much older, extensive fill of the Borealis basin and (ii) the overlying, finely layered deposits that constitute the bulk of the 3-km-high mound (Byrne and Murray, 2002). The layered deposits extend out to roughly the 80° latitude and are surrounded by a vast dune field that is in places rich in gypsum (Langevin et al., 2005). Radar sounding shows that the layers in the upper unit form four distinct packets and individual layers can be traced large distances across the entire cap both in the radar returns (Phillips et al., 2008) and in the images (Milkovitch and Head, 2005). The southern deposits are more complicated. A 3-km-high central mound extending roughly 5° from the pole is partly surrounded by thinner, older deposits that extend several degrees further out, where a much older layered unit, the Dorsa Argentea formation, is exposed. Crater counts on the central mound indicate an age of the order of $10^7$ years. Herkenhoff and Plaut (2000) attribute the difference in ages between the two caps to differences in the persistence of the residual $CO_2$ cap at the two poles. If composed mostly of water ice, the total volume of the water in the layered deposits is roughly equivalent to a 20-m-deep global layer, far short of the volume of water needed to cut the Hesperian flood channels.

The layering has long been attributed to accumulations of dust and ice modulated by orbital and rotational motions (Murray et al., 1972) and this is still the prevailing theory. Phillips et al. (2008) suggest that the weakest radar reflectors detected by SHARAD could contain as little as 2% dust, the rest being ice; the strongest reflectors could contain as much as 30% dust. Variations in obliquity would affect deposition and removal of ice at the poles and the incidence of dust storms and hence the deposition of dust (Toon et al., 1980). While attempts have been made to correlate specific layers with recent obliquity variations (Milkovich and Head, 2005), the correlations will remain uncertain until samples are available for dating. Nevertheless, the layering appears to reflect geologically recent events. The absence of an older record is consistent with the interpretation that many features at midlatitudes result from removal of ice at high latitudes and deposition at lower latitudes during periods of high obliquity. Accumulation and removal of layered deposits at the poles probably have been occurring repeatedly throughout the history of the planet. At the north pole we have only a recent record, but a partial record of older polar events may be preserved in the south.

## 2.7 Summary

Mars accumulated and differentiated into crust, mantle, and core within a few tens of millions of years of Solar System formation. The global inventory of near-surface water available to participate in a geologic process is poorly constrained because of large uncertainties in the amount of water originally accreted and subsequently lost during the first 0.5 Gyr of the planet's history. The Noachian period (4.1–3.7 Gyr ago) was characterized by the presence of a magnetic field, high rates of cratering, erosion, and valley formation. Most of Tharsis formed and surface conditions were at least episodic such as to cause the widespread production of hydrous weathering products such as phyllosilicates. Erosion rates, though high compared with later epochs, fell