

## Appendix 4

### Brief Geologic History of the Flathead Subbasin

The Precambrian rocks of the Belt Supergroup that underlie the Flathead Subbasin formed from sediments deposited in and near a large but shallow sea or inland lake during the middle Proterozoic (from roughly 1,600 to 800 million years ago). This large body of water, which may have been similar to today's Caspian Sea, occupied parts of present-day eastern Washington, the panhandle of Idaho, western Montana, and adjacent areas of Canada. Over a period of 800 million years, more than 18,000 feet of sediment accumulated from surrounding highlands. The ever-increasing load depressed the sea floor, and variations in the downwarping, combined with changes in the amount and type of sediment flowing into the basin, resulted in alternate layers of different kinds of sediment, including sand, silt, and limey mud.

As the great mass of sediment accumulated, moderate heat and pressure associated with deep burial caused mild metamorphism, converting the rocks to quartzite, siltite, argillite, recrystallized limestone, and dolomite. The rocks, however, retained much of their sedimentary character; features such as ripple marks, mud cracks, salt casts, and fossil algal stromatolites are well preserved. In some areas, igneous rocks were injected into the sedimentary rocks and formed sills that today parallel the layering in the rocks.

Approximately 150 million years ago the North American plate began colliding with numerous large island arcs in the Pacific. The impacts created and elevated mountain chains, forming the ancestral Rocky Mountains. Immense compressive forces persisted for some 90 million years and were enough to produce mountains several hundred miles inland from the edge of the continent. In response to the enormous force, the Belt sediments buckled into folds, and finally large masses of relatively stronger rocks slipped over softer and more easily deformed rocks, creating what is known today as the Lewis Thrust Fault: a huge rock wedge, several miles thick and several hundred miles wide, moving eastward more than 50 miles. Erosion through more millions of years stripped away the upper part of the original rock wedge and exposed the rocks evident in the Flathead Subbasin today.

Rivers and streams eroded and transported enormous amounts of sediment from the high ground to the oceans. By the end of the Tertiary Period, the mountains of the subbasin were fairly high but rounded, and the area contained broad stream valleys.

About 2 million years ago, with the onset of the Ice Age, ice sheets periodically covered much of Canada and northern Montana. Glaciers that supplied ice to the Flathead lobe in the Flathead Valley include the Cordilleran Ice Sheet that flowed southeast along the Rocky Mountain trench, valley glaciers in the Whitefish Range, valley and trunk glaciers along the Flathead River valleys northeast of the Swan Range, and a trunk glacier that flowed northwest along the Swan River valley. Only the highest peaks of the ranges to the north and east remained unglaciated during the late Wisconsin (Johns, 1970; Carrara, 1990; Locke, 1995; Smith, 2000b). The ice carried away enormous quantities of the bedrock of the valley floors and mountainsides, producing the topography we see today in places like Glacier National Park and the Bob Marshall and Mission Mountains Wilderness Areas. During relatively warm "interglacial" periods, the valleys were freed of ice, and rapidly flowing rivers cut deep gorges into the ice-carved rocks. The ice age persisted for almost 2 million years. The last of the huge glaciers disappeared from the subbasin about 12,000 years ago.