NNE–SSW extension to form the rifts may have occurred over hundreds of millions of years, and thinned the crust under the canyons (Anderson and Grimm, 1998). Extension may also have been accompanied by dike intrusions (McKenzie and Nimmo 1999; Mège and Masson 1996). East of roughly 310 E structural control by Tharsis radials is much less obvious as the roughly E–W canyons merge with more northerly trending outflow channels.

The age of the canyons is difficult to determine precisely. Since Tharsis appears to have largely been formed by the end of the Noachian, it is likely that the canyons started to form in the Upper Noachian, although we have no observational evidence. Side canyons and gullies on the canyon walls cut Hesperian plains and are themselves cut by faults. There is little if any evidence of alluvial fans on the canyon floors. The canyon floors were probably still subsiding when erosion occurred, and the fans that resulted were either eroded away or buried by younger deposits. In contrast, the landslides, the youngest features that cut the adjacent plains, accumulated on the canyon floor and are rarely cut by faults. Most of the landslides are Amazonian but some may be as old as upper Hesperian (Quantin et al., 2004). The floors of Coprates and Ganges are continuous eastward with the Upper Hesperian-aged Tiu and Simud Valles. These data collectively suggest that canyons started opening in the Noachian and that faulting, subsidence of the floor, and erosion of the walls continued through the upper Hesperian, after which faulting and subsidence was minor and widening was largely restricted to landslides.

Mounds of layered sediments are widespread within the canyons, at elevations that range from under –3000 m in Melas to over 3000 m in west Candor. Most are rich in hydrated, mainly Mg and Ca, sulfates (Bibring et al., 2006; Gendrin et al., 2005). For the last 30 years the favored origin for the sediments is that they were deposited in intracanyon lakes (Komatsu et al., 1993; Lucchitta et al., 1992; McCauley, et al.,1978; Nedell et al., 1987; Weitz and Parker, 2000; see Chapters 5 and 6). Such an origin is consistent with the eastward merger of the canyon floors with large outflow channels, the fine layering of the sediments, superposition relations across the Ophir–Candor divide, the marked contrast in erosional styles between the sediments and the canyon walls, and the presence of sulfates. The only plausible shoreline so far identified within the canyons, however, is one in Coprates Chasma at an elevation of roughly –3500 m (Harrison, 2007), 6500 m below the top of the sediments in Candor. The lake hypothesis does not necessarily imply deep lakes. The sediments, together with evaporitic minerals, may have accumulated over many millions of years by repeated episodes of evaporation and/or sublimation following injections of water into the canyons as a result of climatic events, faulting, or other causes. As indicated above, outflow channels commonly start at faults, so it is not unreasonable to conclude that the huge faults that created the canyons could have been conduits that supplied groundwater for lakes within the canyons. If climatic conditions were similar to today's, the lakes would have frozen and been hindered from draining away by a thick cryosphere.

Even if the canyons did at times contain lakes, the origin of the layered deposits still remains puzzling. One possibility is that they are a mixture of subaqueous and subaerial deposits, the materials having been brought in by the wind and deposited in water when lakes were present and subaerially when lakes were not present. Such an origin is