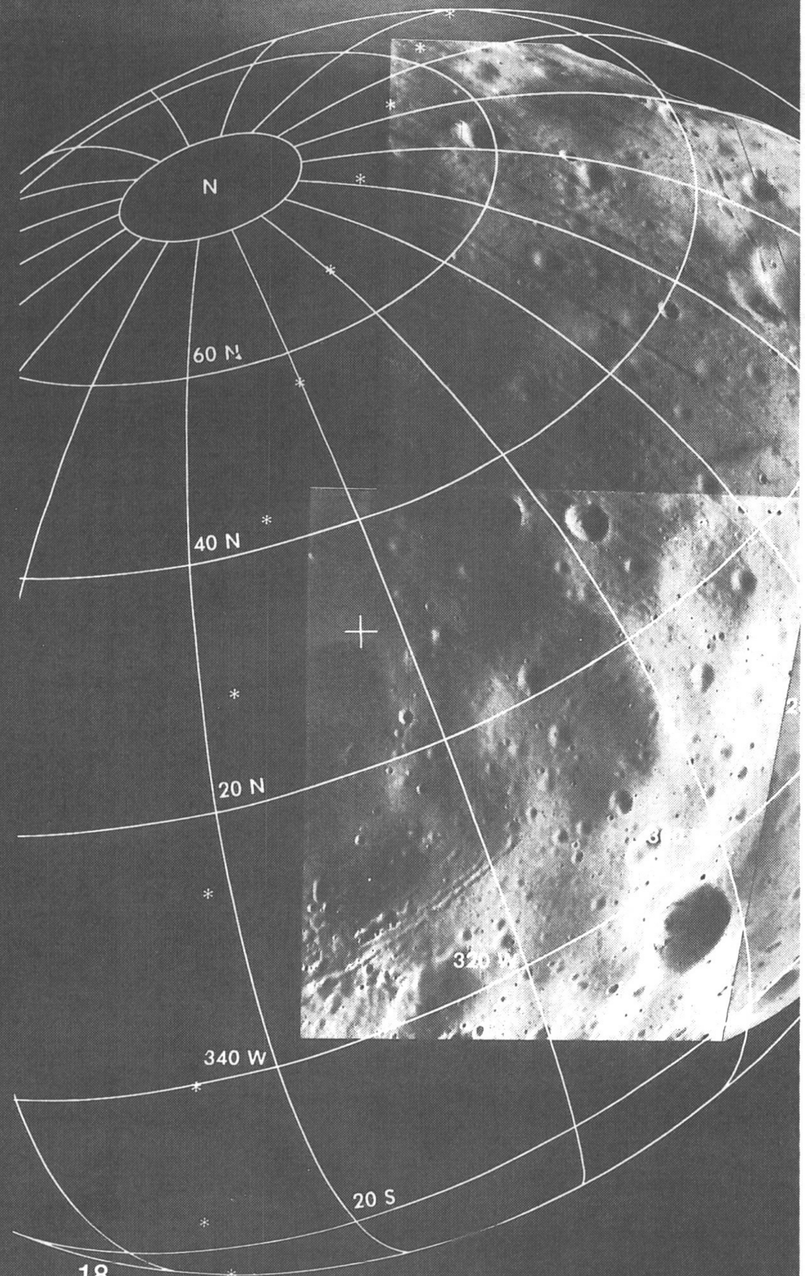
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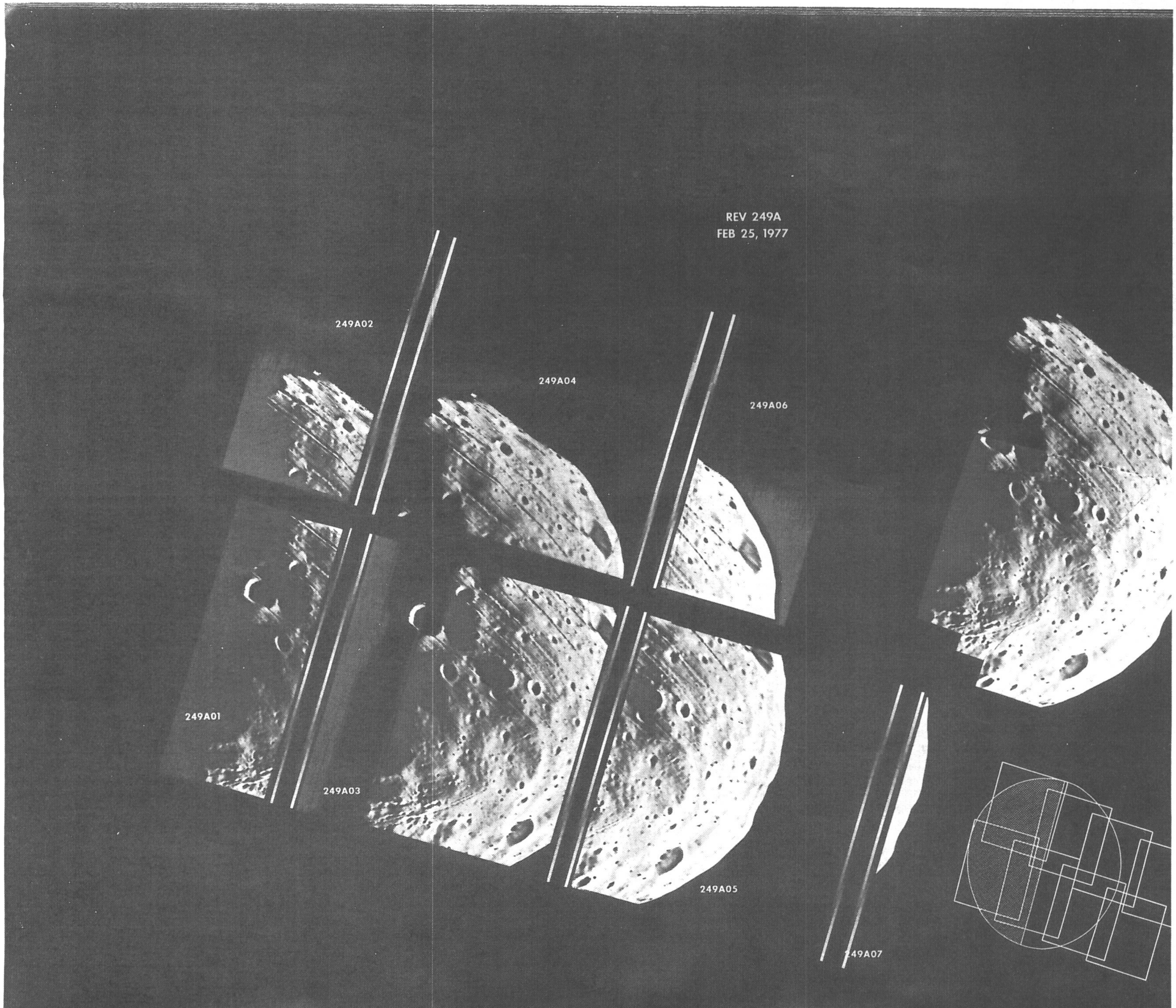
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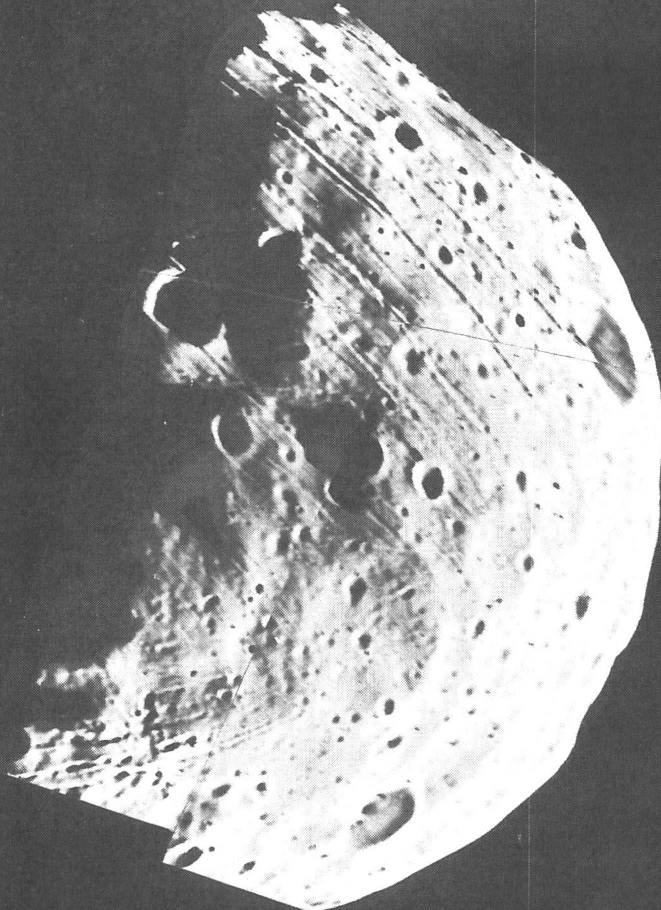

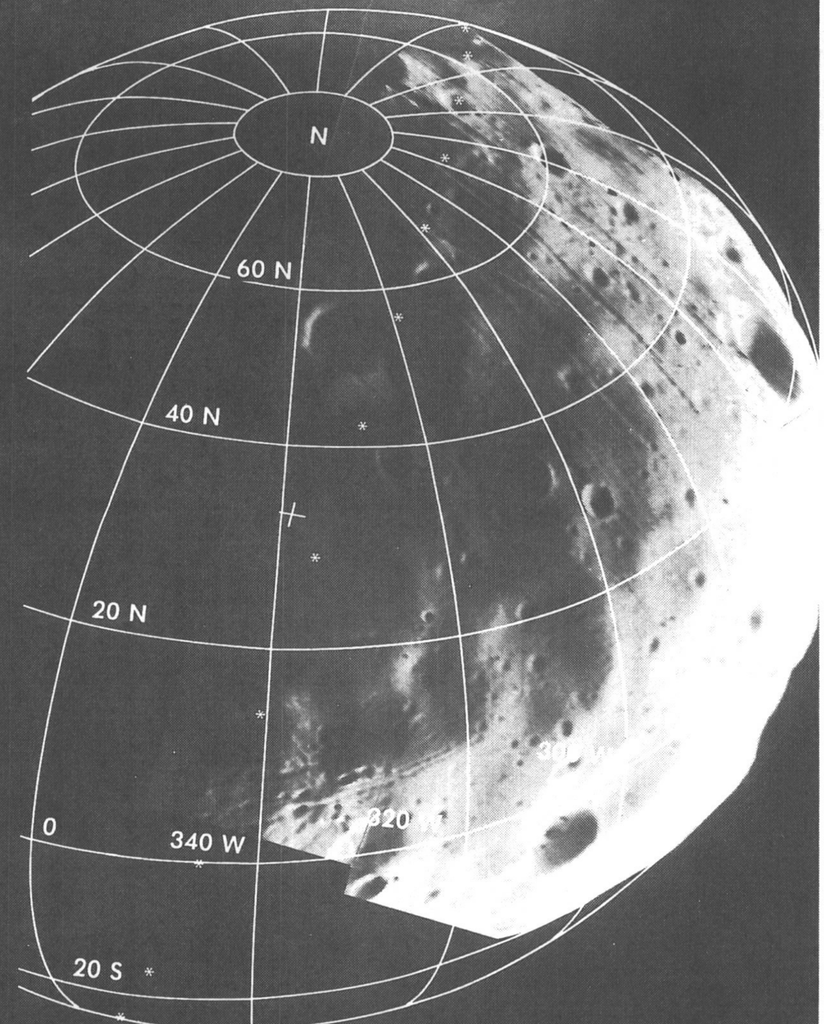

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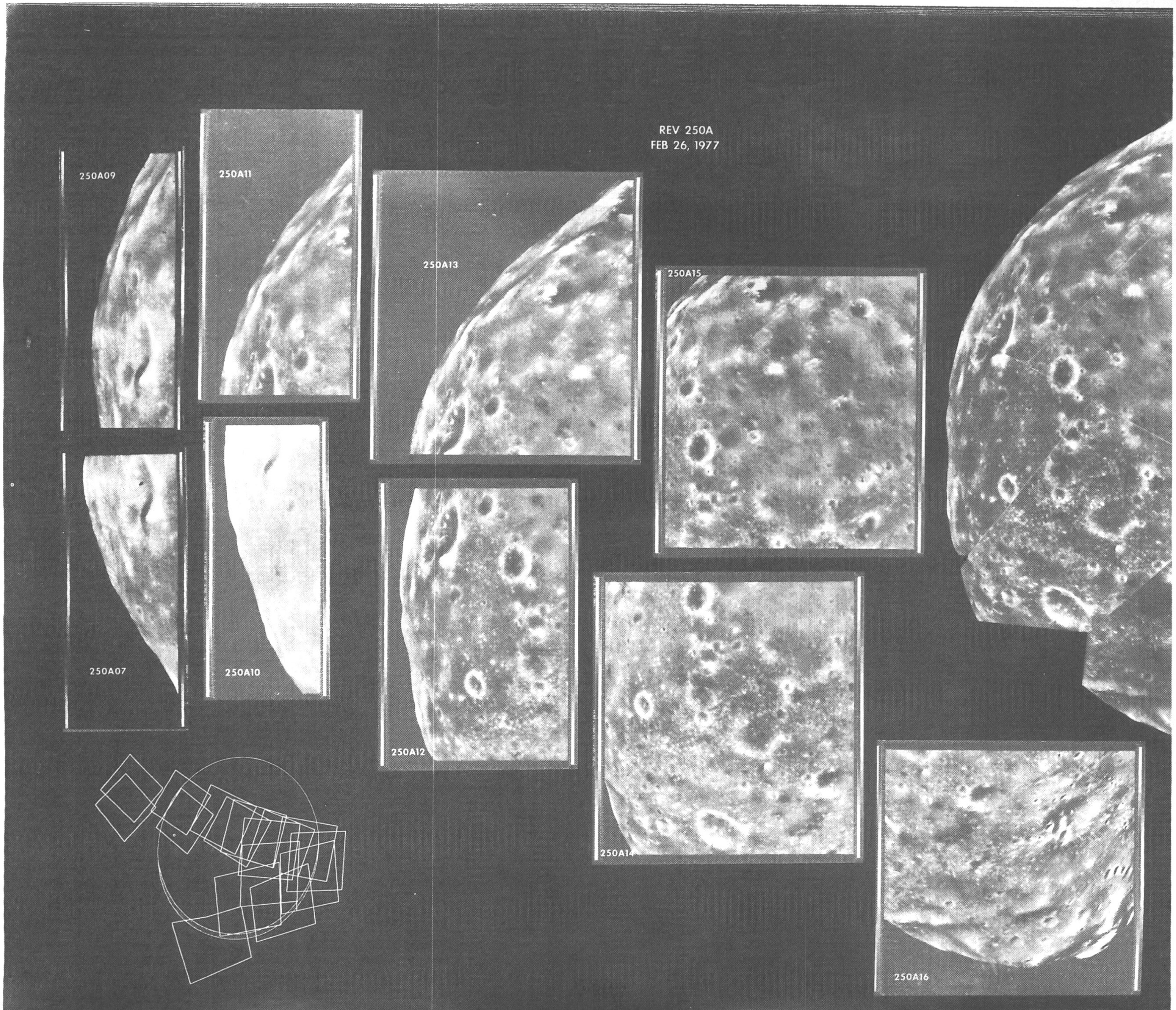
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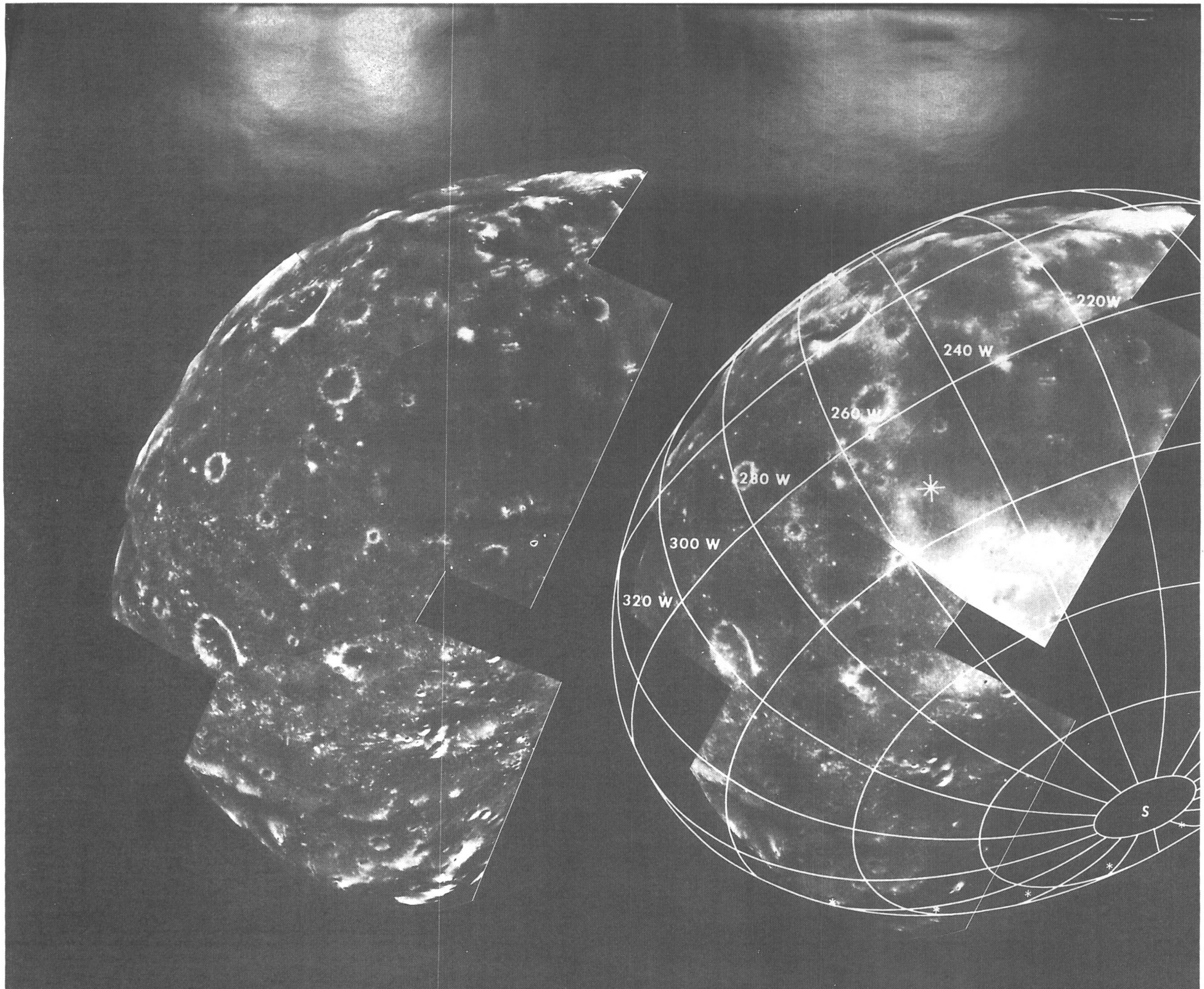
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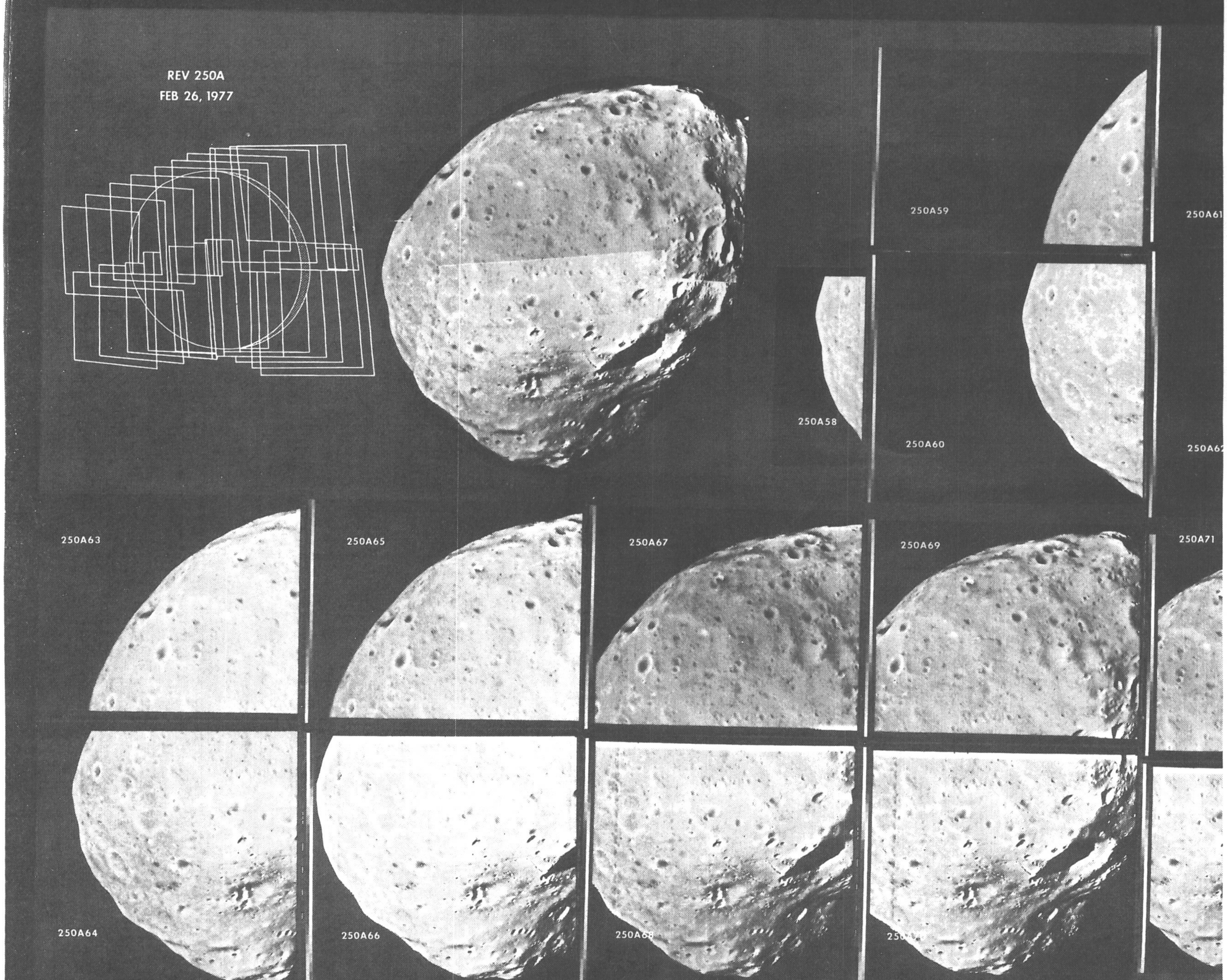
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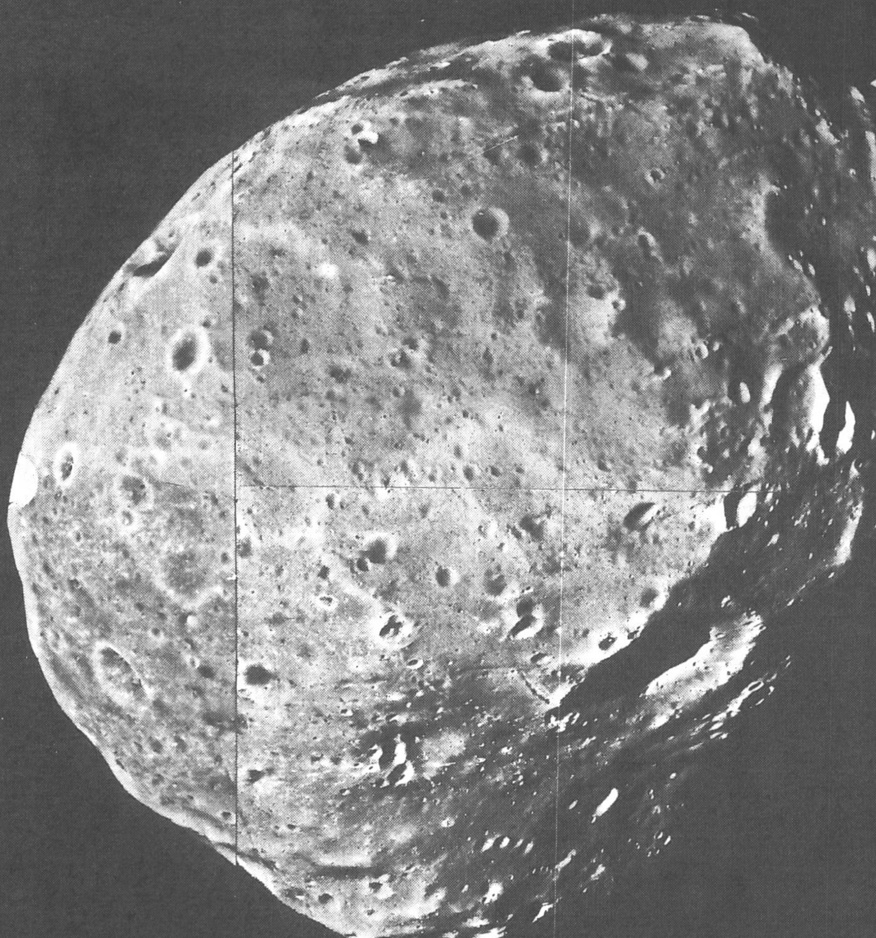

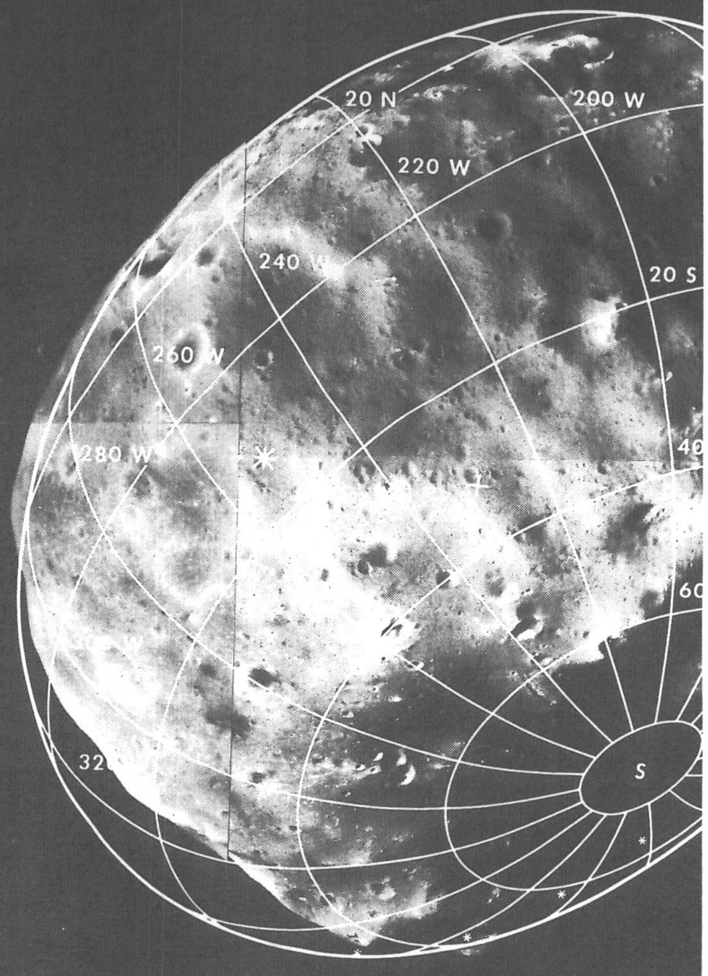
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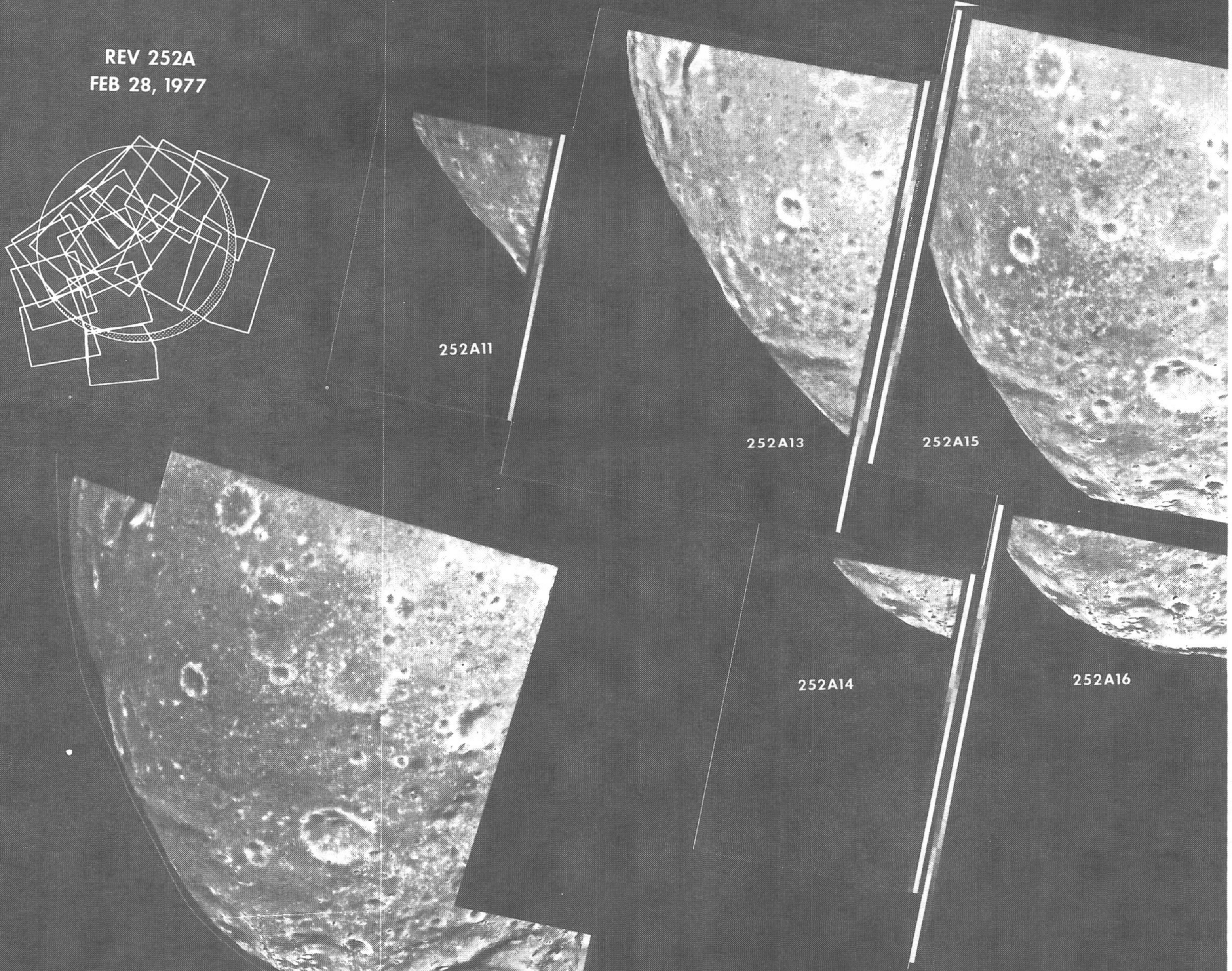
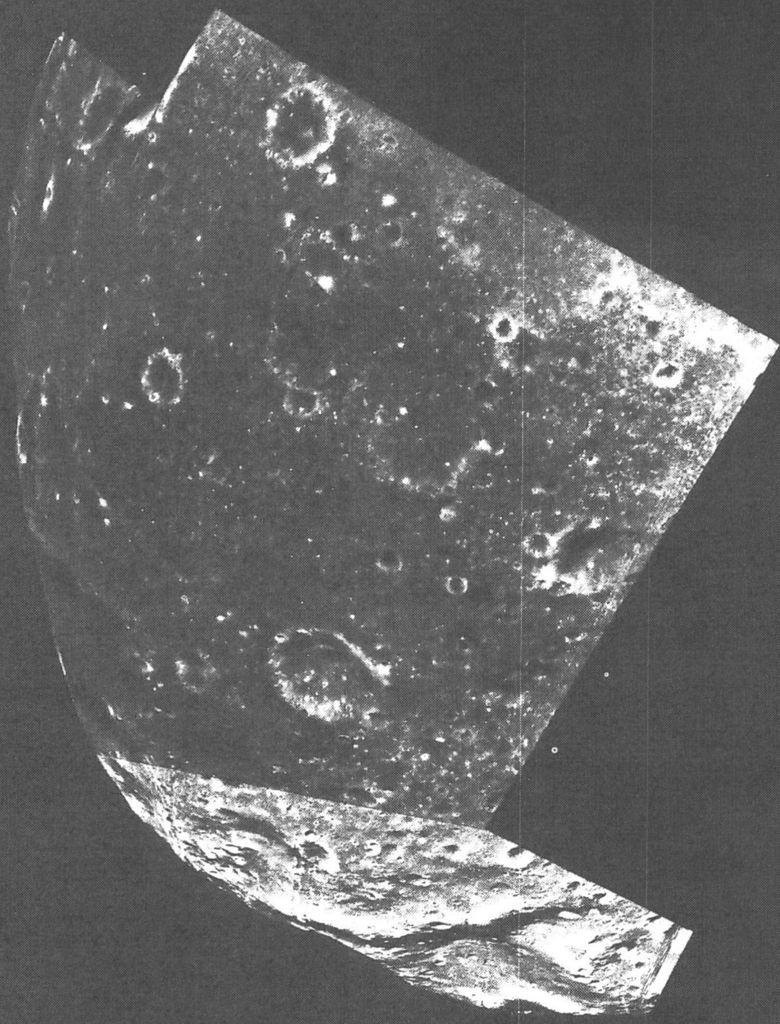
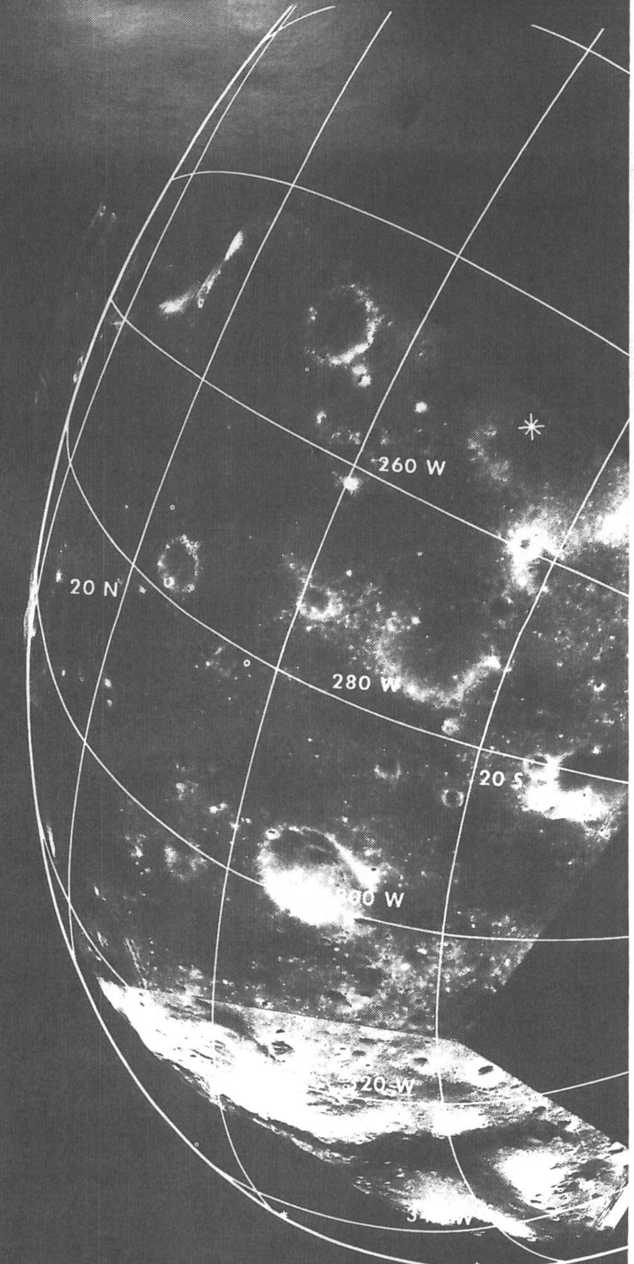
40
60
32
S

REV 252A
FEB 28, 1977



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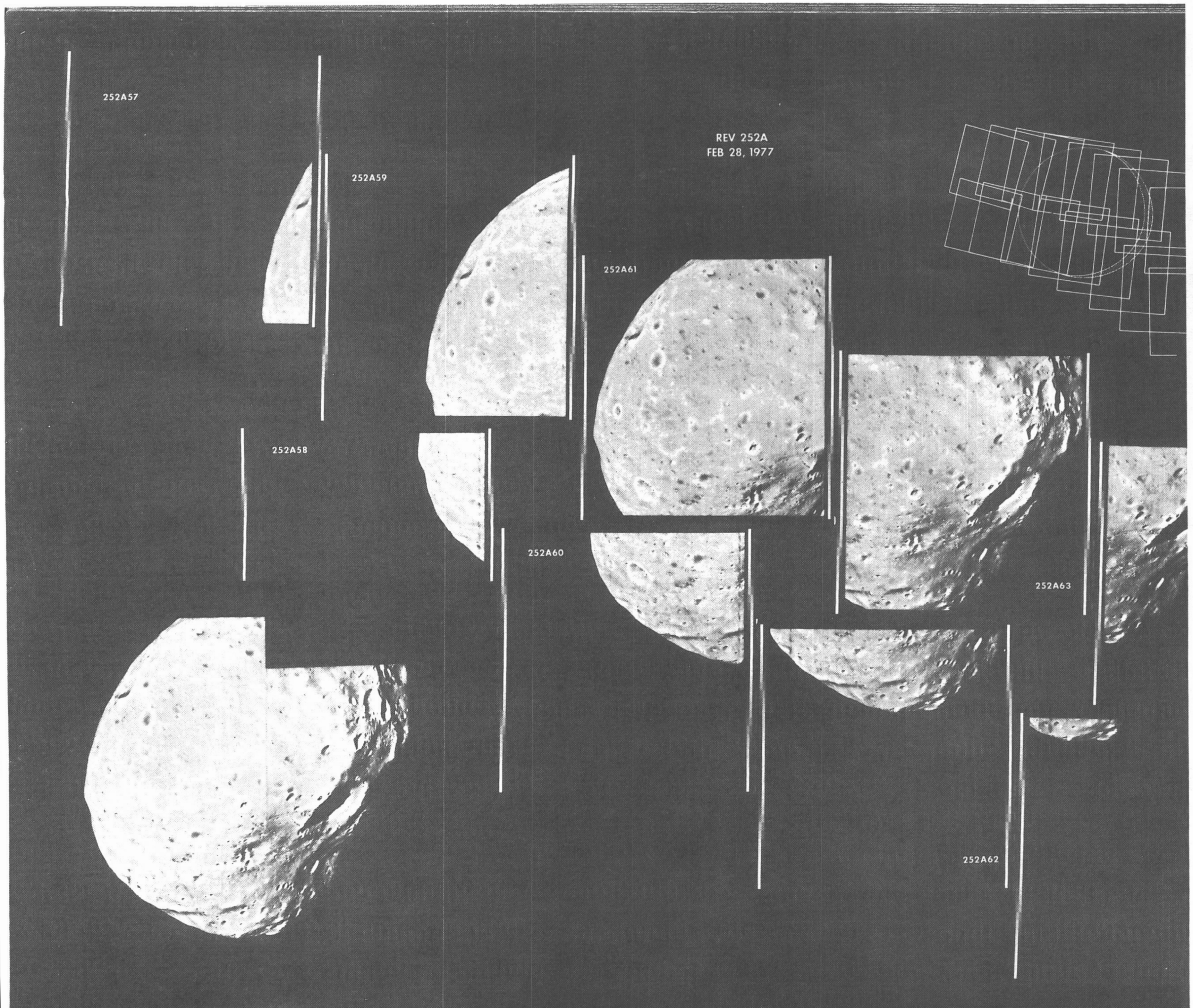
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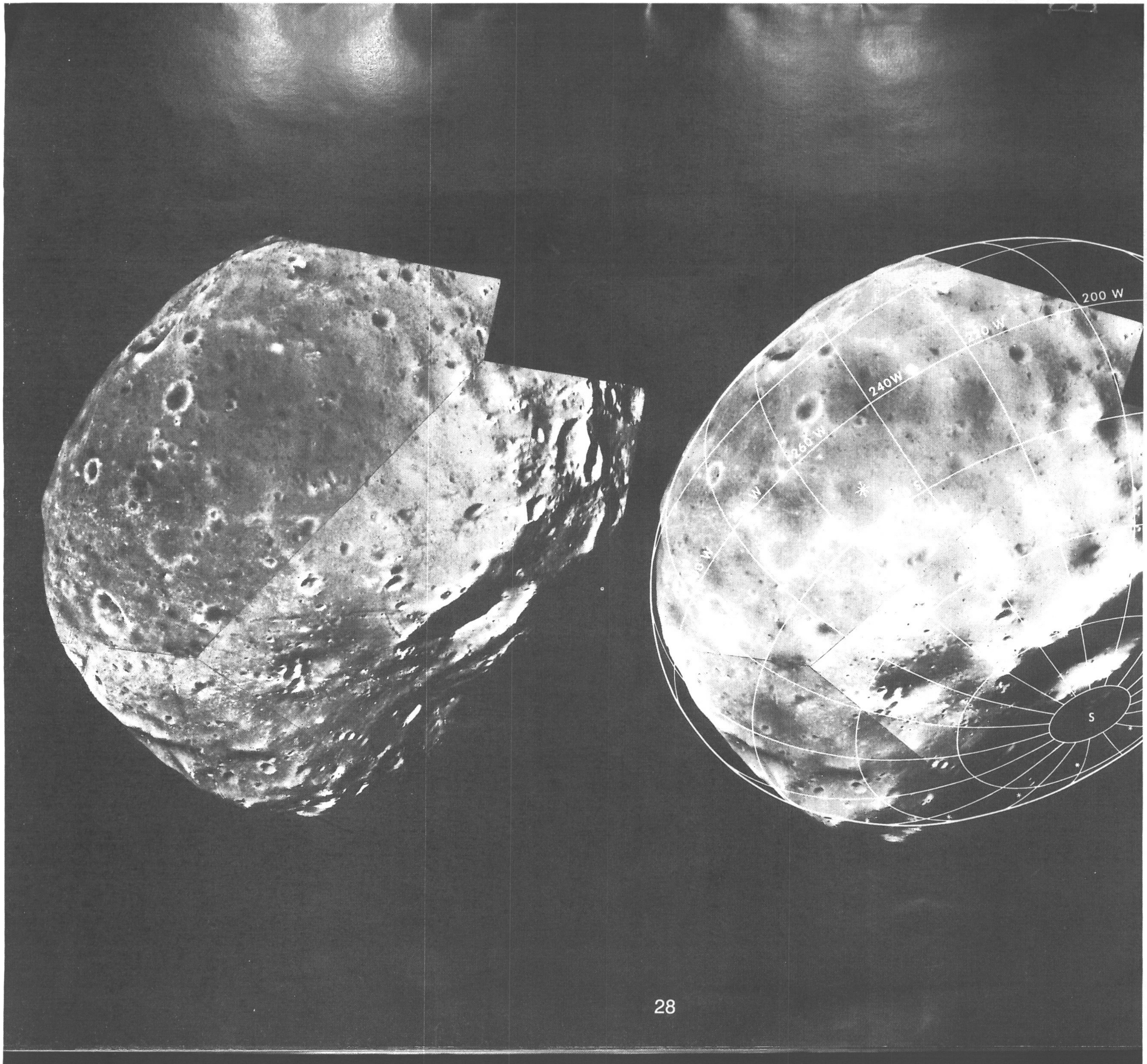
200 W
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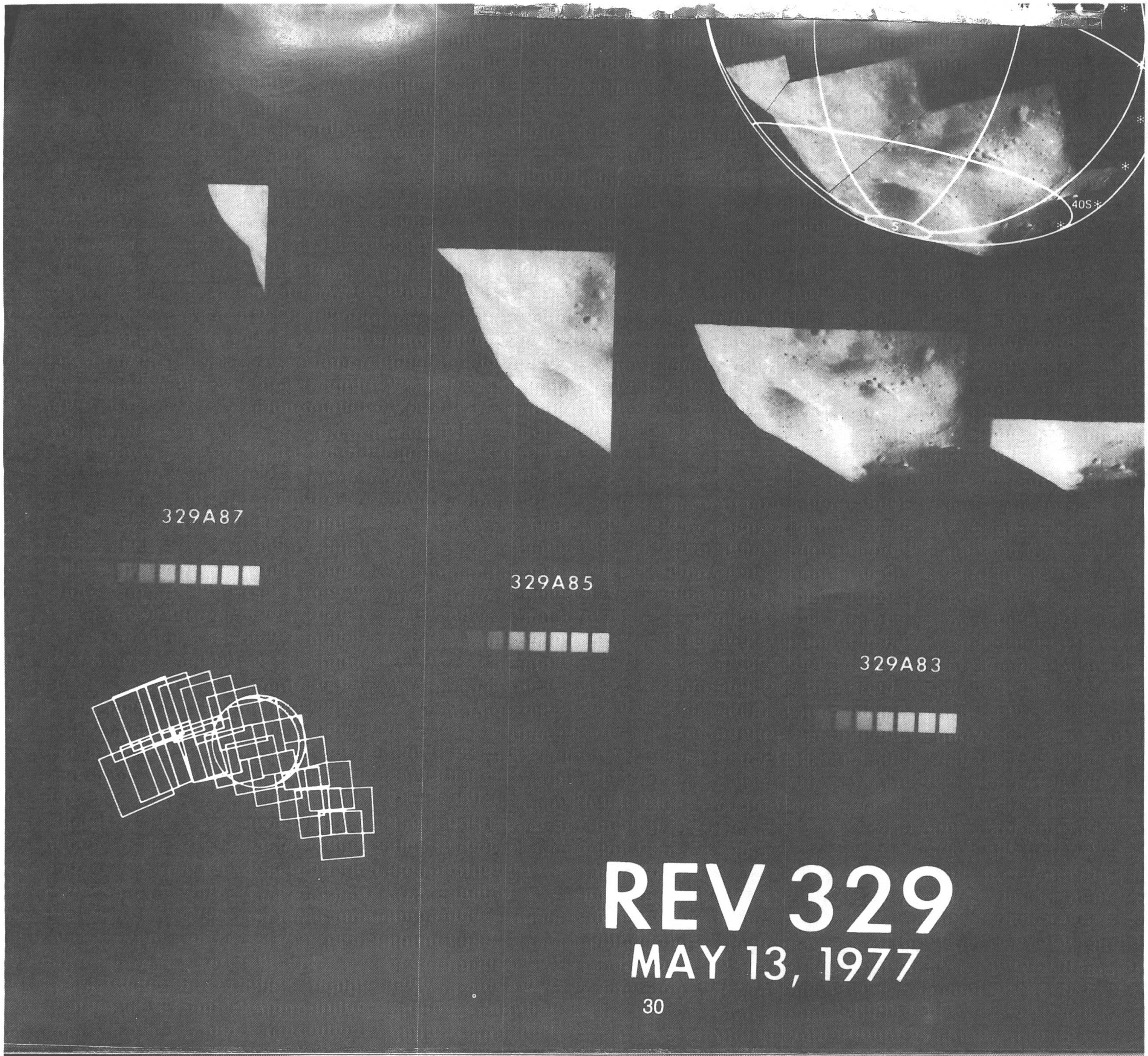
260 W
S

SECOND ENCOUNTER

The second close encounter period of VO-1 with Phobos occurred during April 30 to June 23, 1977. The orbital periods of VO-1 and Phobos were again near commensurate with a close flyby occurring every fourteen VO-1 revolutions about Mars. All encounters were within 2000 km with the closest encounter of 300 km occurring on May 27, 1977 (REV 343A). Originally, VO-1 would have flown over the dark side of Phobos on REV 343A and considerably closer than 300 km. However, since the probability of impact was not negligible for this encounter, the flyby was retargeted to 300 km over the illuminated side of Phobos. This flyby gave the best viewing of the linear grooves emanating from the large crater Stickney.

The following figures are similar in layout to the figures for the first encounter. All of the pictures in a sequence which contain the image of Phobos are shown along with the planned picture coverage of the sequence. For the close encounters, mosaics of raw and filtered pictures are given with a Phobocentric latitude/longitude grid superimposed on the raw picture mosaic.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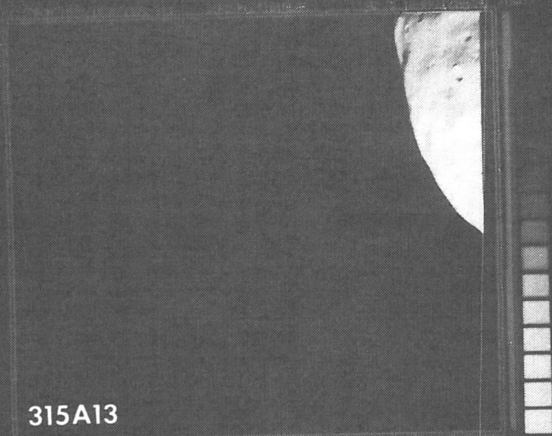
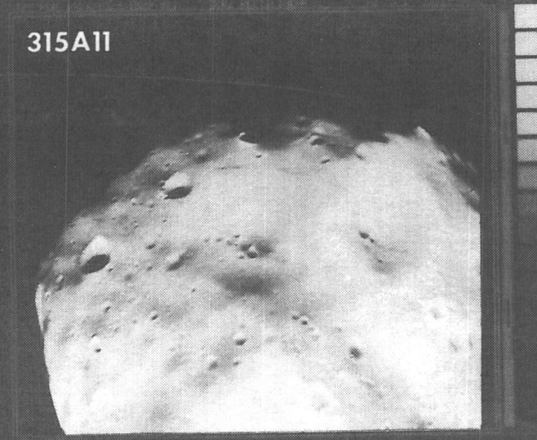
REV 329
MAY 13, 1977

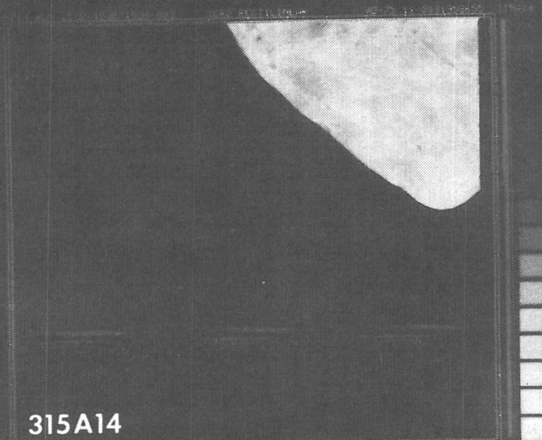
REV 31
APRIL 30, 197



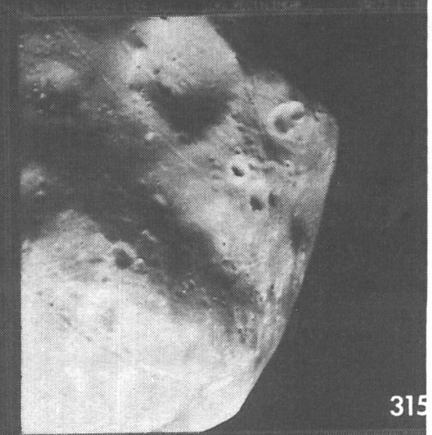
315A13



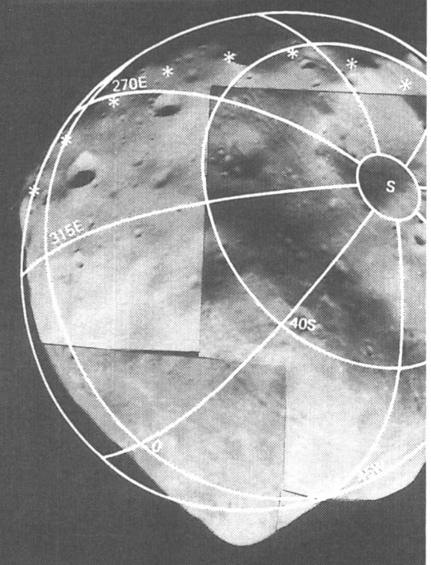
315A11

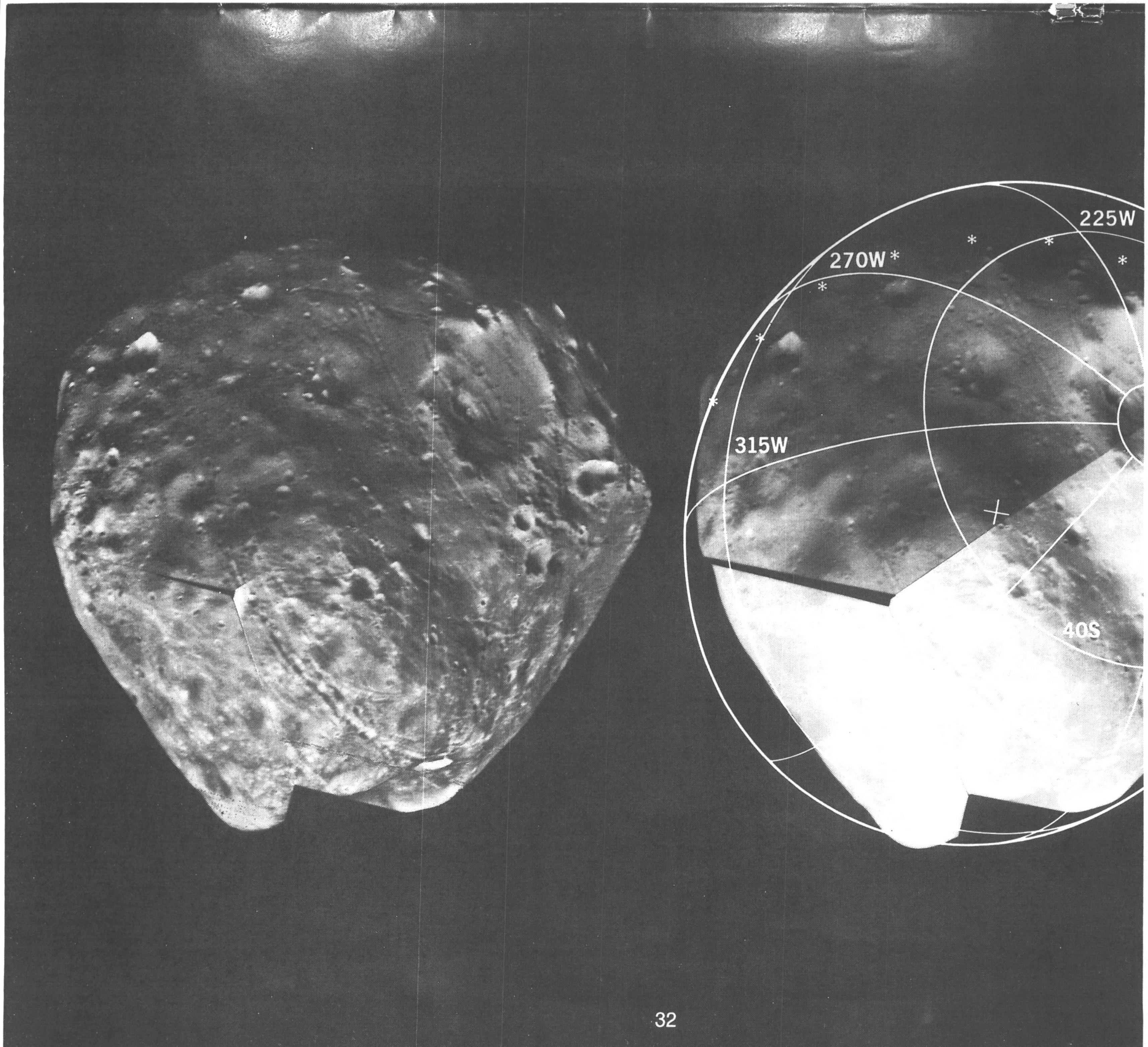


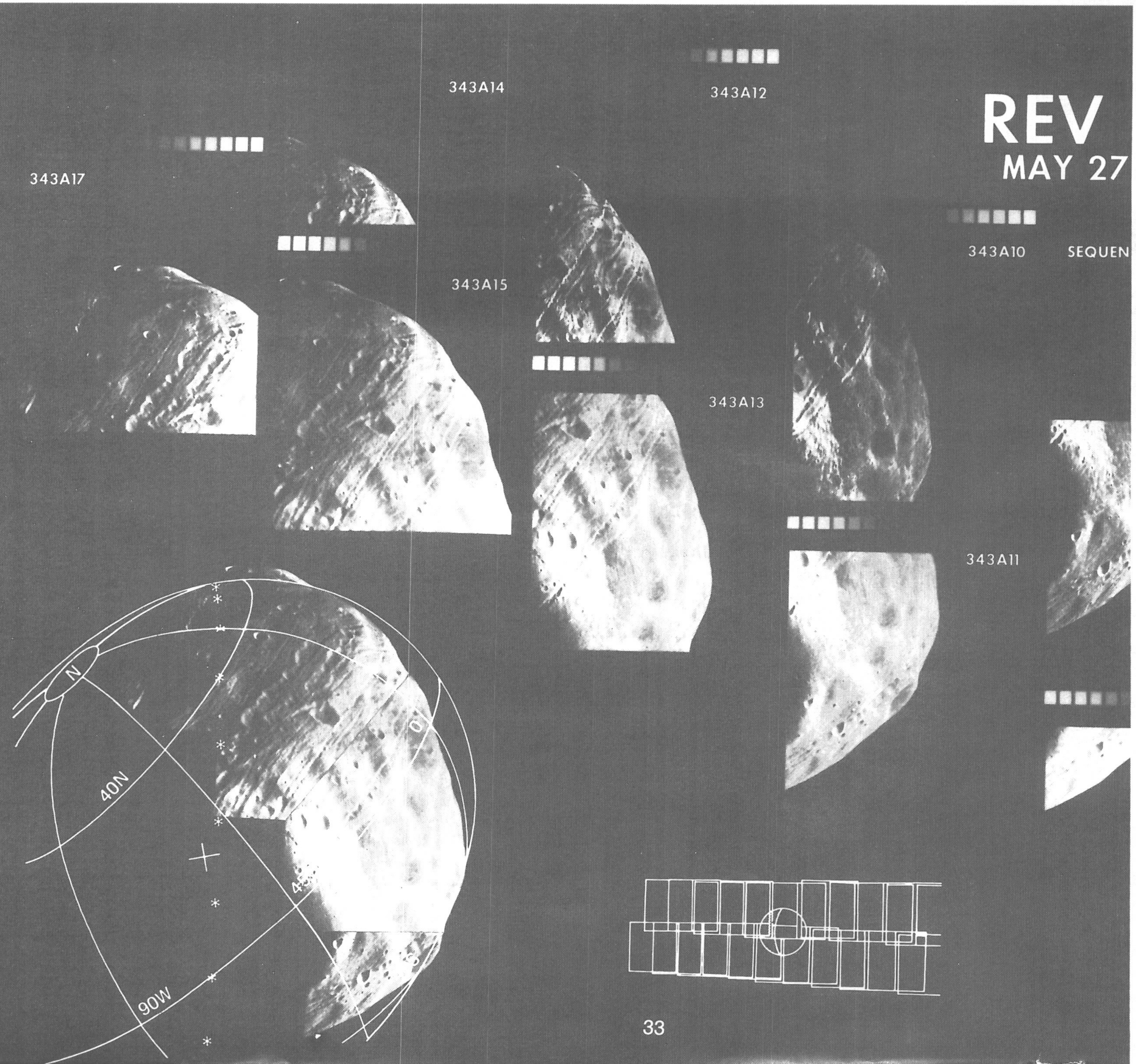
315A14

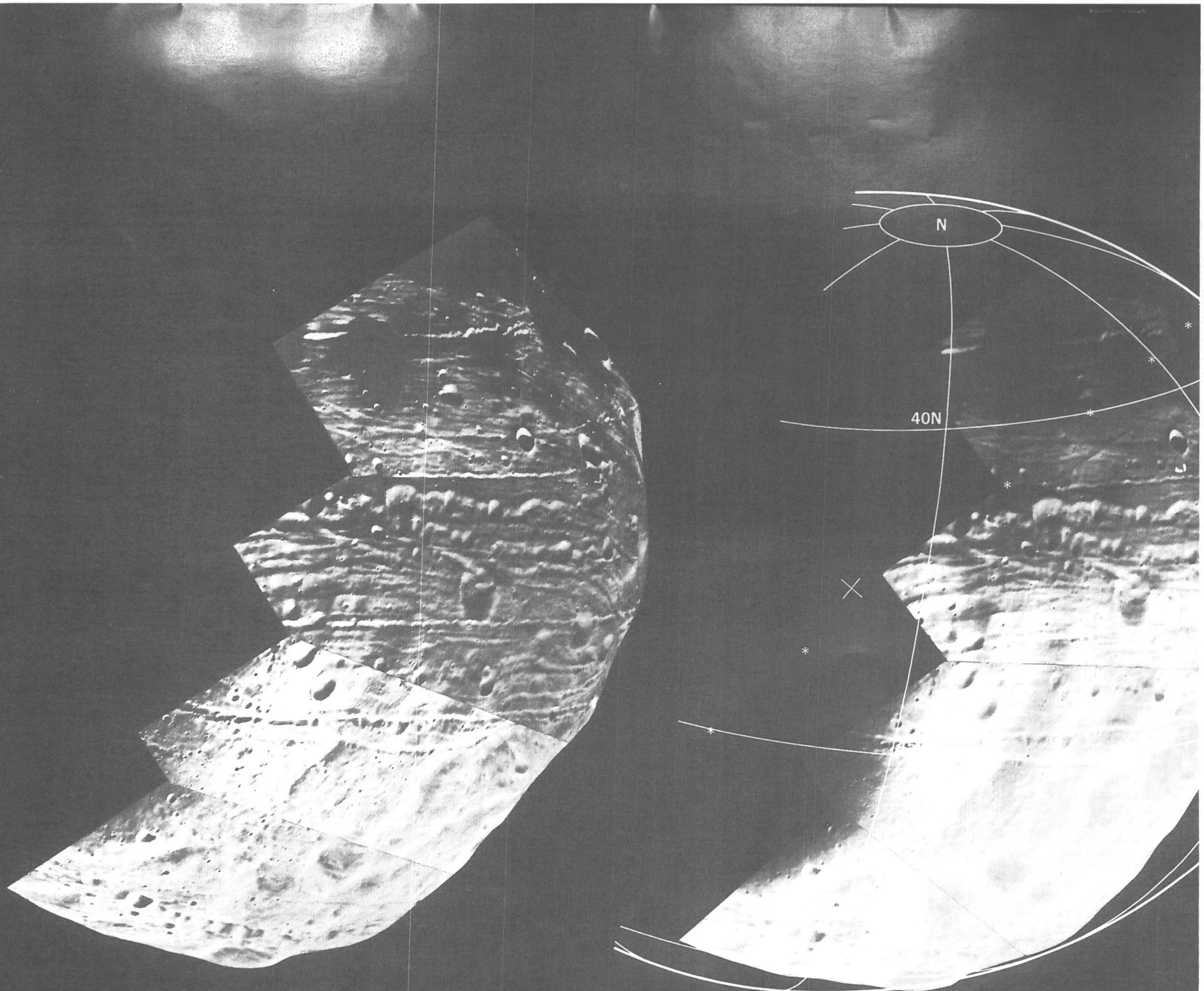


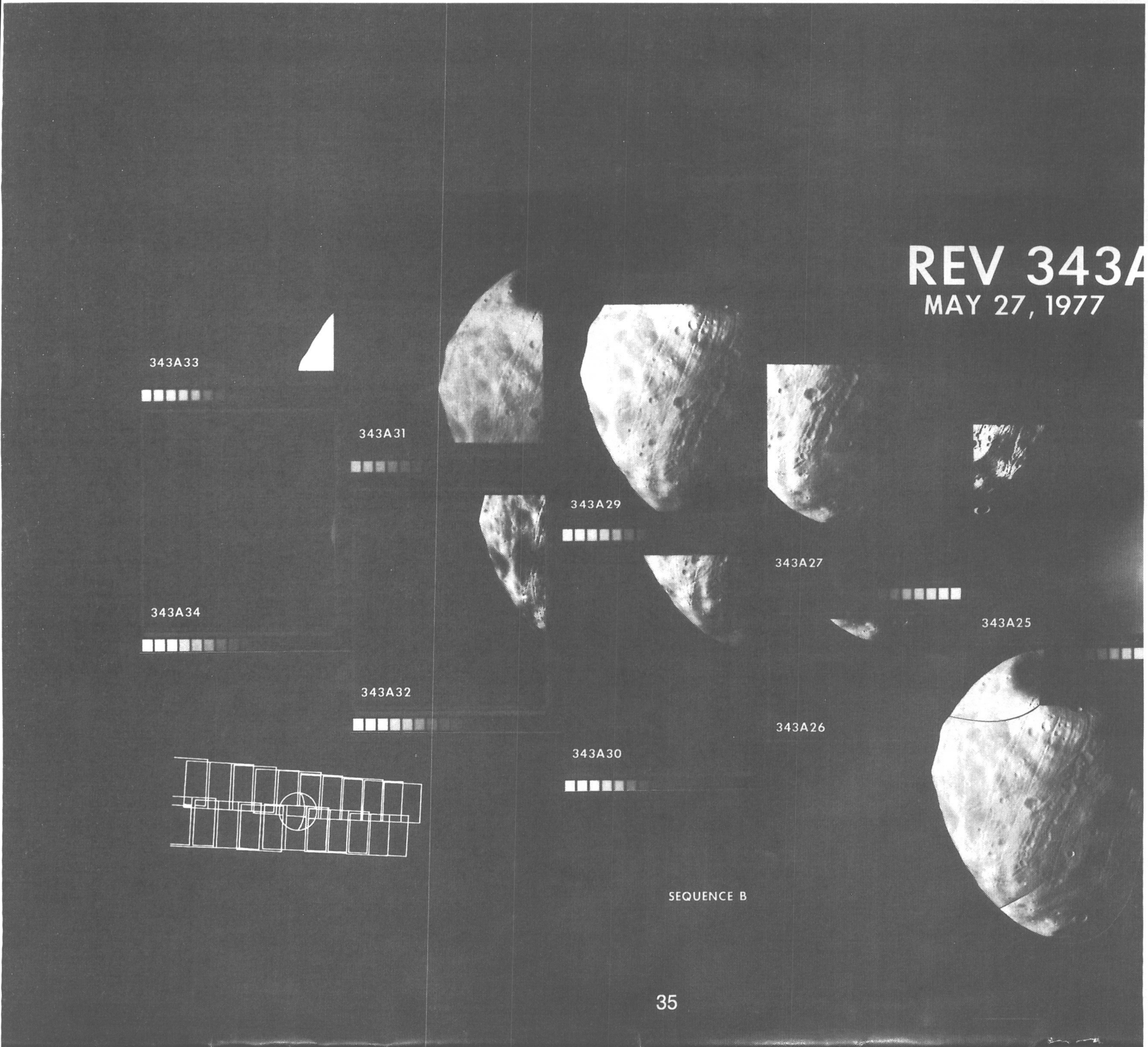
315

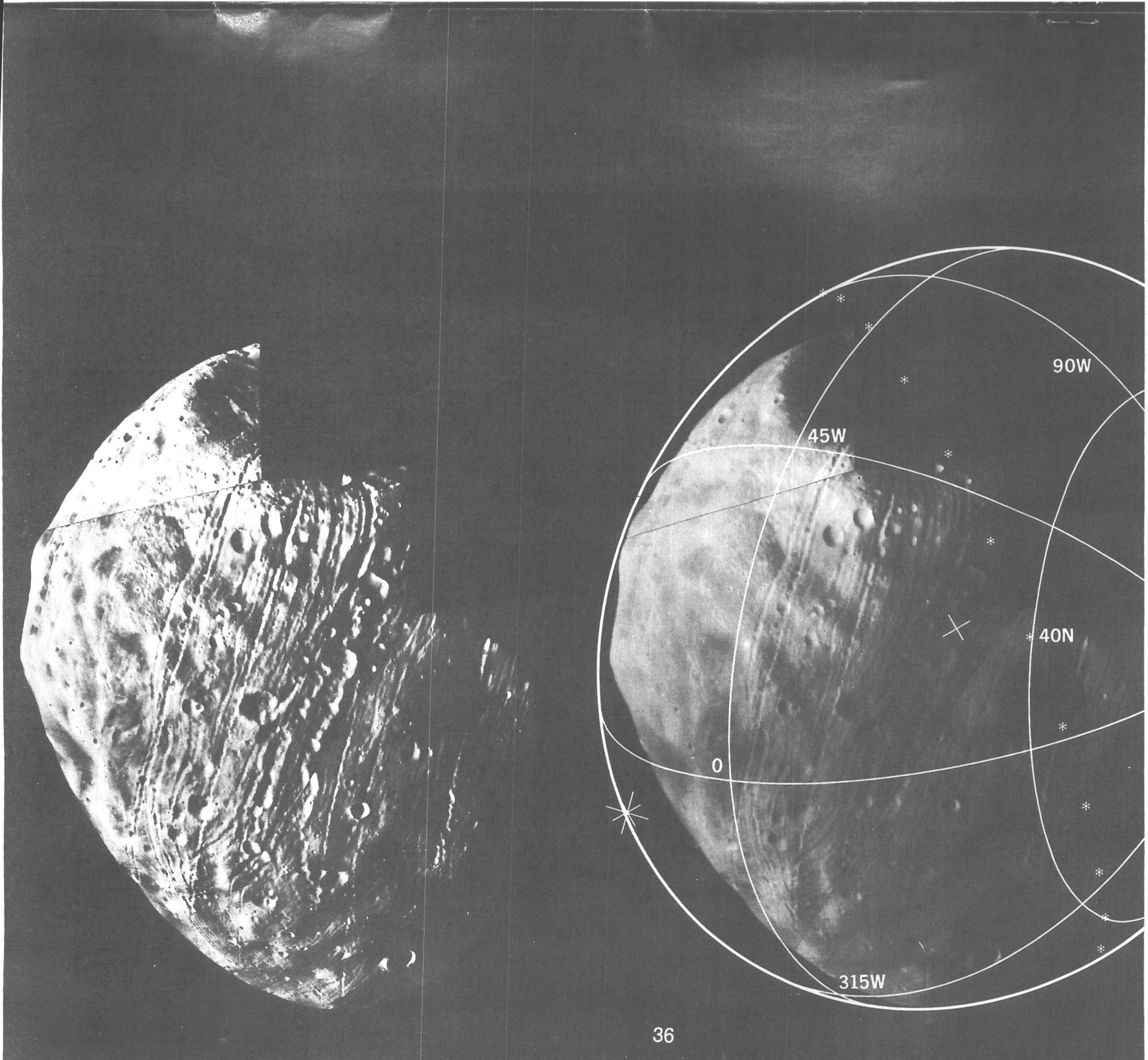



225W
270W
315W
40S


REV
MAY 27
SEQUEN
343A10
343A11
343A12
343A13
343A14
343A15
343A17
N
40N
90W


N
40N


REV 343A
MAY 27, 1977
343A33
343A31
343A29
343A27
343A25
343A34
343A32
343A26
343A30
SEQUENCE B


90W
45W
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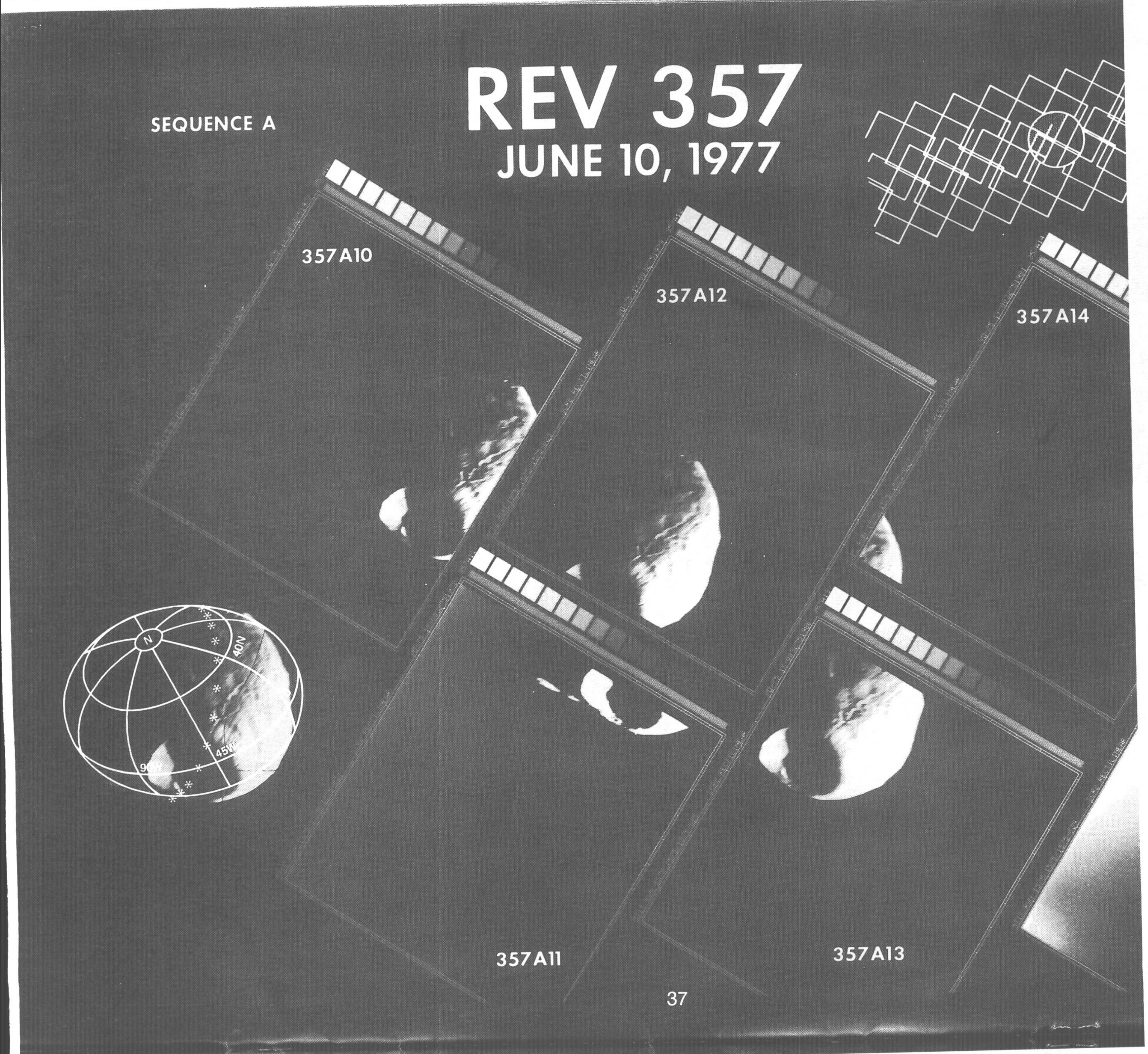
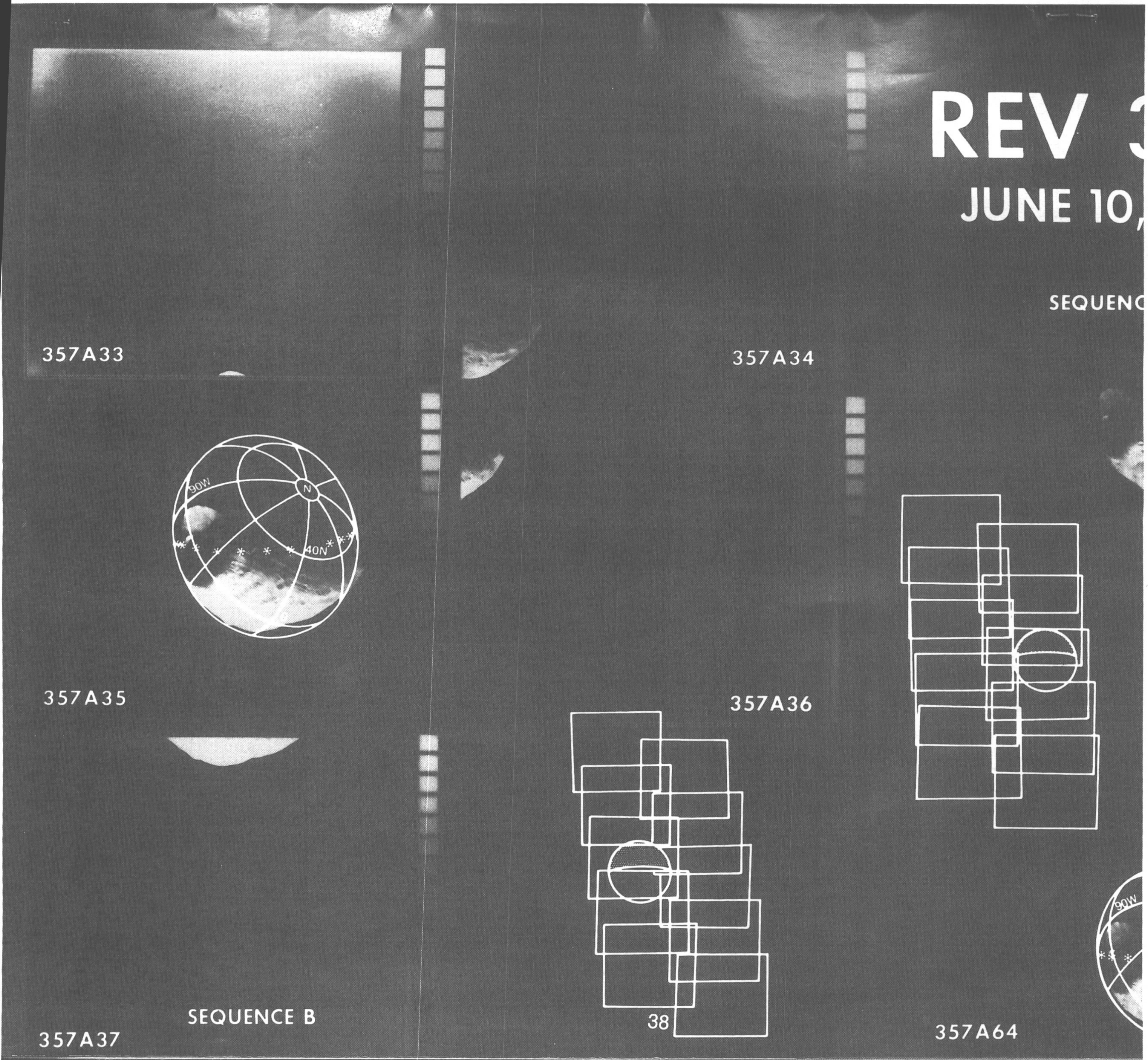
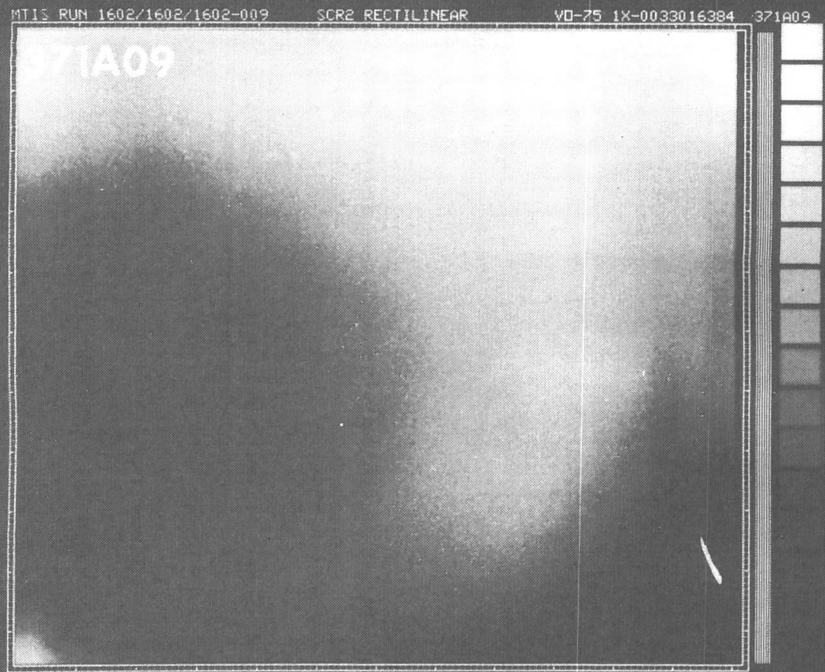
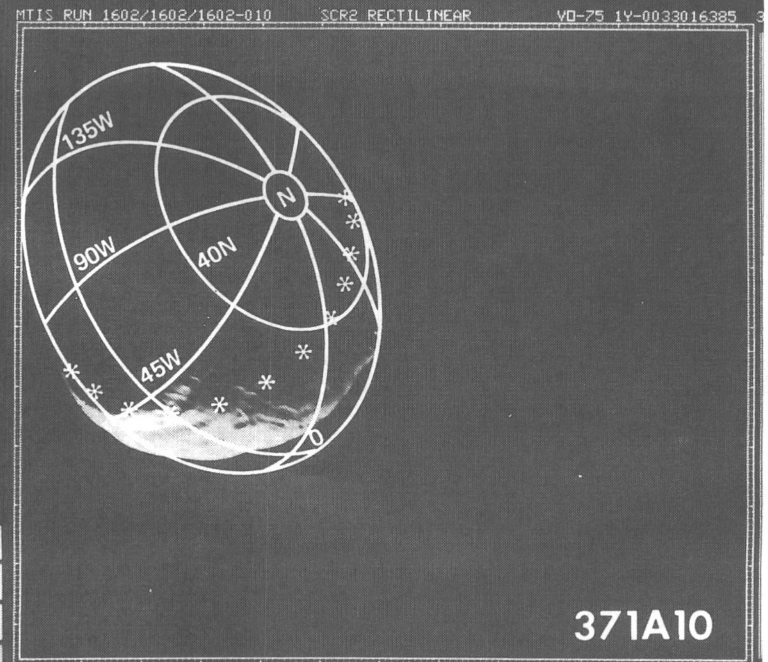
315W

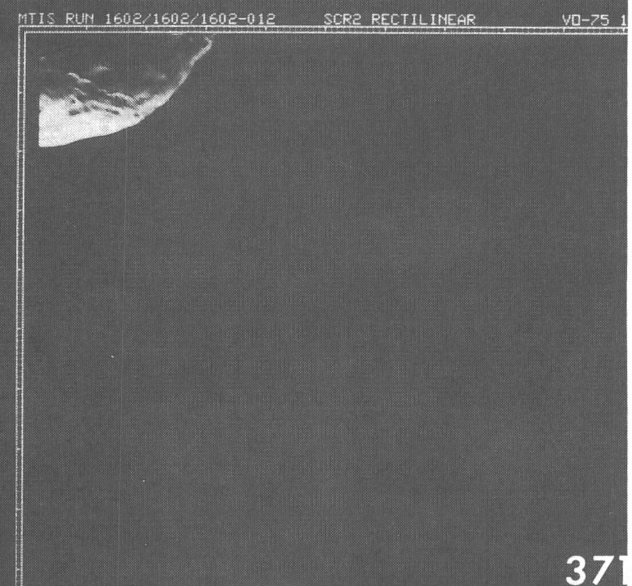

SEQUENCE A
REV 357
JUNE 10, 1977
357A10
357A12
357A14
357A11
357A13
N
40N
45W
90W


REV 3
JUNE 10,
SEQUENC
357A33
357A34
90W
N
40N
357A35
357A36
SEQUENCE B
38
357A37
357A64
90W

REV 371
JUNE 23, 1977
SEQUENCE A



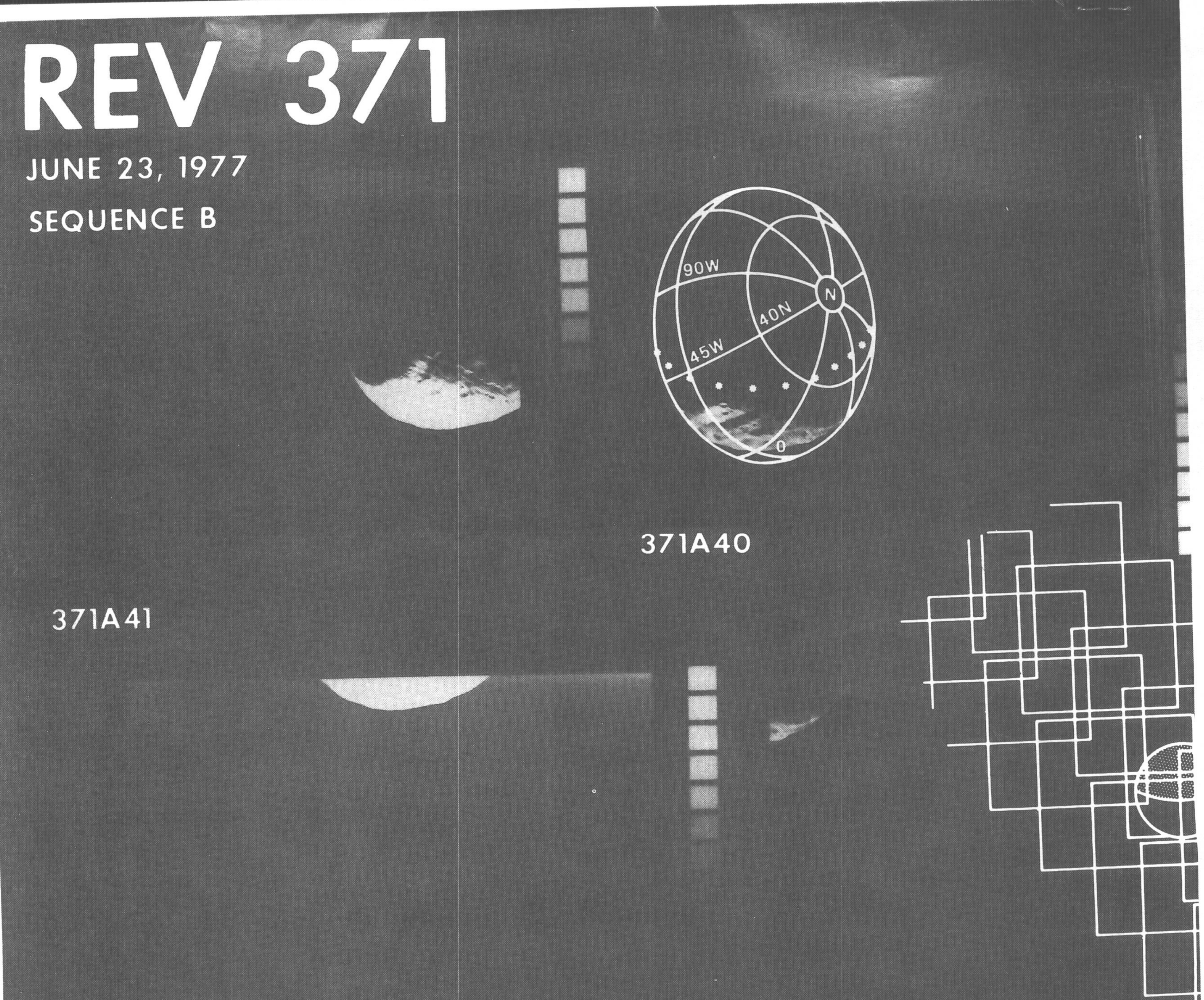




REV 371

JUNE 23, 1977

SEQUENCE B



371A40

371A41

371A43

371A42

THIRD ENCOUNTER

The final close encounter of VO-1 with Phobos occurred on October 19, 1977. No commensurability of the VO-1 and Phobos orbital periods was in effect so only one close flyby was obtained. VO-1 flew in front of Phobos to view the side facing Mars. The large crater Stickney was near the evening terminator with its floor hidden in shadow. As was the case with Mariner 9, high resolution (tens of meters) viewing of the floor of Stickney was not obtained by the Viking Orbiters.

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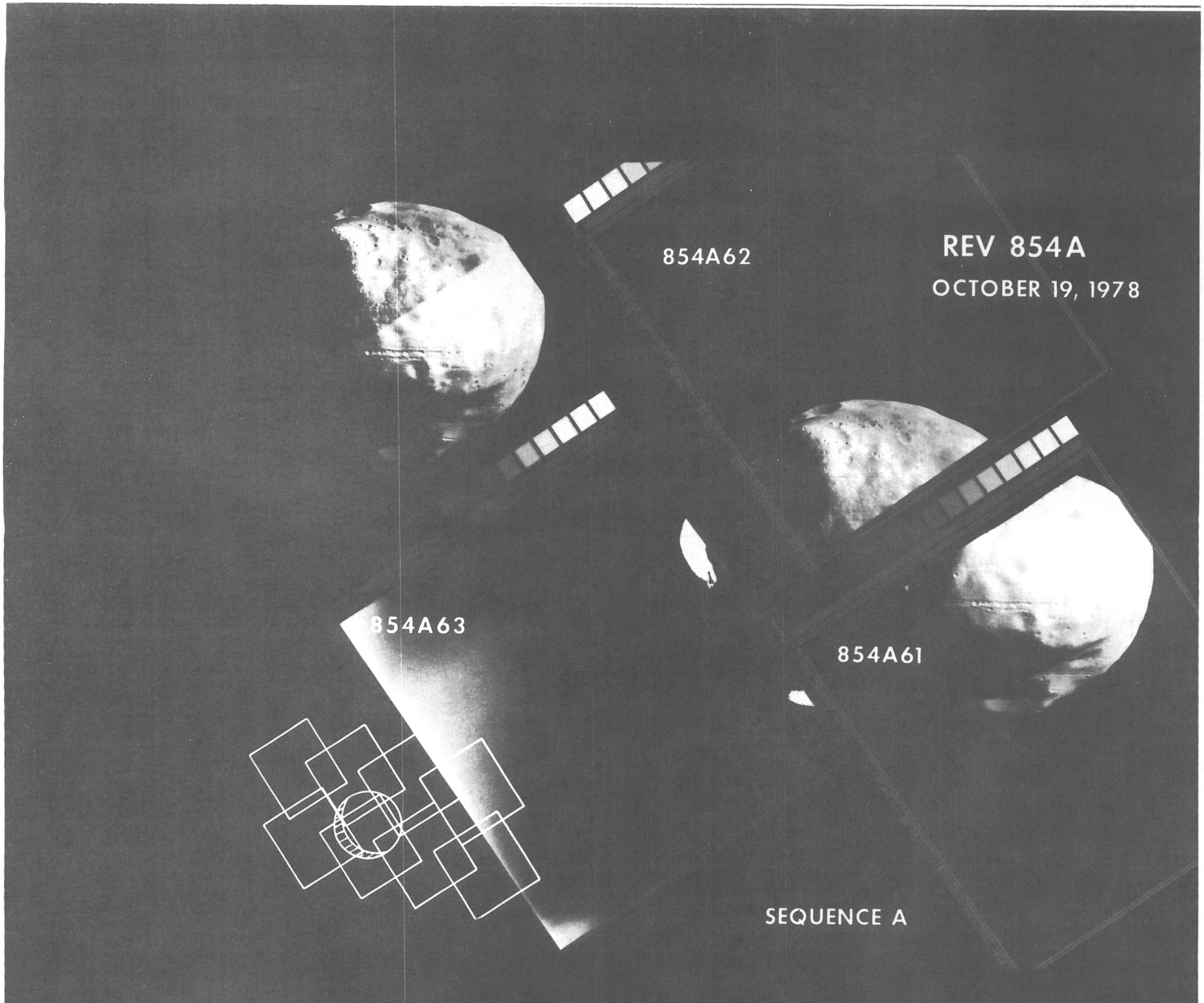
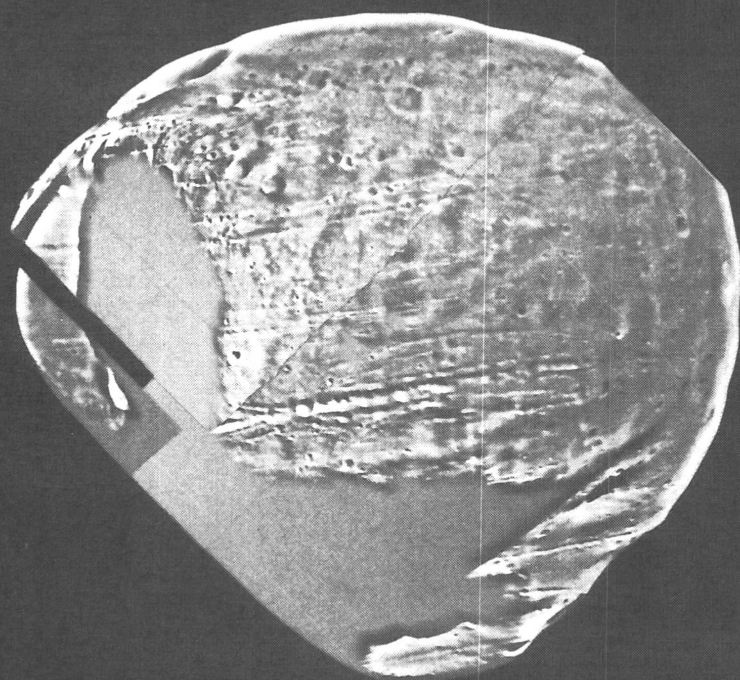
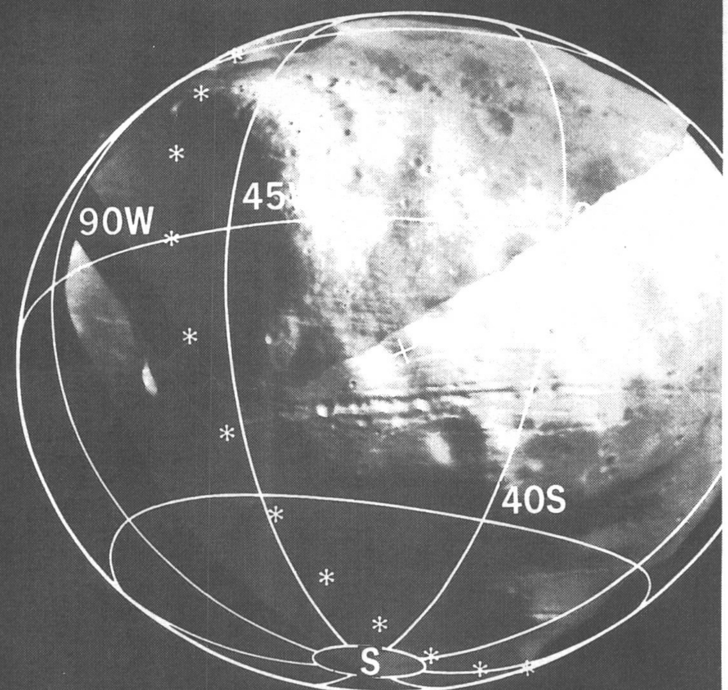
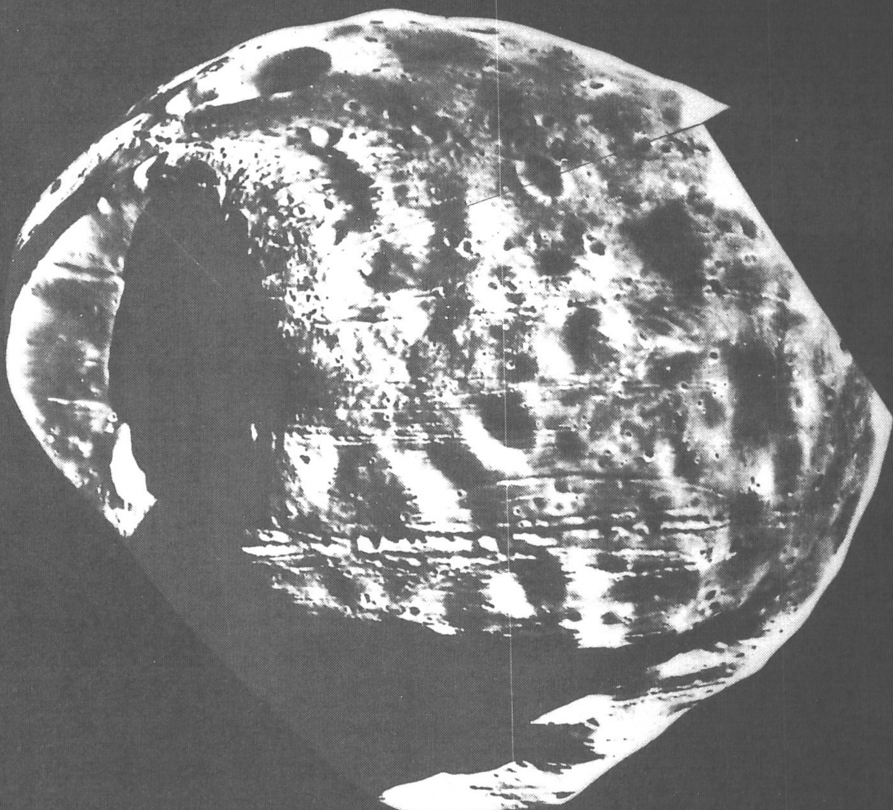
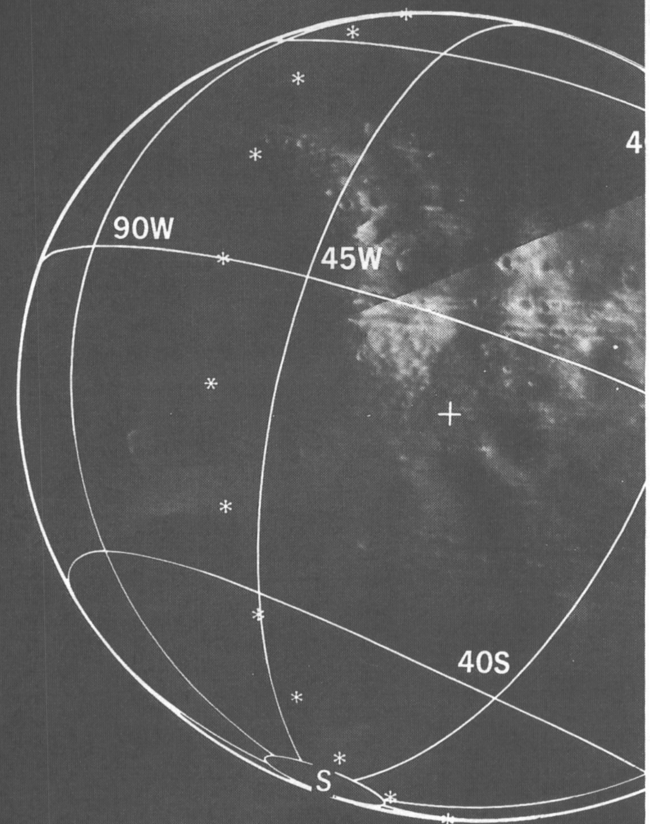

REV 854A
OCTOBER 19, 1978
854A62
854A63
854A61
SEQUENCE A




90W
45
40S
S


REV 854A
OCTOBER 19, 1978
854A82
854A83
854A81
SEQUENCE B




90W
45W
40S
S

VIEWING GEOMETRY

The following table lists the viewing geometry for each picture in the previous figures. Each picture is identified by its picture number (PICNO). The first three numbers of the PICNO are the orbiter revolution number about Mars since orbit insertion. The letter A indicates VO-1. The last two numbers indicate the specific picture on a given revolution. For each picture the sub-spacecraft and sub-solar points are given. All angles are planetocentric with longitude measured positive west and have units of degrees. The range from VO-1 to the center of Phobos is given in km. It was assumed that Phobos was in synchronous rotation with no rotational librations.

Table 1. Phobocentric Positions of VO-1 and the Sun

PICNO	SPACECRAFT			SUN	
	LAT (deg)	LONG (+W) (deg)	RANGE (km)	LAT (deg)	LONG (+W) (deg)
242A02	-23.14	206.10	467.6	-10.41	254.64
242A04	-23.64	206.02	486.7	-10.41	254.76
242A06	-24.05	205.96	503.7	-10.41	254.86
242A16	-25.94	205.78	599.7	-10.41	255.46
242A17	-26.11	205.78	610.4	-10.41	255.52
242A18	-26.25	205.77	619.0	-10.41	255.58
242A19	-26.41	205.77	629.7	-10.41	255.64
242A20	-26.53	205.77	638.3	-10.41	255.70
242A21	-26.68	205.77	649.0	-10.41	255.76
242A22	-26.80	205.77	657.6	-10.41	255.82
243A05	57.10	255.51	102.8	-10.62	251.11
243A06	52.63	248.58	100.6	-10.62	251.18
243A07	48.73	243.83	99.6	-10.62	251.23
243A08	43.55	238.83	99.4	-10.62	251.30
243A09	39.25	235.47	100.1	-10.62	251.35
243A68	-25.58	206.76	501.0	-10.62	254.25
243A69	-25.75	206.73	509.6	-10.62	254.31
243A70	-25.92	206.69	518.1	-10.62	254.36
243A71	-26.12	206.65	528.8	-10.62	254.43
243A72	-26.28	206.61	537.3	-10.62	254.48
244A02	53.22	301.68	140.8	-10.83	250.32
244A03	52.19	295.85	134.6	-10.83	250.38
244A04	51.09	290.95	130.2	-10.83	250.43
244A05	49.29	284.81	125.2	-10.83	250.50
244A08	42.39	269.53	116.3	-10.83	250.67
244A09	38.92	264.16	114.5	-10.83	250.74
244A52	-23.01	213.42	383.4	-10.83	253.04
244A54	-23.65	212.95	402.2	-10.83	253.15
244A68	-26.82	210.81	535.4	-10.83	253.99
244A69	-27.00	210.69	546.1	-10.83	254.05
244A70	-27.14	210.61	554.7	-10.83	254.11
244A71	-27.31	210.51	565.4	-10.83	254.17
244A72	-27.45	210.43	573.9	-10.83	254.22
246A02	39.56	325.77	277.3	-11.24	248.71
246A03	39.32	324.31	270.6	-11.24	248.76
246A04	38.98	322.39	262.5	-11.24	248.82
246A05	38.67	320.77	256.1	-11.24	248.88
246A06	38.20	318.68	248.3	-11.24	248.94
246A07	37.77	316.91	242.3	-11.24	249.00
246A08	37.18	314.61	235.1	-11.24	249.06
246A09	36.64	312.70	229.3	-11.24	249.12
246A10	35.89	310.20	222.6	-11.24	249.18
246A53	-25.67	223.16	480.3	-11.24	252.67
246A54	-25.92	222.77	490.5	-11.24	252.73
246A55	-26.12	222.49	498.7	-11.24	252.79
246A56	-26.36	222.13	509.0	-11.24	252.85

Table 1. Phobocentric Positions of VO-1 and the Sun (Continued)

PICNO	SPACECRAFT			SUN	
	LAT (deg)	LONG (+W) (deg)	RANGE (km)	LAT (deg)	LONG (+W) (deg)
246A57	-26.55	221.87	517.2	-11.24	252.91
246A58	-26.72	221.60	525.5	-11.24	252.96
246A59	-26.93	221.29	535.8	-11.24	253.02
246A60	-27.09	221.05	544.2	-11.24	253.08
246A61	-27.28	220.76	554.5	-11.24	253.14
246A62	-27.44	220.54	562.8	-11.24	253.20
246A63	-27.61	220.26	573.2	-11.24	253.26
246A64	-27.75	220.06	581.6	-11.24	253.32
246A65	-27.92	219.81	592.1	-11.24	253.38
246A66	-28.05	219.61	600.4	-11.24	253.43
246A67	-28.20	219.38	610.9	-11.24	253.50
246A68	-28.33	219.20	619.4	-11.24	253.55
246A69	-28.47	218.99	629.9	-11.24	253.62
246A70	-28.59	218.82	638.3	-11.24	253.67
246A71	-28.72	218.61	648.9	-11.24	253.74
246A72	-28.83	218.46	657.3	-11.24	253.79
248A01	33.73	324.79	313.1	-11.66	247.50
248A02	33.30	323.27	305.0	-11.66	247.57
248A03	32.92	322.02	298.7	-11.66	247.62
248A04	32.39	320.39	290.9	-11.66	247.69
248A05	31.94	319.03	284.9	-11.66	247.74
248A06	31.33	317.25	277.6	-11.66	247.80
248A07	30.77	315.81	271.9	-11.66	247.86
249A01	34.95	339.92	451.7	-11.86	245.93
249A02	34.83	339.32	444.1	-11.86	245.99
249A03	34.66	338.54	434.5	-11.86	246.05
249A04	34.53	337.89	426.8	-11.86	246.10
249A05	34.36	337.04	417.4	-11.86	246.17
249A06	34.20	336.34	410.0	-11.86	246.22
249A07	33.98	335.42	400.6	-11.86	246.29
250A07	-19.00	251.48	311.4	-12.07	248.97
250A09	-20.38	249.20	324.8	-12.07	249.09
250A10	-20.92	248.24	331.0	-12.07	249.14
250A11	-21.59	247.09	338.9	-12.07	249.21
250A12	-22.10	246.19	345.3	-12.07	249.26
250A13	-22.68	245.11	353.5	-12.07	249.33
250A14	-23.14	244.27	360.1	-12.07	249.38
250A15	-23.57	243.48	366.9	-12.07	249.43
250A16	-24.08	242.51	375.4	-12.07	249.50
250A58	-28.93	232.12	509.4	-12.07	250.45
250A59	-29.10	231.69	517.2	-12.07	250.50
250A60	-29.32	231.19	527.0	-12.07	250.57
250A61	-29.47	230.80	535.0	-12.07	250.62
250A62	-29.67	230.32	544.9	-12.07	250.69
250A63	-29.81	229.95	552.9	-12.07	250.74
250A64	-29.99	229.51	562.9	-12.07	250.81

Table 1. Phobocentric Positions of VO-1 and the Sun (Continued)

PICNO	SPACECRAFT			SUN	
	LAT (deg)	LONG (+W) (deg)	RANGE (km)	LAT (deg)	LONG (+W) (deg)
250A65	-30.12	229.16	571.0	-12.07	250.86
250A66	-30.25	228.82	579.0	-12.07	250.91
250A67	-30.41	228.42	589.1	-12.07	250.98
250A68	-30.52	228.10	597.3	-12.07	251.03
250A69	-30.67	227.73	607.4	-12.07	251.10
250A70	-30.78	227.43	615.6	-12.07	251.15
250A71	-30.90	227.08	625.8	-12.07	251.22
250A72	-31.01	226.80	633.9	-12.07	251.27
252A11	-20.71	255.04	388.9	-12.48	248.28
252A13	-21.80	253.12	401.9	-12.48	248.40
252A14	-22.36	252.08	409.3	-12.48	248.47
252A15	-22.78	251.29	415.3	-12.48	248.52
252A16	-23.31	250.31	423.2	-12.48	248.59
252A57	-28.67	238.79	554.9	-12.48	249.59
252A58	-28.91	238.21	564.3	-12.48	249.66
252A59	-29.09	237.76	571.8	-12.48	249.71
252A60	-29.25	237.32	579.4	-12.48	249.76
252A61	-29.46	236.80	588.9	-12.48	249.83
252A62	-29.62	236.38	596.5	-12.48	249.88
252A63	-29.81	235.88	606.1	-12.48	249.95
252A64	-29.96	235.49	613.8	-12.48	250.00
252A65	-30.14	235.01	623.5	-12.48	250.06
315A11	-48.29	341.76	712.7	-22.67	11.34
315A12	-47.55	341.83	713.9	-22.67	11.39
315A13	-46.62	341.91	715.6	-22.67	11.46
315A14	-45.87	341.98	717.2	-22.67	11.51
329A81	-13.79	332.51	548.8	-23.87	2.74
329A83	-12.25	333.00	563.1	-23.87	2.85
329A85	-10.80	333.45	578.0	-23.87	2.97
329A87	-9.42	333.89	593.0	-23.87	3.09
343A06	13.97	61.59	295.9	-24.53	348.58
343A08	15.74	58.04	302.0	-24.53	348.70
343A09	16.49	56.49	305.2	-24.53	348.75
343A10	17.37	54.59	309.5	-24.53	348.82
343A11	18.05	53.10	313.3	-24.53	348.87
343A12	18.86	51.27	318.3	-24.53	348.93
343A13	19.48	49.84	322.6	-24.53	348.99
343A14	20.20	48.08	328.3	-24.53	349.05
343A15	20.76	46.72	333.1	-24.53	349.10
343A17	21.90	43.76	344.7	-24.53	349.22
343A25	27.64	24.10	480.6	-24.53	350.28
343A26	27.78	23.42	488.3	-24.53	350.33
343A27	27.94	22.59	498.1	-24.53	350.40
343A29	28.21	21.17	515.9	-24.53	350.52

Table 1. Phobocentric Positions of VO-1 and the Sun (Continued)

PICNO	SPACECRAFT			SUN	
	LAT (deg)	LONG (+W) (deg)	RANGE (km)	LAT (deg)	LONG (+W) (deg)
343A30	28.31	20.57	523.9	-24.53	350.57
343A31	28.44	19.85	534.0	-24.53	350.63
343A32	28.53	19.29	542.1	-24.53	350.68
343A33	28.65	18.61	552.4	-24.53	350.75
343A34	28.73	18.10	560.5	-24.53	350.80
357A10	37.67	46.31	1143.0	-24.63	338.58
357A11	37.73	45.73	1150.2	-24.63	338.64
357A12	37.77	45.28	1156.0	-24.63	338.69
357A13	37.83	44.71	1163.4	-24.63	338.76
357A14	37.87	44.26	1169.4	-24.63	338.81
357A15	37.92	43.70	1176.9	-24.63	338.88
357A33	38.18	33.51	1355.7	-24.63	340.28
357A34	38.16	33.11	1364.9	-24.63	340.34
357A35	38.15	32.80	1372.1	-24.63	340.40
357A36	38.13	32.41	1381.3	-24.63	340.46
357A37	38.12	32.10	1388.7	-24.63	340.51
357A64	37.47	25.43	1590.4	-24.63	341.86
357A66	37.39	24.94	1608.7	-24.63	341.98
371A09	41.65	67.02	1426.8	-24.17	325.76
371A10	41.53	66.63	1437.8	-24.17	325.76
371A11	41.63	66.18	1440.8	-24.17	325.82
371A12	41.76	65.62	1444.6	-24.17	325.88
371A40	43.75	50.48	1593.6	-24.16	327.76
371A41	43.77	50.09	1598.9	-24.16	327.81
371A42	43.79	49.62	1605.4	-24.16	327.87
371A43	43.80	49.23	1610.6	-24.16	327.93
854A61	-17.30	19.21	964.8	6.69	338.94
854A62	-17.14	19.29	953.0	6.69	339.01
854A63	-17.01	19.36	943.6	6.69	339.06
854A81	-10.38	21.92	633.3	6.69	340.80
854A82	-10.00	22.03	621.9	6.69	340.87
854A83	-9.70	22.11	612.9	6.69	340.92

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		6. Performing Organization Code 990
7. Author(s) Thomas C. Duxbury, John D. Callahan, and Adriana C. Ocampo		8. Performing Organization Report No.
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16. Abstract

This document will form the foundation of current Mars Data Analysis and future mission studies such as Mars, Comet and Asteroid Rendezvous, etc., for the detailed, definitive studies of Phobos and small bodies in general.

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