consistent with the common presence of mounds of sediments in upland craters, mounds that resemble those in the canyon (Carr, 2006, figure 2.7, 2.9). Other suggestions are that the canyon internal deposits are young pyroclastic deposits (Hauber et al., 2006), or products of sub-ice or subaqueous volcanism (Chapman and Tanaka, 2001).

Malin and Edgett (2000) and Catling et al. (2006) suggest a very different origin for the sediments. They argue that the sediments do not postdate the canyons but are instead simply remnants of the Noachian–Hesperian materials into which the canyons are cut. By this hypothesis, the layering, the contrasting erosional styles, and the superposition relations are inherited from the original pre-canyon materials. Lakes may still have been present at times but they did not result in the deposition of kilometer-thick stacks of sediments, and the apparent young age of the sediments is an exposure age and not a depositional age.

2.5.3 Oceans

If the outflow channels were formed by floods, as is likely, then large bodies of water must have been left at their termini, which are mostly in the northern plains. Evidence for such bodies of water remains equivocal. Several possible shorelines have been tentatively identified in and around the northern plains (Clifford and Parker, 2001; Parker et al., 1989, 1993; see Chapters 9 and 10) and Hellas (Moore and Wilhelms 2001; see Chapter 7) but they remain controversial. Supporting evidence for the presence of former bodies of water of Hesperian age in the northern plains are partly buried ridges and craters, interpreted as the result of burial by sediments carried by the large floods (Head et al., 2002). The burying unit, part of the Vastitas Borealis Formation (Tanaka et al., 2005), covers an area of $1–2 \times 10^7\,km^2$ and has a minimum volume of $3 \times 10^6\,km^3$ (Kreslavsky and Head, 2002). The boundary of the unit is roughly coincident with the Deuteronilus shoreline identified by Parker and coworkers (Chapter 9). Its enclosed volume is more than adequate to account for even the largest flood volumes estimated by Andrews-Hanna and Phillips (2007) and Leask et al. (2007). Also supporting the former presence of bodies of water in the northern plains are numerous features that suggest that stagnant ice sheets could have been left behind when the bodies of water froze (Kargel et al., 1995, see also Chapter 10). Most of the features (e.g., thumbprint terrain, polygonal ground) are found around the edge of the Vastitas Borealis formation (Tanaka et al., 2005). Arguing against the former presence of large bodies of water in the northern plains are the lack of detection of evaporites (Bibring et al., 2005) and the presence of large boulders up to 2 m in diameter in low areas where fine-grained sediments would be expected by the flood hypothesis (McEwen et al., 2007).

2.5.4 Erosion and weathering

Both orbital and surface observations (summarized in Golombek et al., 2006) indicate that average erosion rates dropped 2–5 orders of magnitude at the end of the Noachian. The low rates were sustained for the rest of the planet's history. The rates of 0.02–0.03 nm $year^{-1}$ estimated for the uppermost Noachian or Hesperian lava