is 400 km across. Unlike Herschel on Mimas, Odysseus has become subdued in relief, presumably due to flow in the crust. Even more remarkable is the long system of valleys and troughs (named Ithaca Chasma) which reaches for 2 000 km – about three-quarters of the way around Tethys. Although just possibly related to the giant impact, it is more likely to be due to cracking of the surface as a liquid water layer froze and expanded.

Dione also shows some signs of geological activity, and many areas appear to have been resurfaced. Its density is higher than that of Tethys, so it probably had a greater source of interior heat from its rocky materials. The trailing hemisphere (all the Saturnian satellites appear to have synchronous rotation) is covered in streaks which seem to consist of surface ice deposits. These could have formed by venting of water through cracks early in the history of the satellite, perhaps being destroyed on the leading hemisphere as this would be more subject to meteoritic impacts.

Rhea and Iapetus

Rhea also shows similar wispy markings on its trailing hemisphere, presumably caused by the same process as those on Dione. The surface is heavily cratered, but the distribution of sizes suggests that there were distinct episodes of cratering, the later one with many smaller bodies and perhaps being associated with the fragmentation of another satellite (or satellites), or even with the formation of the rings.

Iapetus has always been known to show a remarkable change in brightness around its orbit. We now know that the leading hemisphere is generally reddish-black – as black as pitch! – while the trailing hemisphere is white. It cannot be decided if the material is of internal or of external origin, since there is no evidence for white spots on the leading hemisphere as might be expected from impacts breaking through a thin surface layer deposited from outside; yet the very orientation suggests just such a source, perhaps from Phoebe, the outermost satellite. On the trailing side the dark material is concentrated on crater floors, suggesting an internal origin, although whether ammonia- or methane-volcanism can account for this distribution is an open question.

The smaller satellites

Hyperion is irregular in shape, suggesting that it is a result of fragmentation, and it is distinctly darker than most of the other satellites, possibly indicating that it has retained some of its original dirty ice crust.

Little is known of the outermost satellite, Phoebe, which has a retrograde orbit at nearly four times the distance of Iapetus. Its albedo is low, comparable with that of the carbonaceous minor planets, and this together with its orbit suggests that it has been captured, perhaps at a relatively recent time.

Between the orbits of Mimas and the 'shepherd' satellites controlling the F Ring, two bodies circle the planet. Their behaviour is quite unlike that of any other objects in the Solar System. These 'co-orbital satellites' have orbits which are separated by less than the size of the objects themselves. Every four years the inner one catches up with the outer, but finds no room to pass. However, as they approach they attract one another gravitationally, swing round one another, and exchange orbits! Four years later they go through the same performance, which can apparently be repeated indefinitely.

Of the remaining small satellites, two, Telesto and Calypso, occupy Lagrangian positions in the orbit of Tethys, just as the Trojan minor planets do in Jupiter's orbit around the Sun (page 153), and one a similar situation in the orbit of Dione. Two more are suspected in the orbit of Tethys, and another in that of Dione. A further suspected body may be in a special form of interaction with Mimas, placing it into

Table 5·16 **Satellites of Saturn**

number	name	distance (km)	sidereal period (d)	inclination	eccentricity	diameter (km)	magnitude
XVII*	–	137 000	0·602	0·3	·002	40 × 20 × ?	18
XVI*	–	139 400	0·613	0·0	·004	140 × 100 × 80	16
XV*	–	141 700	0·629	0·1	·004	110 × 90 × 70	16
X*	–	151 400	0·694	0·3	·009	220 × 200 × 160	15
XI*	–	151 500	0·695	0·1	·007	140 × 120 × 100	16
I	Mimas	186 000	0·942	1·5	·020	392	12.1
II	Enceladus	238 000	1·370	0·0	·004	510	11.8
III	Tethys	295 000	1·888	1·1	·000	1060	10.3
XIII*	–	295 000	1·888	–	–	34 × 28 × 26	19
XIV*	–	295 000	1·888	–	–	34 × 22 × 22	20
IV	Dione	377 000	2·737	0·0	·002	1120	10.4
XII*	–	377 000	2·737	0·2	·005	36 × 32 × 30	19
V	Rhea	527 000	4·518	0·4	·001	1530	9.7
VI	Titan	1 222 000	15·95	0·3	·029	5150	8.4
VII	Hyperion	1 481 000	21·28	0·4	·104	410 × 260 × 220	14.2
VIII	Iapetus	3 561 000	79·33	14·7	·028	1460	11.0
IX	Phoebe	12 954 000	550	150	·163	220	16.5

*Unofficial number. The satellites also have the following informal designations:
XVII A ring shepherd; XVI Inner F ring shepherd; XV Outer F ring shepherd;
X & XI Co-orbital satellites; XIII & XIV Tethys Lagrangian; XII Dione Lagrangian.
In addition, at least six further objects are unconfirmed, among them those with the informal designations: Mimas Horseshoe; Tethys Lagrangian (2); Dione Lagrangian. The remaining two possible objects are situated between the orbits of Tethys and Dione, and between Dione and Rhea.