

## Panel 7: *Homo sapiens* out of Africa (ca. 60 ka to now)

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The Holocene, or post-glacial, is the last formal stage in the Geologic Time Scale (A). The term “anthropocene,” meaning the time during which human beings have seriously affected climate and other aspects of the Earth, was proposed by non-geologists, and geologists are now debating whether it should be formalized and adopted, and if so, when it should begin and what marker would identify it in the stratigraphic record.<sup>1</sup>

For the temperature (and ice volume) of the last 60,000 years, the best record comes from the Greenland ice core, GISP-2 (B).<sup>2</sup> Water evaporating from the sea is enriched in the more-easily-evaporated light isotope, <sup>16</sup>O; when this is stored in ice sheets, the sea is correspondingly enriched in <sup>18</sup>O. As a result, oxygen from H<sub>2</sub>O in GISP-2 ice gets lighter in warm intervals, while oxygen from CaCO<sub>3</sub> in benthic forams (Panels 4 to 6) gets heavier. The GISP-2 record dramatically shows the end of the Pleistocene Ice Age about 11 ka, the Bølling-Allerød warm and Younger Dryas cold intervals that preceded the deglaciation, and the remarkably constant temperature of the Holocene. The still poorly-understood Dansgaard-Oeschger warm events within the last glacial probably reflect local North Atlantic-Greenland-Canada conditions; they are not visible in the benthic-foram record (Panel 6), which responds to global conditions.

During the glacial times of the Tarantian Stage, six levels rich in ice-rafted debris are recognized in North Atlantic sediment cores (C). These Heinrich events represent times when large numbers of icebergs calved off the northern-hemisphere ice sheets and floated southward, dropping their entrained rocks as they gradually melted.<sup>3</sup> The unexplained Heinrich sedimentary events do not seem to correlate with the equally mysterious Dansgaard-Oeschger thermal events.

During the maximum glacial advance, around 20 ka, the ice sheet of the Canadian Rockies blocked the valley of the Clark Fork River in northern Idaho, impounding the huge Glacial Lake Missoula. When the lake water rose high enough, it floated the ice

dam off its rocky floor; the ice dam disintegrated into icebergs which were swept down the Columbia River in a colossal flood.<sup>4</sup> This scenario happened dozens of times between 21.4 and 13.4 ka;<sup>5</sup> its recognition by J Harlen Bretz in 1923 opened the first crack in the uniformitarian gradualist mindset which had dominated geological thinking since Charles Lyell in the 1830s.<sup>6</sup> Similar though less studied superfloods have been recognized in Asia as well as on Mars.<sup>7</sup> The slow build-up of the Northern-Hemisphere ice sheets was followed by their very rapid melting, complicated by the warm and cold couplet of the Bølling-Allerød and the Younger Dryas.

Until recently it seemed that among humans, only Neanderthals and modern *Homo sapiens* lived during this time interval, with Neanderthals dying off about 40 ka (D). With the last Neanderthals living so recently, it has been possible to sequence their genome.<sup>8</sup> And then, in 2003, came the discovery on the Indonesian island of Flores of fossils of a new species of humans, standing about 1 m high, who have been named *Homo floresiensis*, and are sometimes informally called “hobbits.”<sup>9</sup> The discoverers pointed out that in stature and brain size these fossils resemble the pre-human Australopithecines, but with anatomical features that place them in genus *Homo*. They appear to be an example of the dwarfing that has occurred among other mammals, notably elephants, isolated on islands in the Mediterranean.<sup>10</sup> Dating *H. floresiensis* has been controversial; the latest work dates the fossils and enclosing sediment at 100-60 ka, and associated stone tools to 190-50 ka,<sup>11</sup> and it is unknown whether these small humans lived long enough to encounter modern *H. sapiens* spreading from Africa toward Australia.

The “multiregional” hypothesis — that *Homo erectus* evolved into *Homo sapiens* independently in different parts of Eurasia — is now less supported than the “Out-of-Africa” hypothesis — that *H. sapiens* evolved in Africa and then spread over Eurasia, replacing the earlier people who had lived

outside Africa since about 1.8-1.7 Ma. Much effort is currently going into tracing how modern humans spread over every continent except Antarctica (E). It is widely assumed that *H. sapiens*, migrating out of Africa over many generations, would have followed the south coast of Arabia and Asia. This means that archaeological sites will not be very helpful in tracing the migrations, because coastlines during glacial times would have been lower than now and have been drowned by the post-glacial sea-level rise. Tracing the migrations is now done largely by studies of DNA in current indigenous populations — mitochondrial DNA tracing the female line and Y-chromosome DNA the male.<sup>12</sup> Directly dating DNA events involves major assumptions about mutation rates, and available maps of the human migration show very different ages for the departure from Africa and arrival in successive places. The place names across the bottom of the green diagram give a general idea but their ages are not at all well constrained. The blue “spindle diagram” at the top (a double-sided histogram common in the paleontological literature) is one example of the kind of detail that DNA studies should eventually provide.<sup>13</sup> It shows a single population occupying Europe, with a couple of bottlenecks during the last glacial interval, followed by extinction of the main genetic line during the Late Glacial (the Younger Dryas cold interval), and a subsequent replacement by an offshoot of the main line.

By 60 ka, humans were probably using fire everywhere<sup>14</sup> (although evidence for fire use by *H. floresiensis* is still controversial). The use of Middle Paleolithic stone tools overlapped with the Late Paleolithic stone industry from about 40 to 30 ka, with the latter gradually dying out about 10 ka, as the use of copper and then bronze gradually spread, eventually succeeded by iron (F).<sup>15</sup> The Agricultural (or Neolithic) Revolution seems to have begun in the Near East about 12 ka (10,000 BC). Metal tools, agriculture, and writing will be dominant in the 5.5 ka Panel 8 (G).