estimated length of the Noachian. Clearly the rim of Hellas has not been eroded by 20 km. We do not know how much fill is in Hellas, but with a depth of over 9 km, it is unlikely to contain more than a few kilometers. If we assume the floor of the basin ($2.5 \times 10^6\,km^2$) has 2 km of fill derived from the surrounding drainage area ($17 \times 10^{-6}\,km^2$), we derive a denudation rate of $0.75\,m\,10^6$ years, almost 2 orders of magnitude lower than the US rates. Thus, the data from crater preservation and the paucity of filling within Hellas are consistent. Average Noachian erosion rates, while orders of magnitude greater than the rates for subsequent eras, still fell short of terrestrial rates.

2.4.2 Valley networks

Valley networks provide compelling evidence of former conditions that enabled sustained flow of liquid water across the Martian surface. Much, but not all, of the Noachian terrain is dissected by valley networks. Most drain into local lows and are only up to a few hundred kilometers long, particularly in Cimmeria and Serinum where there is no strong regional slope. However, between Syrtis Major Planitia and Argyre several valleys thousands of kilometers long drain northwest down the long regional slope from the high ground around Hellas toward the Chryse–Acidalia low. Stream profiles are poorly graded and closely follow the regional slopes (Howard et al., 2005). There is little indication that formation of the presently identifiable valleys resulted in a general lowering and grading of the landscape as occurs with long-lived terrestrial rivers. The result is low basin concavities (Aharonson et al, 2001), poorly graded stream profiles, and poor correlation of basin circularity with elevation within the basins (Stepinski and O'Hara, 2003). Drainage densities vary considerably with location, up to the low end of the terrestrial range (Craddock and Howard, 2002; Hynek and Phillips, 2003). The apparent low drainage densities, amphitheater heads of tributaries, and rectangular cross-section suggested to many early workers that groundwater sapping had played a major role in the formation of many of the valleys (Baker, 1990; Carr and Clow, 1981; Gulick, 1998, 2001; Pieri 1980), although all acknowledged that precipitation and/or hydrothermal circulation were/was needed to recharge the groundwater system to enable sustained or episodic flow. Better imaging and altimetry now show that dense, area-filling networks are common throughout the Noachian terrains (Figure 2.1, see also Chapter 10). They indicate that precipitation followed by surface runoff, coupled with infiltration and groundwater seepage, must have occurred at least episodically in the Noachian (Carr, 2006; Howard et al., 2005; Hynek and Phillips 2003; Irwin and Howard, 2002). Major uncertainties are how persistent conditions necessary for precipitation and surface runoff were sustained and how such conditions were achieved.

Many lows, such as craters having inlet and outlet valleys, indicate that lakes formerly occupied lows in the dissected terrains, as expected for a poorly graded landscape undergoing fluvial erosion (Cabrol and Grin, 1999, 2001, 2002, 2005; Fasset and Head, 2008) (Figure 2.2). Deltas or alluvial fans are commonly observed where valleys enter the lows. Particularly striking examples of deltas are in Eberlswalde crater, Holden Crater (Chapter 12), and in the Nili Fossae (Fassett and