Panel 11: Sunset of the Millennium (1995 to 2000 AD)

Panel 10 was the last one for which there is major historical content to portray graphically and describe. Two more panels, 11 and 12, have been added in order to continue to the last day of 1999, so that ChronoZoom can display a continuous, linear historical sequence from one day to the entire duration of the Cosmos — a zoom factor of 5 x 10^{12} (5 trillion). Blank space again is left for users, and a few natural events have been selected to populate the two panels, but rather than describing them in detail, the available text space is used to consider broader issues of Big History — Dating and periodizing history (Panel 11), and the Character of history (Panel 12).

Dating and periodizing history

Human beings are not born with the ability to date events in the past, or even to remember and pass on their memories of bygone events for more than a few generations. Before writing and written documents became available, the more distant past would become part of legend. Under those conditions, serious history was not possible.

Writing does not guarantee dated history, however. First a calendar is needed, and the recognizable changes of the four seasons make *years* the obvious calendrical basis. Modern calendars count years in continuous sequence, but students of early civilizations must deal with dates like "in the fourteenth year of the reign of King So-and-So." Much effort has gone into translating phrases like this into years BC, but questions remain — for example, there are several decades difference between the "high" and "low" Egyptian Bronze Age chronologies. The Mayan calendar was still more complicated and challenging to decipher.[1] Even for times and places with well-established chronologies, many documents are not dated. However, once the modern times of Panel 9 are reached, there are few problems with dating the written historical record. This has led generations of scholars to consider that the only "history" is written history. Historical scientists and Big Historians consider this view outmoded, and it is gradually passing away.

During the 20th century, historical *scientists* learned to date many kinds of events that occurred before the invention of writing. Geology was the first, starting with fossils in the 19th century, which allowed rocks to be placed in chronological sequence, followed by several systems of radiometric dating in years during the 20th century. Two things make radiometric dating possible. First, radioactive atoms in a mineral grain decay at a statistically constant rate given by the half-life, so that the ratio of daughter atoms to parent atoms gives the age of the mineral grain (although this is more complicated in practice!). Second, radioactive decay takes place in the tiny nucleus of the atom, shielded by the much larger surrounding electron cloud, so the decay rate is protected from the temperature and pressure conditions that make rates of *chemical* change vary with time. Hundreds of thousands of radiometric dates now constrain the chronology of Earth history. In the later 20th century, additional ways of dating rocks were developed, including fingerprinting with geomagnetic polarity reversals, various kinds of stable isotope stratigraphy, cyclostratigraphy and, for other solar-system bodies, crater-count statistics.[2]

Archaeologists date their findings in ways similarly to those used in geology, although with radiocarbon dating being of great importance, because ^{14}C, produced by cosmic-ray bombardment of nitrogen in the atmosphere, has a half life of only ~5,730 years, so it is suitable for obtaining dates back to about 40,000 years. In archaeology, artifacts, especially pottery shards and coins, play the same role as fossils do in geology.

Paleontologists cannot get dates in years directly from fossils, except for very young ones where radiocarbon dating can be used. Dating of fossils is done indirectly, often by dating volcanic mineral grains in associated volcanic ash beds. The grains in an ash bed will have had their age set to zero when hot magma cooled during the eruption, and if the grains then fell in an ash bed, their radiometric age also dates the bed. Much work is currently being done on establishing evolutionary trees based on the DNA of living organisms, and attempts have been made to date nodes in these family trees using the assumption that rates of mutation are constant through time.[3] This assumption seem unlikely to be correct, since it involves chemical changes in DNA, unlike the protected nuclear changes that make radiometric dating so successful.

Astronomers have come most recently to dating history. With cosmic expansion understood, redshift allows the dating of light emitted from distant galaxies. Globular clusters, huge gravitationally-bound collections of stars in the Milky Way can be been dated by the mass of the stars that turn off the main sequence, for larger, brighter stars burn out more quickly.[4] It has long been impossible to date individual stars, but this may be solved by a new technique called gyrochronology, for it has been shown, perhaps surprisingly, that the rotation rate of a star is a function of its age.[5] The ages of events during the Big Bang are calculated theoretically.

Dividing history into periods is essential for understanding it. Historians and archaeologists use informal periodizations (e.g., Roman Empire, Late Bronze Age). Only in geology and paleontology are there formal periodizations (e.g., Cretaceous), established by standard procedures and accepted internationally, leading to the constantly improving geologic time scale.[6]