

'quasi-circular depressions' in both hemispheres (Frey *et al.*, 1999). If these are counted as vestigial remains of ancient craters, the underlying crust in the northern lowlands might be a great deal older than suggested by surface appearance. The northern lowlands are thought to have experienced sedimentary or volcanic resurfacing in the Late Hesperian and Amazonian ages. The origin of the crustal dichotomy remains a mystery, one that is fundamental to Mars evolution. It has been attributed to a large impact (Wilhelms and Squyres, 1984) or impacts (Frey and Schultz, 1988) and alternatively to tectonic processes (Wise *et al.*, 1979; Sleep, 1994). The similar apparent dichotomy in crustal magnetization gives some hope that the magnetic record, correctly deciphered, can help solve one of the most important outstanding questions of Mars evolution. How did the crust form?

1.1. PRIOR OBSERVATIONS

There have been in excess of 30 attempted missions to planet Mars, beginning with an unnamed Soviet probe launched in 1960 (Table I). Only 1 in 4 achieved any measure of success, a grim reminder of the difficulty of planetary exploration, particularly in the early days of space exploration. In the last decade, the demonstrated rate of success has improved to about 50%.

The first successful mission to Mars was that of the USA spacecraft Mariner 4, which passed within 4 Mars radii on July 15, 1965. The magnetic field was indistinguishable from that of the undisturbed interplanetary environment, with no indication of a Mars magnetosphere, magnetopause or bow shock (Smith *et al.*, 1965). Thus Smith *et al.* set an upper limit on a present-day magnetic dipole moment of 3×10^{-4} Me (Me is the Earth's dipole moment, 8×10^{25} G cm³), equivalent to an equatorial field of less than 100 nT.

For the next 32 years, despite numerous opportunities, no space probe instrumented to measure magnetic fields would pass close enough to the planet's surface to establish the presence of an intrinsic magnetic field. Soviet spacecraft were all instrumented to measure magnetic fields, and while Mars 2, 3 and 5, and Phobos 2 returned useful magnetic field data, they did not pass close enough to unambiguously detect an intrinsic field. The first US Mars missions were instrumented with magnetic sensors, but like the early Soviet missions, they either failed or remained too distant. Beginning with the launch of Mariner 6 in 1969, and excepting Mars Observer (MO) and its replacement, Mars Global Surveyor (MGS), spacecraft and landers sent by the USA to Mars did not carry magnetometers. The very successful Viking orbiters, with periapses at an altitude of 300 km, would surely have detected the crustal magnetic field in 1976 had they carried magnetometers.

The lack of a definitive measurement in the thirty years leading up to MGS, and the great interest in the question of Mars magnetism, spawned an enormous body of literature and much debate on the subject. By all accounts, the intrinsic magnetic field of Mars had to be quite small, so as to not produce a well developed and easily identified magnetosphere like that of Earth. But was a modest intrinsic

TABLE I
Chronology of Mars mission attempts^a

Attempt	Launch date	Name	Country	Magnetic field investigation?	Mission outcome
1	October 14 1960	None	USSR	Y	Failed to reach Earth orbit
2	October 24 1962	None	USSR	Y	Failed to leave Earth Orbit
3	November 1 1962	Mars 1	USSR	Y	Flyby June 19, 1963; telemetry failed
4	November 4 1962	None	USSR	Y	Failed to leave Earth Orbit
5	November 5 1964	Mariner 3	USA	Y	Shroud separation failure
6	November 28 1964	Mariner 4	USA	Y	Successful flyby; imagery and magnetic measurements (distant)
7	November 30 1964	Zond 2	USSR	Y	Contact lost before Mars encounter
8	July 18 1965	Zond 3	USSR	Y	No Mars encounter
9	February 24 1969	Mariner 6	USA		Successful flyby July 31
10	March 27 1969	Mariner 7	USA		Successful flyby August 5
11	March 27 1969	None	USSR	Y	Launch Failure
12	April 14 1969	None	USSR	Y	Launch failure
13	May 8 1971	Mariner 8	USA		Launch failure
14	May 10 1971	Kosmos 419	USSR	?	Failed to leave Earth orbit
15	May 19 1971	Mars 2	USSR	Y	Orbited Mars; descent module crashed
16	May 28 1971	Mars 3	USSR	Y	Orbited Mars; descent module landed, telemetry failure
17	May 30 1971	Mariner 9	USA		MOI November 13; successful mission
18	July 21 1973	Mars 4	USSR	Y	Failed to orbit Mars
19	July 25 1973	Mars 5	USSR	Y	Orbited Mars; partially successful mission
20	August 5 1973	Mars 6	USSR	Y	Flyby; descent module landed, little data
21	August 9 1973	Mars 7	USSR	Y	Flyby; descent module missed Mars
22	August 20 1975	Viking 1	USA		MOI June 19, 1976; landed July 20
23	September 5 1975	Viking 2	USA		MOI August 7 1976; landed September 3
24	July 7 1988	Phobos 1	USSR	Y	Contact lost before Mars encounter
25	July 12 1988	Phobos 2	USSR	Y	MOI January 29, 1989; lost telemetry March 27
26	September 25 1992	Mars Observer	USA	Y	Failed to achieve Mars orbit
27	November 7 1996	Mars Global Surveyor	USA	Y	MOI September 12, 1997; successful mission (currently in extended mission)
28	December 4 1996	Mars Pathfinder	USA		Landed July 4, 1997; successful mission
29	July 4 1998	NOZOMI	JAPAN	Y	Mission replan for 2004 arrival at Mars
30	December 11 1998	Mars Climate Orbiter	USA		Failed to achieve Mars orbit
31	January 3 1999	Mars Polar Lander	USA		No contact subsequent to landing attempt; No contact with 2 microprobes deployed
32	April 7 2001	Mars Odyssey	USA		MOI October 24, 2001; successful mission

^aEntries through 1988 from Snyder and Moroz (1992).



<http://www.springer.com/978-1-4020-2048-3>

Mars' Magnetism and Its Interaction with the Solar Wind

Winterhalter, D.; Acuña, M.; Zakharov, A. (Eds.)

2004, XI, 265 p., Hardcover

ISBN: 978-1-4020-2048-3