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High-resolution Atlases of Mimas, Tethys, and Iapetus derived from Cassini-ISS images

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ABSTRACT

The Cassini Imaging Science Subsystem (ISS) acquired 282, 258, and 513 high-resolution images (<800 m/pixel) of Mimas, Tethys, and Iapetus, respectively, during two close flyby of Tethys and Iapetus and eight non-targeted flybys between 2004 and 2007. We combined these images with lower-resolution Cassini images and others taken by Voyager cameras to produce high-resolution semi-controlled mosaics of Mimas, Tethys, and Iapetus. These global mosaics are the baseline for high-resolution Mimas and Iapetus maps and a Tethys atlas. The nomenclature used in these maps was proposed by the Cassini imaging team and was approved by the International Astronomical Union (IAU). The two maps and the atlas are available to the public through the Imaging Team's website [http://ciclops.org/maps] and the Planetary Data System [http://pds.jpl.nasa.gov].

1. Introduction

The Cassini spacecraft started its tour through the Saturnian system in July 2004. The Imaging Science Subsystem onboard the orbiter consists of a high-resolution Narrow Angle Camera (NAC) with a focal length of 2000 mm and a Wide Angle Camera (WAC) with a focal length of 200 mm (Porco et al., 2004). One of the main objectives of the Cassini mission is to investigate the icy Saturnian satellites. Mimas, Tethys, and Iapetus were imaged by the Cassini spacecraft during ten flybys, two targeted to Tethys and Iapetus, and eight non-targeted flybys at a distance of 18,000 km and higher (Table 1). The images taken during these flybys allowed us to create global mosaics of Mimas, Tethys, and Iapetus with a spatial resolution of about 430, 290, and 800 m/pixel, respectively. Unfortunately, the Cassini ISS has not yet imaged the northern high latitude regions (>79°) because they are shrouded in seasonal darkness and will not be illuminated by the Sun until later in the decade during the Cassini Extended mission. Fortunately, the Voyager camera was able to take images from these regions during its flyby in the early 1980s. We thus used Voyager images to fill the North Polar gaps in the global mosaic.

Details of the image processing will be described in Section 2. Section 3 summarizes the high-level cartographic work that produced the high-resolution maps and the atlas. Three examples of these maps are shown. A brief overview of future work is given in Section 4.

2. Data processing

2.1. Image processing

The image processing chain is the same as it was used for the generation of the high-resolution Dione mosaic (Roatsch et al., 2008b). At the time of this writing, a total of 2434, 2131, and 3896 images of Mimas, Tethys, and Iapetus are available. This total data set contains images obtained through a variety of different ISS color filters and at spatial resolutions ranging from 15 m/pixel up to 160 km/pixel. For our mosaics, we selected only those images taken with the filters CL1, CL2 or GRN, as these images show comparable albedo contrasts among different terrains. Figs. 1–3 show the location of the individual Cassini images. The resolution of the selected Cassini images is given in Tables 2–4.

The Cassini orbit and attitude data used for the calculation of the surface intersection points are provided as SPICE kernels [http://naïf.jpl.nasa.gov] and were improved using a limb-fitting technique (Roatsch et al., 2006). It was not possible to improve the attitude data using a least-squares adjustment as it was possible

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for the Enceladus mosaic (Roatsch et al., 2008a) due to insufficient stereo data.

As the medium-sized Saturnian satellites are best described by tri-axial ellipsoids as derived from ISS images by Thomas et al. (2007), ellipsoids were used for the calculation of the ray intersection points during the map projection process. However, to facilitate comparison and interpretation of the maps, the projection itself was done onto a sphere with a mean radius. The radii used for the calculation of the mosaics are summarized in Table 5.

2.2. Coordinate system

The coordinate system adopted by the Cassini mission for satellite mapping is the IAU "planetographic" system, consisting of planetographic latitude and positive West longitude. The ephemeris position of the prime meridians as defined by Davies and Katayama (1983a, b, 1984) and adopted by the IAU cartography working group as standard (Seidelmann et al., 2007) is defined by a crater Palomides, Arete, and Almeric, for Mimas, Tethys, and Iapetus, respectively. Our mosaics which were calculated using the limb-fitted attitude data has a slight offset to this definition. Therefore we decided to shift the whole mosaics to be consistent with the IAU longitude definition (Table 6). This may lead to an update of a rotational parameter, the so called W_0, which is used for the calculation of the prime meridian location (Seidelmann et al., 2007).

3. Cartographic maps

Three different quadrangle schemes were used for the generation of the maps and the atlas (Figs. 4, 6 and 8):

- A synoptic map for making planet-wide maps on a single sheet was used for Mimas. The same format has already been used for the Phoebe map (Roatsch et al., 2006).
- A quadrangle scheme with 15 tiles for Mercury-sized bodies and high-resolution imaging was used for Tethys. The same schema has already been used for Enceladus (Roatsch et al., 2008a) and Dione (Roatsch et al., 2008b).

Table 1
Cassini flybys at Mimas, Tethys, and Iapetus during the Nominal Mission (2004–2008), in which (t) means targeted flyby and (nt) means non-targeted flyby.

Target	Flyby date	Flyby distance (km)
Iapetus (nt)	31 December 2004	123,402
Tethys (nt)	9 March 2005	82,868
Mimas (nt)	15 April 2005	82,489
Tethys (nt)	2 May 2005	51,858
Mimas (nt)	2 August 2005	61,149
Mimas (nt)	23 September 2005	70,012
Tethys (t)	24 September 2005	1,498
Tethys (nt)	27 June 2007	18,420
Iapetus (t)	10 September 2007	1,645
Mimas (nt)	3 December 2007	84,165

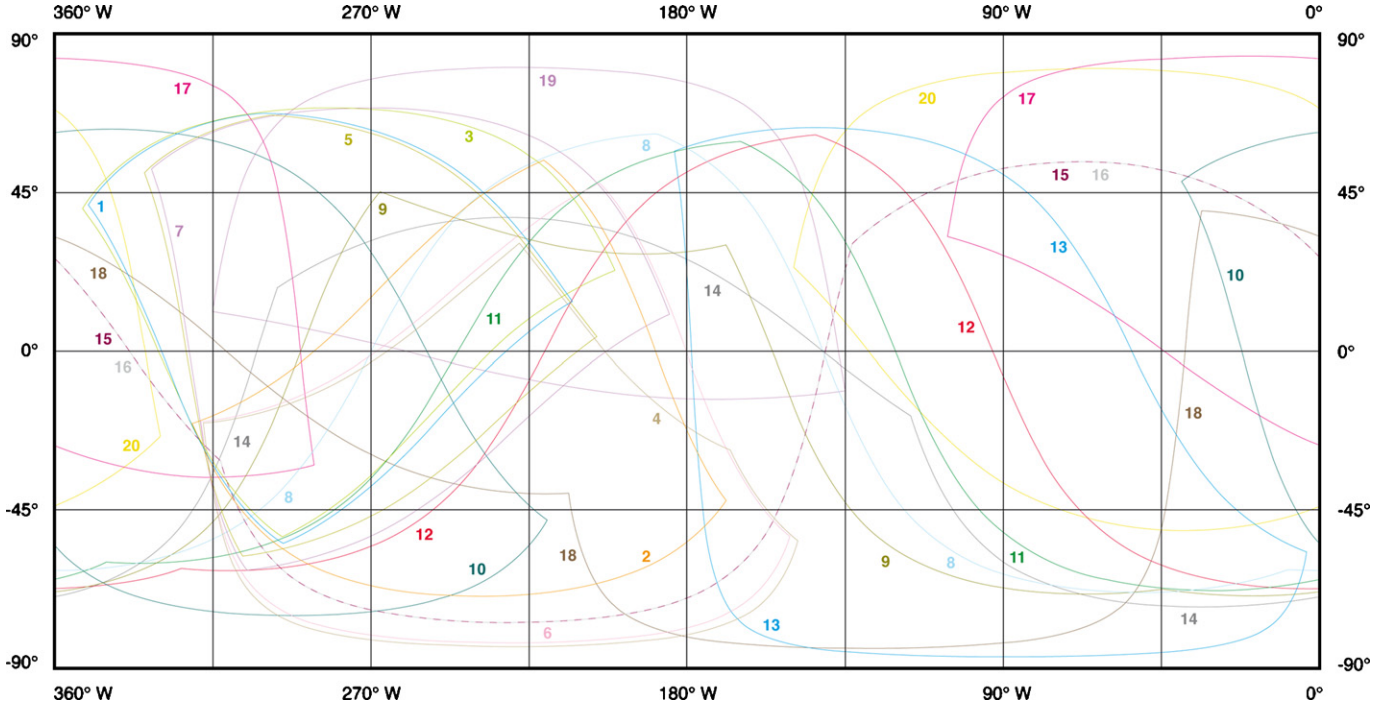

Fig. 1. Global mosaic showing the location of the Cassini ISS images used for the calculation of the Mimas mosaic (see Table 2). Mosaic is in Simple Cylindrical projection with latitude = 0°, longitude = 180°W at the center.

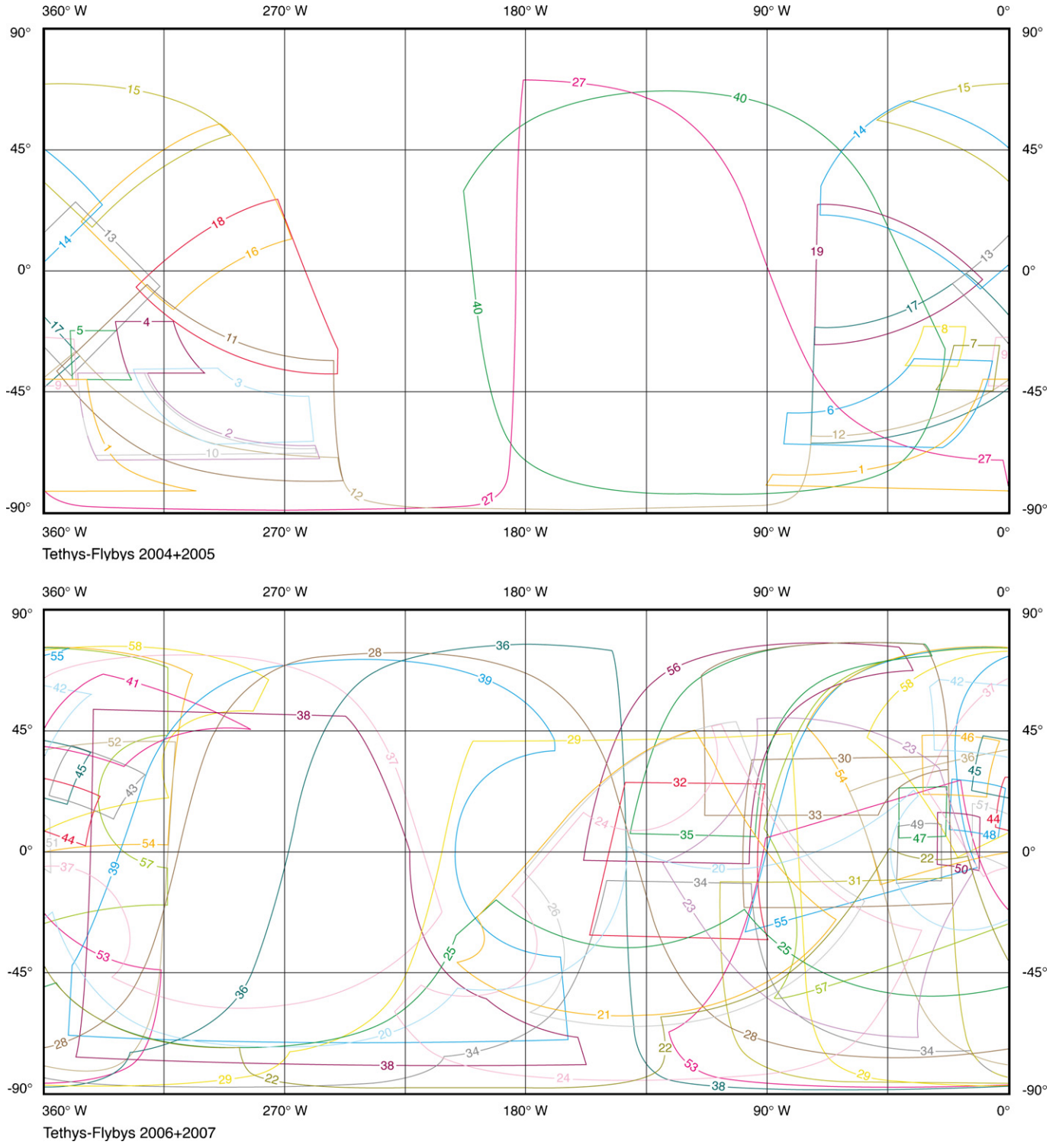

Fig. 2. Global mosaics showing the location of the Cassini ISS images used for the calculation of the Tethys mosaic (see Table 3). Mosaics are in Simple Cylindrical projection with latitude = 0°, longitude = 180°W at the center.

- A quadrangle scheme with 3 tiles, a subdivision of the synoptic map was used for Iapetus.

The individual maps and tiles were extracted from global mosaics and reprojected into the defined map projections. We added resolution maps and index maps for the maps and for every individual tile of the atlas, showing the image resolution, the image numbers and the location of the images for every map, respectively.

The nomenclature proposed by the Cassini-ISS team was approved by the IAU [http://planetarynames.wr.usgs.gov/]. By international agreement, the features must be named after people or locations in

- "Le Morte d'Arthur" for Mimas (Baines, 1962).
- "The Odyssey of Homer" for Tethys (Bates, 1929).
- "The Song of Roland" for Iapetus (Sayers, 1967).

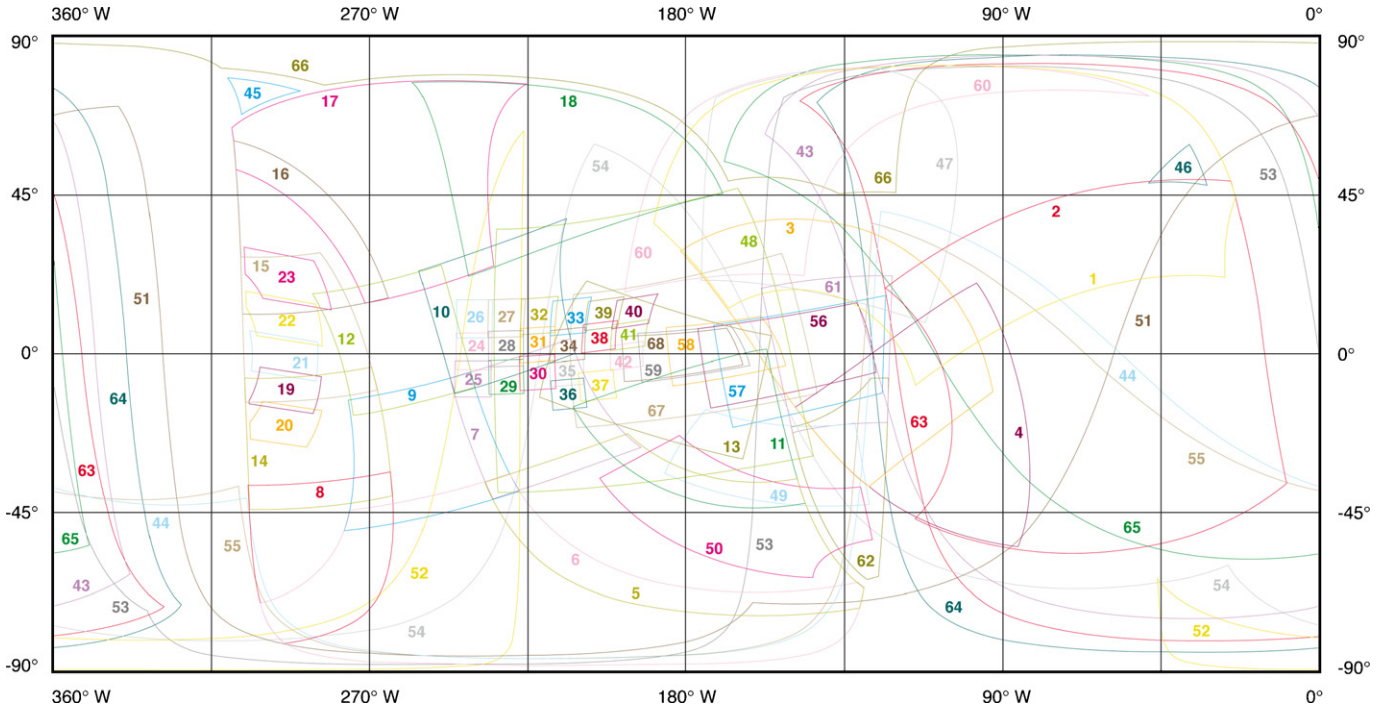

Fig. 3. Global mosaic showing the location of the Cassini ISS images used for the calculation of the Iapetus mosaic (see Table 4). Mosaic is in simple cylindrical projection with latitude = 0°, longitude = 180°W at the center.

Table 2
Cassini images used for the Mimas mosaic.

Image number	Image name	Resolution (km/pixel)	Center latitude (degree)	Center longitude (WEST/degree)
1	N1501649383	0.367	9.4	304.7
2	N1501649103	0.367	−12.1	217.2
3	N1501649653	0.367	42.8	280.7
4	N1501646674	0.381	N/A	N/A
5	N1501647313	0.376	6.1	300.1
6	N1501646883	0.379	−26.3	207.2
7	N1501647096	0.377	31.1	259.6
8	N1501637465	0.670	−30.9	217.3
9	N1501640895	0.522	−55.4	219.0
10	N1492217357	0.566	14.0	290.4
11	N1501632879	0.934	−28.3	167.0
12	N1501627117	1.364	−26.7	141.8
13	N1484517052	2.440	−7.7	129.0
14	N1542758143	0.884	−66.0	294.9
15	N1558927289	1.151	−26.0	104.5
16	N1558927388	1.154	−24.7	103.7
17	N1591657420	1.549	N/A	N/A
18	N1592293760	1.267	N/A	N/A
19	N1585677849	4.277	N/A	N/A
20	N1584745311	8.620	N/A	N/A

Resolution, Center latitude and Center longitude were calculated using reconstructed SPICE kernels.

Table 3
Cassini images used for the Tethys mosaic.

Image number	Image name	Resolution (km/pixel)	Center latitude (degree)	Center longitude (WEST/degree)
1	N1506219253	0.183	−55.2	357.1
2	N1506219411	0.174	−52.0	328.0
3	N1506219569	0.166	−48.7	299.4
4	N1506219742	0.156	−28.2	318.5
5	N1506219906	0.146	−31.3	338.6
6	N1506219094	0.192	−47.1	26.3
7	N1506220229	0.129	−36.0	11.9
8	N1506220392	0.120	−28.3	24.0
9	N1506220068	0.137	−33.9	355.7
10	N1506219461	0.343	−51.0	329.2

Table 3 (*continued*)

Image number	Image name	Resolution (km/pixel)	Center latitude (degree)	Center longitude (WEST/degree)
11	N1506215544	0.392	−38.2	314.0
12	N1506215648	0.385	N/A	N/A
13	N1506215648	0.398	−5.9	346.6
14	N1506215300	0.406	24.9	12.3
15	N1506215195	0.413	58.4	339.6
16	N1506215072	0.419	18.3	308.7
17	N1506215772	0.379	−31.5	22.5
18	N1506214956	0.427	−6.6	281.1
19	N1506215893	0.373	−1.8	56.1
20	N1532362675	0.778	−51.2	92.9
21	N1532368192	0.719	−17.4	126.8
22	N1532368361	0.719	−48.4	8.2
23	N1532368450	0.718	−14.9	67.1
24	N1532369498	0.722	−37.3	103.7
25	N1532368277	0.719	−75.9	150.5
26	N1532368541	0.719	−17.7	114.3
27	N1514130023	1.175	−1.9	87.4
28	N1546290562	2.472	−2.6	206.0
29	N1563698108	1.292	−35.8	154.8
30	N1567092921	0.478	5.5	67.4
31	N1567093505	0.488	−41.4	65.3
32	N1567094660	0.504	−3.3	120.5
33	N1567092361	0.470	44.1	73.8
34	N1567094086	0.496	−42.1	127.3
35	N1567091785	0.460	33.6	120.5
36	N1563723519	2.702	−0.5	225.5
37	N1536538911	1.319	52.4	271.2
38	N1519574913	0.915	−6.2	274.3
39	N1519541542	0.989	−0.3	265.7
40	N1477564227	4.001	6.0	81.1
41	N1561669628	0.220	48.0	334.5
42	N1561669433	0.208	49.1	9.3
43	N1561668893	0.181	26.3	340.9
44	N1561668728	0.172	15.6	351.9
45	N1561669088	0.190	30.4	358.6
46	N1561669268	0.199	31.9	17.9
47	N1561668355	0.155	14.9	30.8
48	N1561668552	0.164	16.6	11.1
49	N1561668192	0.148	0.3	32.1
50	N1561668012	0.141	4.6	17.9
51	N1561667821	0.134	6.6	4.8
52	N1558912068	0.775	−6.4	1.3
53	N1558912312	0.787	−29.3	49.3
54	N1558911852	0.766	41.5	9.2
55	N1558911617	0.754	22.6	65.7
56	N1567098978	0.573	29.1	129.1
57	N1558912903	0.816	10.8	36.8
58	N1561674168	0.503	36.1	4.1

Resolution, Center latitude and Center longitude were calculated using reconstructed SPICE kernels.

Table 4
Cassini images used for the Iapetus mosaic.

Image number	Image name	Resolution (km/pixel)	Center latitude (degree)	Center longitude (WEST/degree)
1	N1483152827	1.031	53.3	97.0
2	N1483151512	1.042	3.5	62.0
3	N1483152915	1.030	N/A	N/A
4	N1483153026	1.029	N/A	N/A
5	N1568158499	0.440	−48.0	196.8
6	N1568158329	0.437	−63.1	243.1
7	N1568158005	0.431	−17.6	225.0
8	N1568160072	0.463	−58.8	314.9
9	N1568158175	0.434	−26.2	253.9
10	N1568157856	0.429	10.3	234.2
11	N1568158669	0.444	−20.2	165.7
12	N1568157685	0.427	2.4	260.8
13	N1568158824	0.444	3.0	194.8
14	N1568159799	0.457	−24.2	288.4
15	N1568159640	0.456	5.1	294.6
16	N1568159484	0.455	37.1	307.2
17	N1568159313	0.451	43.5	262.5
18	N1568159140	0.447	N/A	N/A
19	N1568136967	0.138	−10.5	292.7

Table 4 (*continued*)

Image number	Image name	Resolution (km/pixel)	Center latitude (degree)	Center longitude (WEST/degree)
20	N1568136804	0.135	−19.9	293.5
21	N1568137129	0.140	−0.8	292.8
22	N1568137291	0.142	9.4	292.6
23	N1568137456	0.145	20.7	292.1
24	N1568136493	0.129	1.3	240.4
25	N1568136601	0.131	−7.1	240.7
26	N1568136385	0.128	9.9	240.2
27	N1568136263	0.126	10.0	231.4
28	N1568136155	0.125	1.5	231.4
29	N1568136048	0.123	−6.4	231.2
30	N1568135924	0.122	−5.2	222.6
31	N1568135816	0.120	2.7	222.6
32	N1568135709	0.119	10.7	222.2
33	N1568135485	0.116	10.4	213.4
34	N1568135276	0.113	2.6	214.0
35	N1568135069	0.110	−4.6	214.1
36	N1568134861	0.107	−11.2	213.8
37	N1568134636	0.104	−8.8	205.6
38	N1568134220	0.098	4.7	205.1
39	N1568134012	0.096	11.3	203.4
40	N1568133787	0.093	11.8	195.6
41	N1568133579	0.090	5.3	196.7
42	N1568133373	0.087	−0.6	197.3
43	N1510255179	3.817	15.9	41.9
44	N1523307179	4.143	−43.6	143.9
45	N1568093591	0.468	45.4	29.4
46	N1483280710	1.120	28.7	306.7
47	N1483224049	0.754	N/A	N/A
48	W1568133373	0.866	−1.4	197.9
49	W1568128891	0.272	−29.9	162.8
50	W1568129083	0.290	−40.3	179.8
51	N1516797516	5.734	−29.6	325.6
52	N1477172052	9.375	−42.4	247.3
53	N1482859953	4.293	8.0	65.9
54	N1476736717	6.679	N/A	N/A
55	N1523343899	3.937	−44.7	154.9
56	W1568125216	0.267	1.6	142.9
57	W1568124573	0.348	0.5	135.6
58	W1568125898	0.202	0.3	174.6
59	W1568126253	0.165	0.2	180.0
60	N1483234267	0.790	63.1	205.2
61	N1568091787	0.493	2.7	121.3
62	N1568091950	0.492	−32.5	116.5
63	N1489599730	10.335	40.1	357.5
64	N1510080240	5.570	7.4	39.5
65	N1510425871	2.636	29.2	23.9
66	N1568091469	0.499	73.5	123.7
67	W1568130503	0.472	−0.5	191.7
68	W1568126415	0.145	0.4	177.2

Resolution, Center latitude and Center longitude were calculated using reconstructed SPICE kernels.

Table 5
Three-axial radii and mean radius (in km) of the Saturnian satellites discussed in this paper.

Target	A_axis	B_axis	C_axis	Mean radius
Mimas	207.7	196.7	190.6	198.2
Tethys	540.4	531.1	527.5	536.3
Iapetus	747.1	749.0	712.6	736.0

Table 6
Performed longitude shifts of the maps to conform the IAU definition of the prime meridian location.

Satellite	Reference crater	Longitude shift (West) (degrees)
Mimas	Palomides	−4.0
Tethys	Arete	−1.5
Iapetus	Almeric	5.0

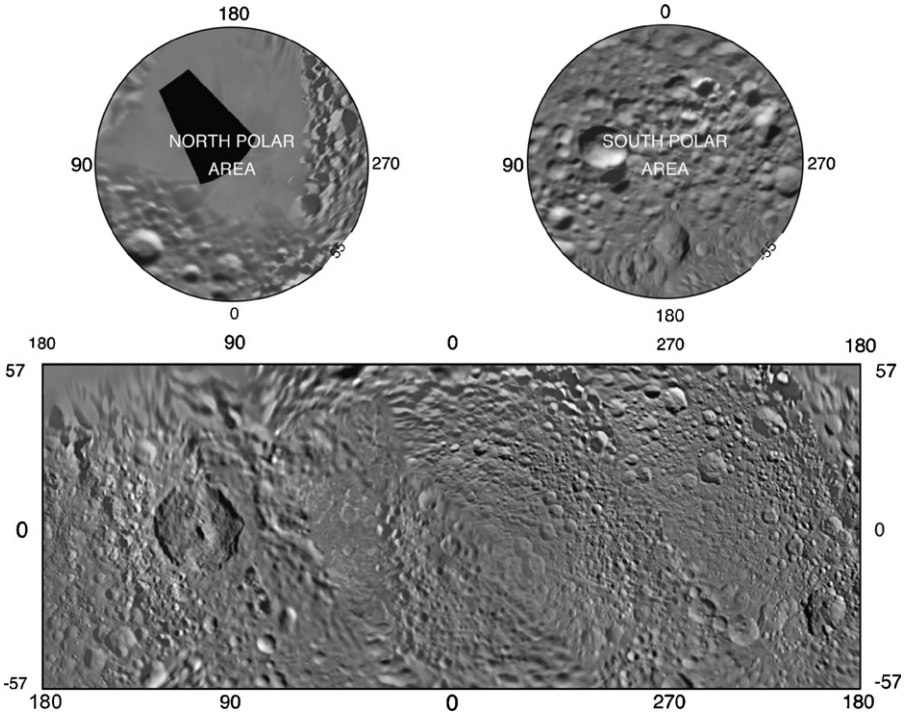

Fig. 4. Quadrangle scheme of the synoptic map filled with the Mimas tiles.

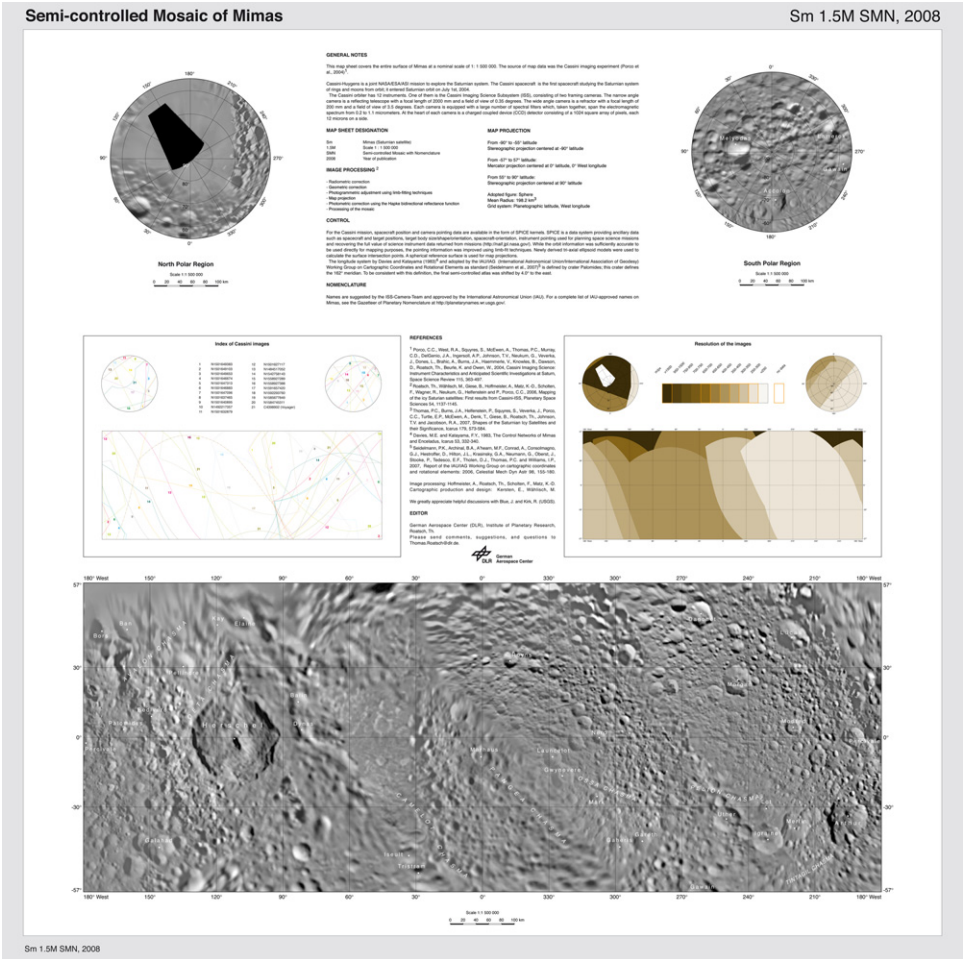

Fig. 5. Synoptic map of Mimas at 1:1,500,000 scale.

The maps and the atlas are available to the public through the Imaging Team's website [http://ciclops.org/maps]. The map tiles are also archived as standard products in the Planetary Data System (PDS) [http://pds.jpl.nasa.gov/].

3.1. Mimas map

The Mimas map was produced in a scale of 1:1,500,000. The quadrangle scheme is proposed by Greeley and Batson (1990) for planet-wide mapping (Fig. 4). The synoptic map consists of an equatorial part from −57° to 57° in Mercator projection, centred at 0° latitude and 0° longitude. The poles (−55° to −90° and 55–90°) are in Stereographic projection and centred at −90° latitude, 0° longitude and 90° latitude, 0° longitude, respectively. The poles have the same resolution as the Mercator mosaic; this is different from the suggested scheme, where as the circumference of the pole should correspond to the width of the equatorial part. We thus avoided a disproportional, enlarged North pole mosaic. The whole map sheet (Fig. 5) is in a size of 1000 mm × 1000 mm with a hardcopy resolution of 3.5 pixel/mm.

3.2. Tethys atlas

The Tethys atlas was produced in a scale of 1:1,000,000 and consists of 15 tiles that conform to the quadrangle scheme proposed by Greeley and Batson (1990) and Kirk et al. (1998) (Fig. 6). A map scale of 1:1,000,000 guarantees a mapping at the highest available Cassini resolution and results in an acceptable printing scale for the hardcopy map of 3.4 pixel/mm and a user-friendly map size of 1200 mm width by 870 mm height. The equatorial part of the map (−22° to 22° latitude) is in Mercator projection, the regions between the equator region and the poles (−66° to

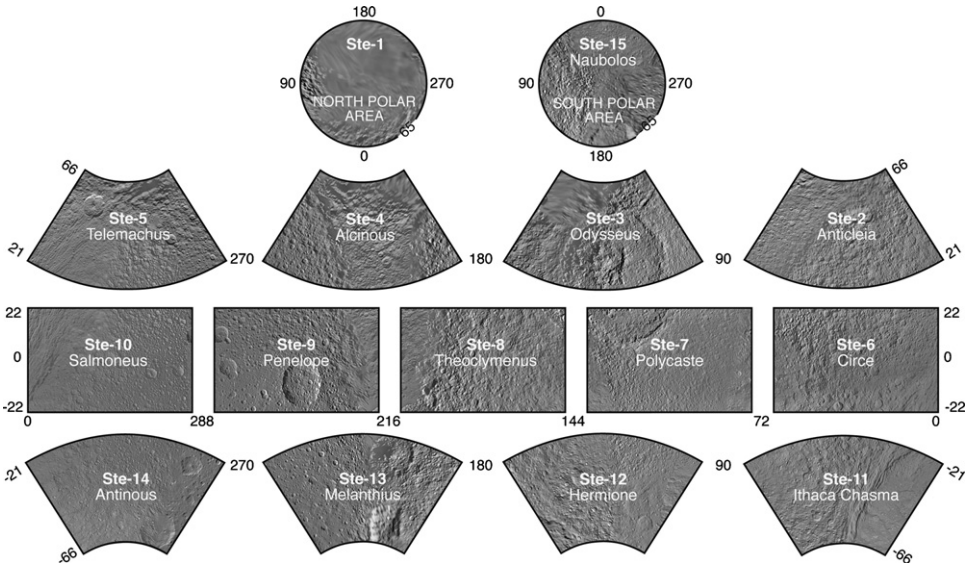

Fig. 6. Fifteen parts of the quadrangle scheme filled with the Tethys.

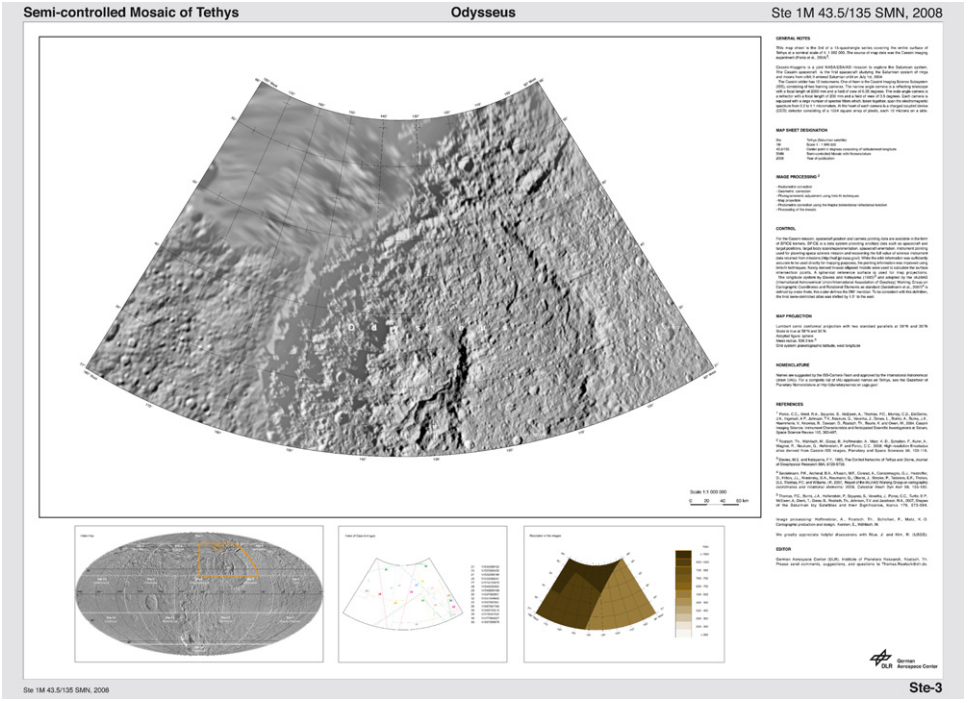

Fig. 7. Tethys map sheet 03: Odysseus.

−21° and 21–66° latitude) are projected in Lambert conic, and the poles (−65° to −90° and 65–90° latitude) in projection. See Roatsch et al. (2008a) for details of the projections. Fig. 7 shows sheet 03 of the Tethys atlas named "Odysseus".

3.3. Iapetus map

The Iapetus map was generated in a scale of 1:3,000,000 using the quadrangle scheme proposed by Greeley and Batson

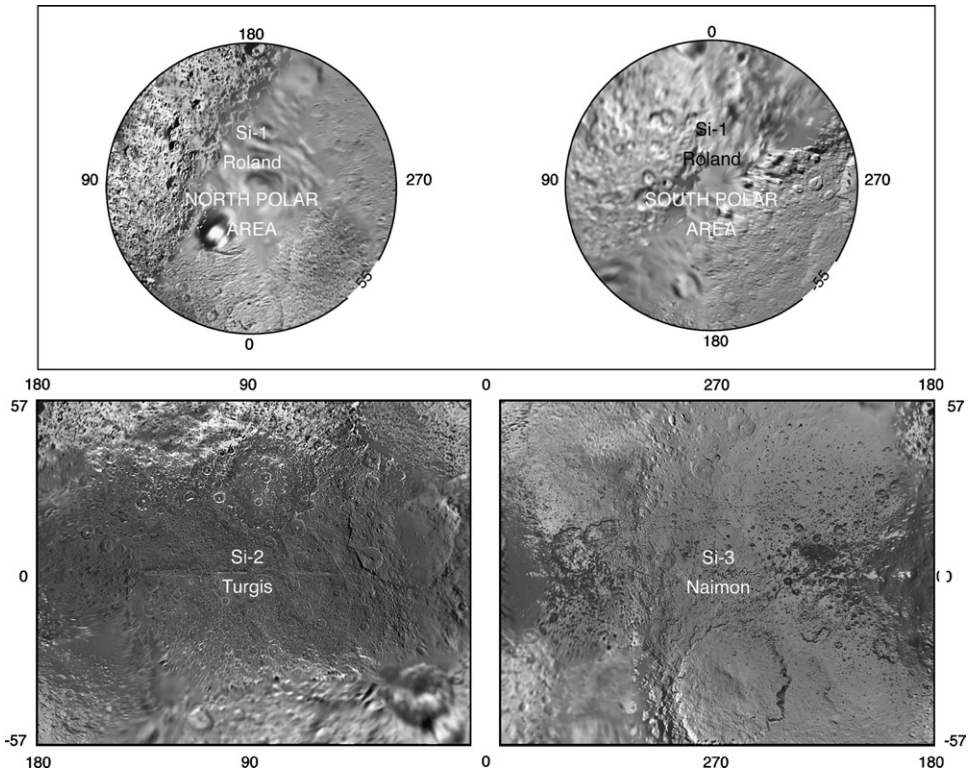

Fig. 8. Quadrangle scheme consisting of three tiles filled with the Iapetus.

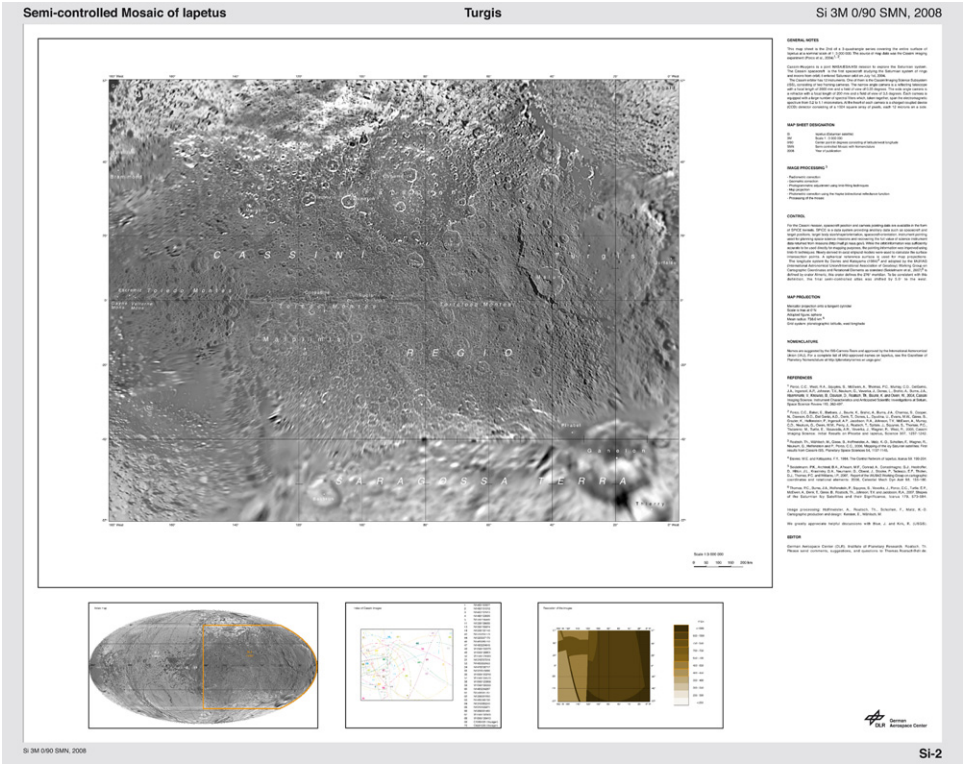

Fig. 9. Iapetus map sheet 02: Turgis.

(1990) for planet-wide mapping on three sheets (Fig. 8). The equatorial part from −57° to 57° is divided into two tiles with 180° longitude width each: tile Si-2 is called "Turgis" (Fig. 9), centred at 0° latitude, 90° West longitude, tile Si-3 is called "Naimon", centred at 0° latitude, 270° West longitude. The poles are on one sheet Si-1, called "Roland" in the same scale like the Mercator tiles. The latitude/longitude dimension, map projection, and the center of projection are the same as described for the synoptic map of Mimas (see Section 3.1). The size of the Mercator tiles and the pole tile is 1300 mm in width, and 1030 or 950 mm in height, respectively. The hardcopy resolution is 3.7 pixel/mm.

4. Future work

The nominal Cassini mission ended in July 2008. Cassini is now operating in an Extended Mission until 2010. The northern parts of Mimas, Tethys, and Iapetus will be illuminated during the extended mission providing an opportunity to obtain high-resolution Cassini coverage of high northern latitudes. Whereas a few non-targetted flybys of Mimas and Tethys are planned, no Iapetus flyby is planned for the Cassini Extended. These upcoming flybys will help to replace some of the low-resolution parts of the maps with higher resolution image data.

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