MIDDLE PROTEROZOIC ERA

k18 Beltian sediments < Middle Proterozoic Era 1.0 -1.6 Ga >

> ... a sense of wonder that we, alone among organisms, have been privileged to see these vanished worlds, and challenged to understand the immensity of time. —Richard Fortey.[1]

Conformable sequences of Cambrian and Late Proterozoic (Neoproterozoic) sediments, on what had by then become the northern margin of Laurentia, transgressively buried there thick basin-fill Middle Proterozoic (Mesoproterozoic) sediments.[2] A famous example of these are Rocky Mountain exposures (***Figure k18.1***) called the *Belt Supergroup* in the northern United States, and the *Purcell Supergroup* for the continuation of these in Canada. The Middle Proterozoic "Beltian" sediments have a thickness of 16,000 meters in places in what is now their western extent where they are mudstones, and thin eastward where they are stromatolitic limestones 600 to 1200 meters thick.[3]

Known from drilling the Amargosa aulacogen, California, and from where exposed in the Grand Canyon, Arizona, Beltian sediments of the Late Precambrian Grand Canyon Supergroup record two prolonged times (in the Neoproterozoic and earlier in the late Mesoproterozoic) of intracratonic rifting and sedimentation in rift basins.[4]

Iron is not abundantly dissolved in river or seawater today as these are both well oxygenated. The reservoir of free oxygen in the atmosphere, is maintained by marine excess. This, as ferric-iron coated grains and mineral grains of hematite in detrital sediments attested, has been the norm since the Mesoproterozoic. Deep oceans too have been normally well oxygenated since 1.0 Ga but not so before.

During the Mesoproterozoic, molybdenum isotope evidence, reported by Gail Lee Arnold in 2004, is of euxinic (anoxic and sulfidic) conditions (only found locally today as in the Black Sea bottom waters).[5] Little iron would be in ocean waters as ferrous sulfides, which have low solubility. However, Ferric iron, Fe(III), is reduced to soluble ferrous iron, Fe(II), by sodium bisulfate. Notably, the continental-shelf deposited Animikie group, Great Lakes area, is comprised of the pyrite (iron sulfide, indicating euxinic conditions) bearing Rove fm and the conformably underlying BIF (iron oxide, indicating oxygenated conditions) bearing Gunflint fm (*see* Topic *k26*).

In 2004, Simon W. Poulton postulated that the transition to the euxinic conditions in the oceans after 1.84 Ga (zircon date on tuffaceous material in the basal Rove fm) was due to increasing atmospheric oxygen levels that caused sulfide weathering on land and hence a flow of sulfate into the oceans.[6] ❑

Figure k18.1 [7] Middle Proterozoic (Mesoproterozoic) limestone strata of the Belt Super group are exposed in the majestic peaks of Glacier National Park. Below is a cross section showing their stratigraphic relationship to other formations.