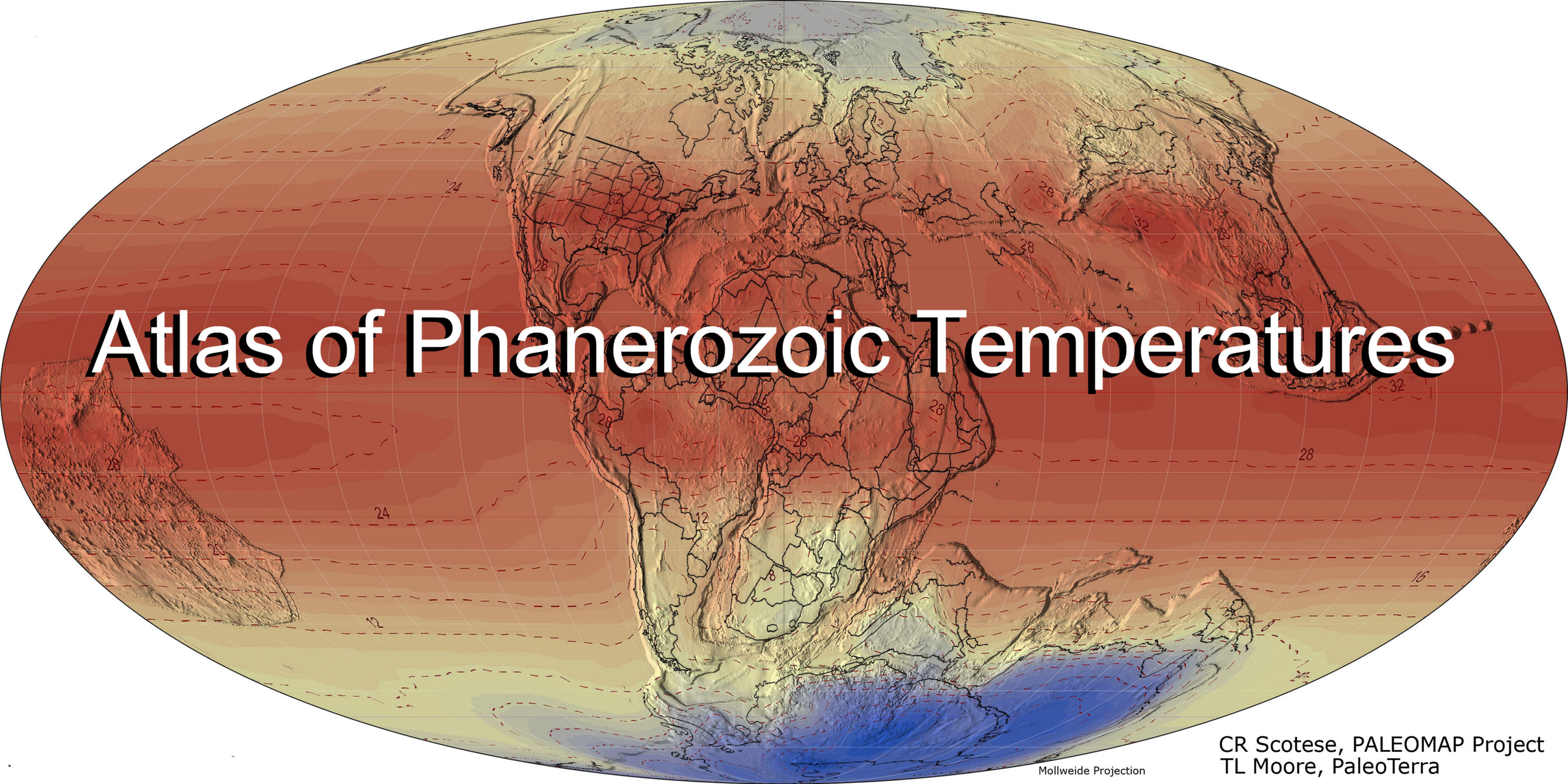
Atlas of Phanerozoic Temperatures
Mollweide Projection
CR Scotese, PALEOMAP Project
TL Moore, PaleoTerra

Atlas of Phanerozoic Temperatures

This Atlas of Phanerozoic Temperatures shows the pattern of global temperatures for the summer months (northern hemisphere) for 22 time periods from the base of the Cambrian (542 Ma) to the Middle/Late Miocene (Serravallian & Tortonian, 10.5 Ma), plus one additional map for the Neoproterozoic (Middle Ediacaran, 600 Ma). Warmer temepratures are shown in shades of red; cooler temperatures are shown in shades of blue. The dashed lines represent isotherms of equal temperature and are often labeled with the temperature in degrees Centigrade.

As expected isotherms are generally parallel to lines of latitude, except in a few regions where land areas are either warmer or cooler than the surrounding marine waters. On all of the maps the blue colors near the south pole represent winter conditions in the southern hemisphere. In the next version of this Atlas maps illustrating the temperature during the northern hemisphere summer, northern hemisphere winter, and mean annual temperature (MAT) will be provided.

These plate tectonic and paleogeographic maps are the work of C. R. Scotese. The paleoclimate simulations were done by T.L. Moore using the FOAM (Fast Ocean and Atmosphere) Climate Simulation Program. The differences in color and symbology from map to map are due to the fact that these figures were originally published in four separate reports (Scotese et al., 2007; 2008; 2009; & 2011).

Though there are minor differences in coloration due to the version of the maps, it is remarkable how similar, overall, the maps are. This is presumably because the basic physics that controls atmospheric temperature has not changed very much in the past 600 million years. The atmosphere receives it energy from the Sun. This energy is modulated by several factors: the shape of the Earth's orbit and the tilt (obliquity) of the Earth's axis, the reflectivity or albedo of the surface of the Earth, the presence or absence of polar ice caps, and the amount of greenhouse gases in the Earth's atmosphere.

The FOAM simulation program has variables that represent these temperature-modifying factors. Though these variables were adjusted to represent prevailing conditions for each simulation, it is remarkable how little effect these adjustments made. Table 1 lists the global mean annual temperature (MAT) for 12 times intervals back to the early Ordovician. The global mean temperature during the last glacial maximum (12 C°; 21,000 years ago), and the global mean temperature for the modern world (about 14 C°) have also been included.

Though mean global temperature does vary from time to time, there is little difference between the MAT of the modern world and the MAT of the warmest time (Early Cretaceous, 18.4 C°; 4.4 degrees difference), or the MAT of the modern world and the MAT of the coolest time (Early Ordovician, 10.6 C°; 3.4 degrees difference). Most of the simulated mean annual temperaturres are within 2.5 degrees of the modern value. Why is this?

The most likely reason why simulated past temperatures are nearly identical to modern temperatures is that the FOAM climate simulation was written to reproduce the patterns of today's climate. If the results of the FOAM model did not closely resemble the modern climate, then there would be little confidence in the climate simulation. Unfortunately, FOAM, as well as all other General Circulation Models, do too good a job! Even when past geographic configurations, changes in land surface cover, or radical changes the abundance of atmospheric

greenhouse gases are taken into account, the results still look a lot like the present-day.

Table I. Global Mean Atmospheric Temperatures (MAT)

Geologic Age		MAT (Mean Annual Temperature) C°
Present-day		14.0 C°
21,000 years ago		12.0 C°
30 Ma	Oligocene	12.8 C°
45 Ma	mid Eocene	13.9 C°
70 Ma	Late Cretaceous	16.2 C°
90 Ma	Mid Cretaceous	17.3 C°
120 Ma	Early Cretaceous	18.4 C°
140 Ma	earliest Cretaceous	13.6 C°
160 Ma	Late Jurassic	14.2 C°
250 Ma	Permo Triassic	11.5 C°
430 Ma	Early Silurian	16.7 C°
480 Ma	Early Ordovician	10.6 C°

The maps are from volumes 1-6 of the PALEOMAP PaleoAtlas for ArcGIS (Scotese, 2014a,b,c,d). Absolute age assignments are from Gradstein, Ogg & Smith (2008).

The following maps are included in the Atlas of Phanerozoic Temperatures:

Map 5 Middle/Late Miocene (Serravallian & Tortonian, 10.5 Ma)
Map 7 Early Miocene (Aquitainian & Burdigalian, 19.5 Ma)
Map 9 Early Oligocene (Rupelian, 31.1 Ma)
Map 12 early Middle Eocene (middle Lutetian, 44.6 Ma)
Map 17 Late Cretaceous (Maastrichtian, 68 Ma)
Map 21 Mid-Cretaceous (Turonian, 91.1 Ma)
Map 23 Early Cretaceous (late Albian, 101.8 Ma)
Map 27 Early Cretaceous (early Aptian, 121.8 Ma)
Map 31 Early Cretaceous (Berriasian, 143 Ma)
Map 35 Late Jurassic (Oxfordian, 158.4 Ma)
Map 39 Early Jurassic (Toarcian, 179.3 Ma)
Map 45 Late Triassic (Carnian, 222.6 Ma)
Map 49 Permo-Triassic Boundary (251 Ma)
Map 54 Early Permian (Artinskian, 280 Ma)
Map 57 Late Pennsylvanian (Gzhelian, 301.2 Ma)

Map 63 Middle Mississippian (early Visean, 341.1 Ma)
Map 65 Late Devonian (latest Famennian, 359.2 Ma)
Map 70 Early Devonian (Emsian, 394.3 Ma)
Map 75 Early Silurian (late Llandovery, 432.1 Ma)
Map 82 Early Ordovician (Tremadoc, 480 Ma)
Map 88 Cambrian – Precambrian Boundary (542 Ma)
Map 90 Late Neoproterozoic (Middle Ediacaran, 600 Ma)

This work should be cited as
Scotese, C.R., and Moore, T.L., 2014. Atlas of Phanerozoic Temperatures (Mollweide Projection), Volumes 1-6, *PALEOMAP Project* PaleoAtlas for ArcGIS, PALEOMAP Project, Evanston, IL.

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Scotese, C.R., Illich, H., Zumberge, J, and Brown, S., and Moore, T., 2007. The GANDOLPH Project: Year One Report: Paleogeographic and Paleoclimatic Controls on Hydrocarbon Source Rock Deposition, A Report on the Methods Employed, the Results of the Paleoclimate Simulations (FOAM), and Oils/Source Rock Compilation, Conclusions at the End of Year One: Cenomanian/Turonian (93.5 Ma), Kimmeridgian/Tithonian (151 Ma), Sakmarian/Artinskian (284 Ma), Frasnian/Famennian (375 Ma), February, 2007. GeoMark Research Ltd, Houston, Texas, 142 pp.

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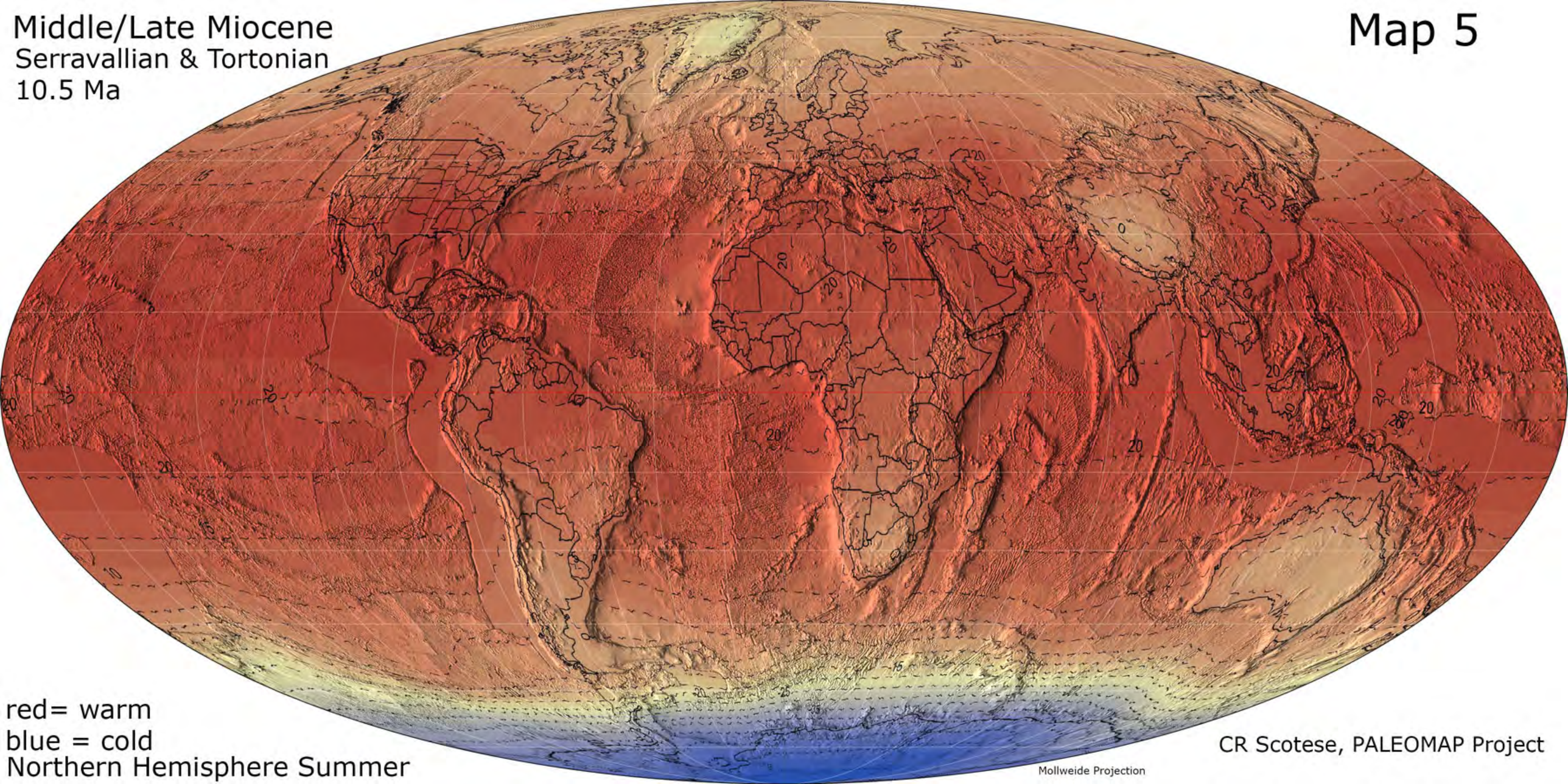
Scotese, C.R., 2014d, *The PALEOMAP Project PaleoAtlas for ArcGIS*, version 2, Volume 4, Late Paleozoic Plate Tectonic, Paleogeographic, and Paleoclimatic Reconstructions, Map 49-74, PALEOMAP Project, Evanston, IL.

Scotese, C.R., 2014e, *The PALEOMAP Project PaleoAtlas for ArcGIS*, version 2, Volume 5, Early Paleozoic Plate Tectonic, Paleogeographic, and Paleoclimatic Reconstructions, Maps 75-88, PALEOMAP Project, Evanston, IL.

Scotese, C.R., 2014f, *The PALEOMAP Project PaleoAtlas for ArcGIS*, version 2, Volume 6, Precambrian Plate Tectonic, Paleogeographic, and Paleoclimatic Reconstructions, Maps 89-103, PALEOMAP Project, Evanston, IL.

Middle/Late Miocene
Serravallian & Tortonian
10.5 Ma

Map 5



red= warm
blue = cold
Northern Hemisphere Summer

Mollweide Projection

CR Scotese, PALEOMAP Project

Early Miocene
Aquitanian & Burdigalian
19.5 Ma

Map 7

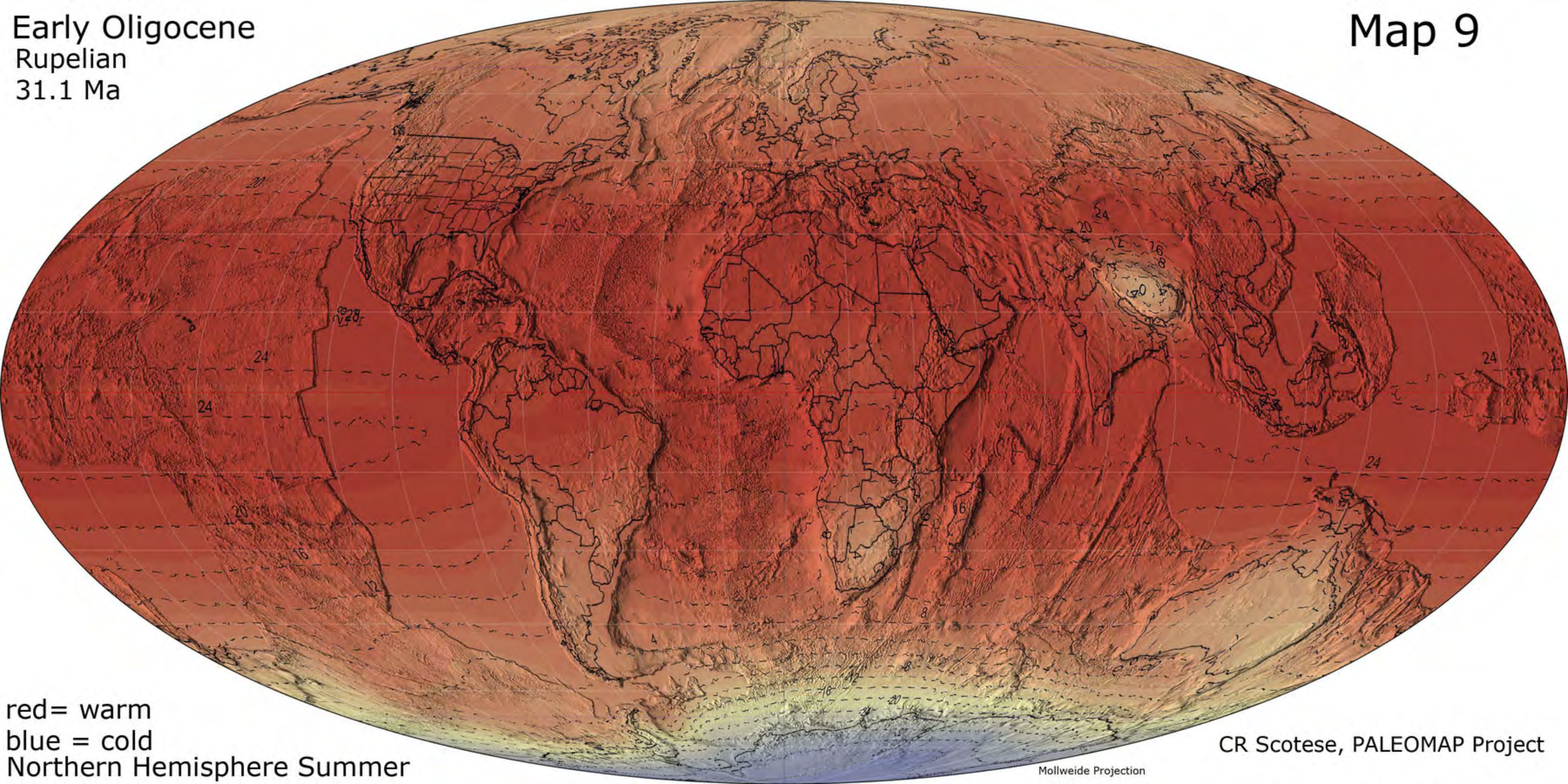
red= warm
blue = cold
Northern Hemisphere Summer

Mollweide Projection

CR Scotese, PALEOMAP Project

Early Oligocene
Rupelian
31.1 Ma

Map 9



red= warm
blue = cold
Northern Hemisphere Summer

Mollweide Projection

CR Scotese, PALEOMAP Project

early Middle Eocene
middle Lutetian
44.6 Ma

Map 12

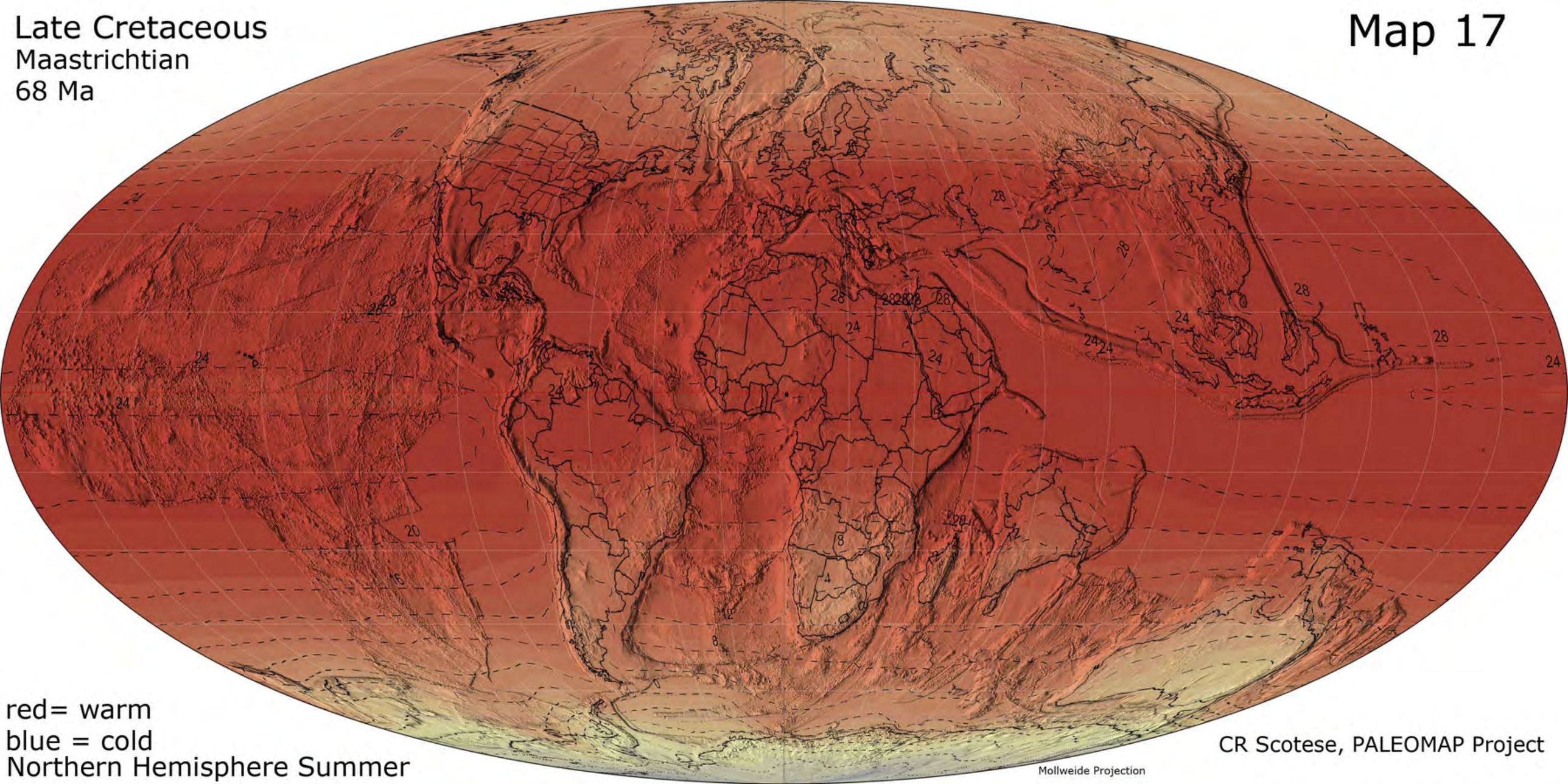
red= warm
blue = cold
Northern Hemisphere Summer

Mollweide Projection

CR Scotese, PALEOMAP Project

Late Cretaceous
Maastrichtian
68 Ma

Map 17



red= warm
blue = cold
Northern Hemisphere Summer

Mollweide Projection

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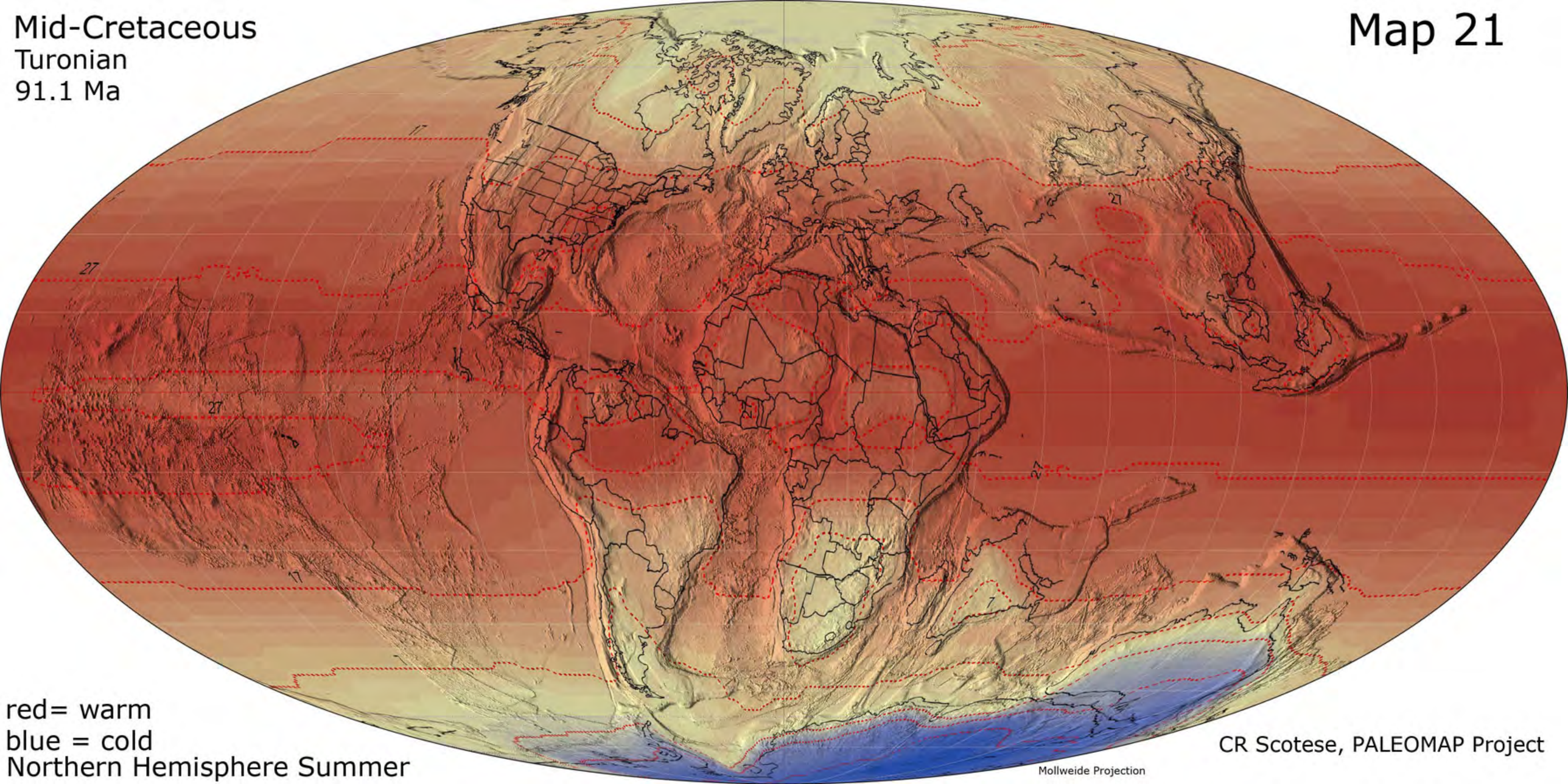
Mid-Cretaceous
Turonian
91.1 Ma

Map 21



red= warm
blue = cold
Northern Hemisphere Summer

CR Scotese, PALEOMAP Project

Mollweide Projection

Early Cretaceous
late Albian
101.8 Ma

Map 23

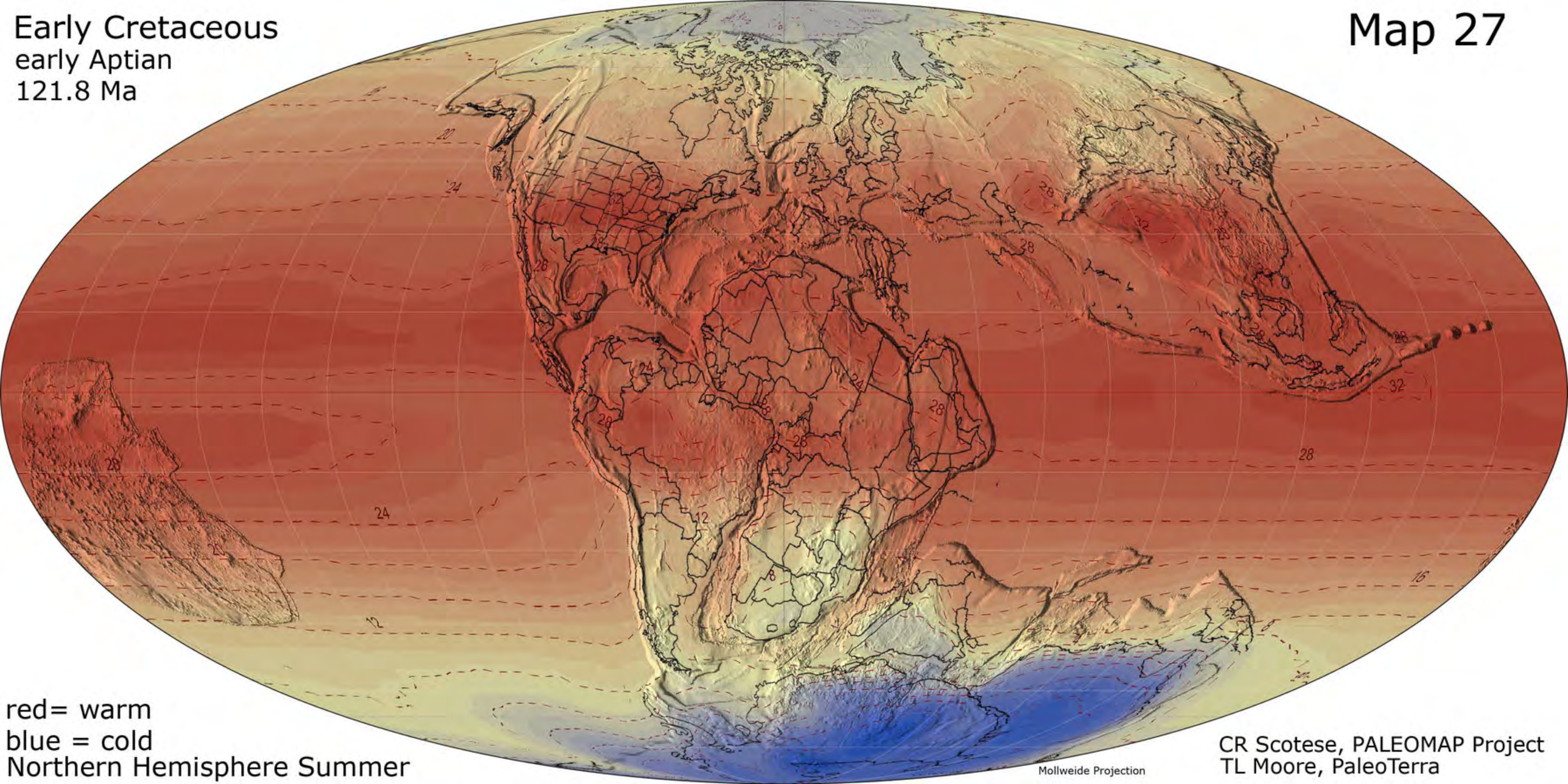
red= warm
blue = cold
Northern Hemisphere Summer

Mollweide Projection

CR Scotese, PALEOMAP Project

Early Cretaceous
early Aptian
121.8 Ma

Map 27



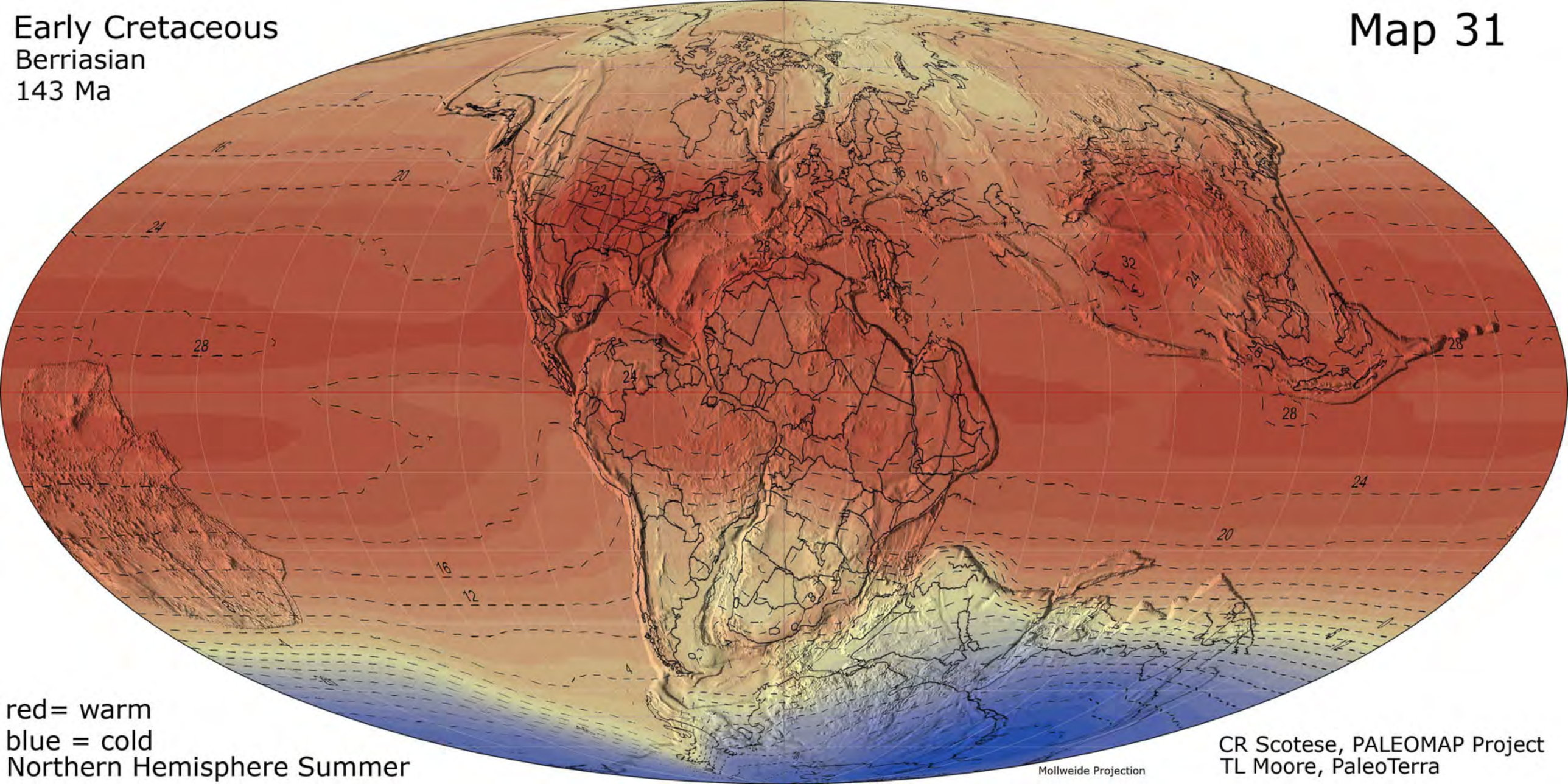
red= warm
blue = cold
Northern Hemisphere Summer

Mollweide Projection

CR Scotese, PALEOMAP Project
TL Moore, PaleoTerra

Early Cretaceous
Berriasian
143 Ma

Map 31



red= warm
blue = cold
Northern Hemisphere Summer

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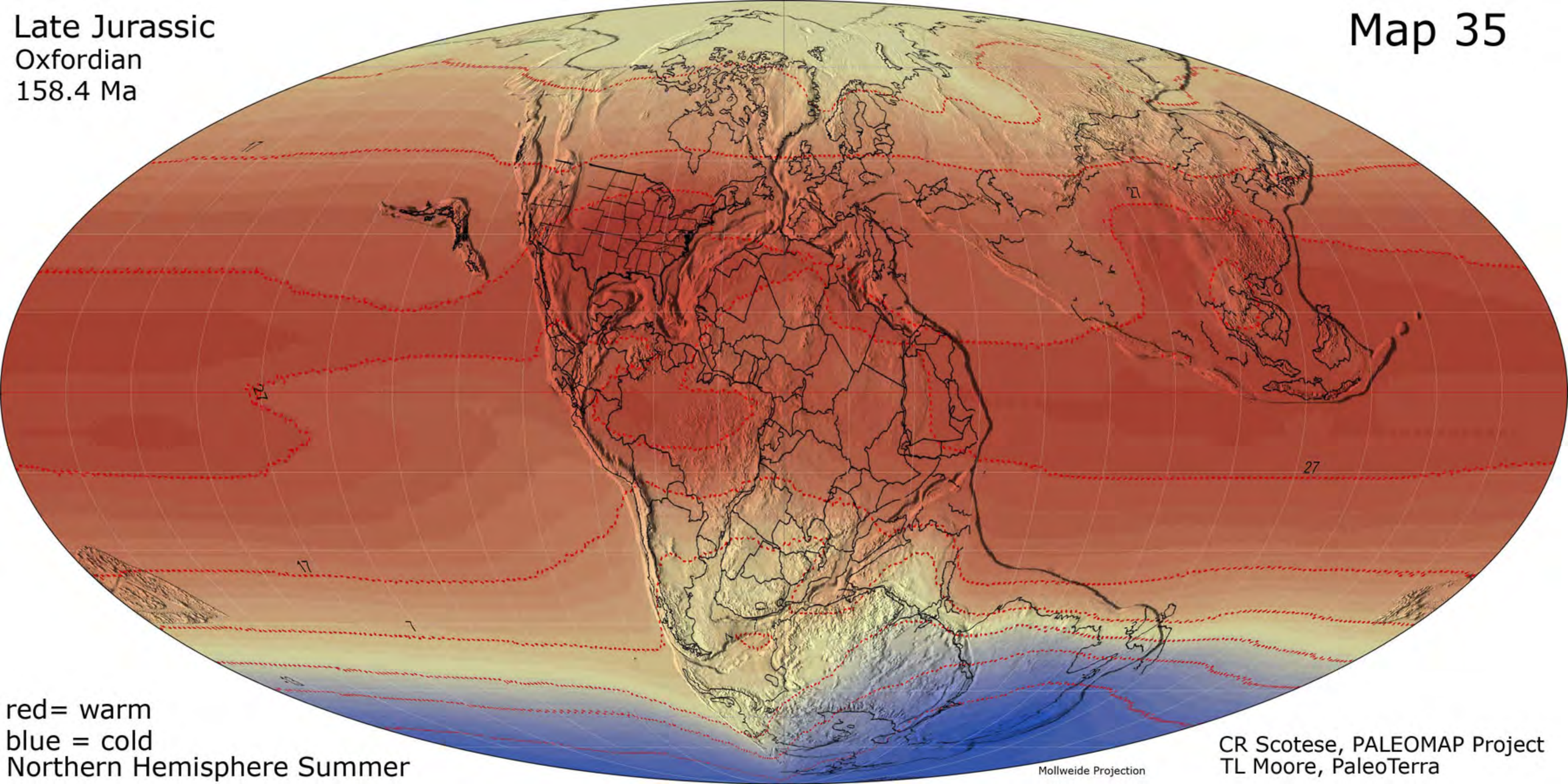
Late Jurassic
Oxfordian
158.4 Ma

Map 35



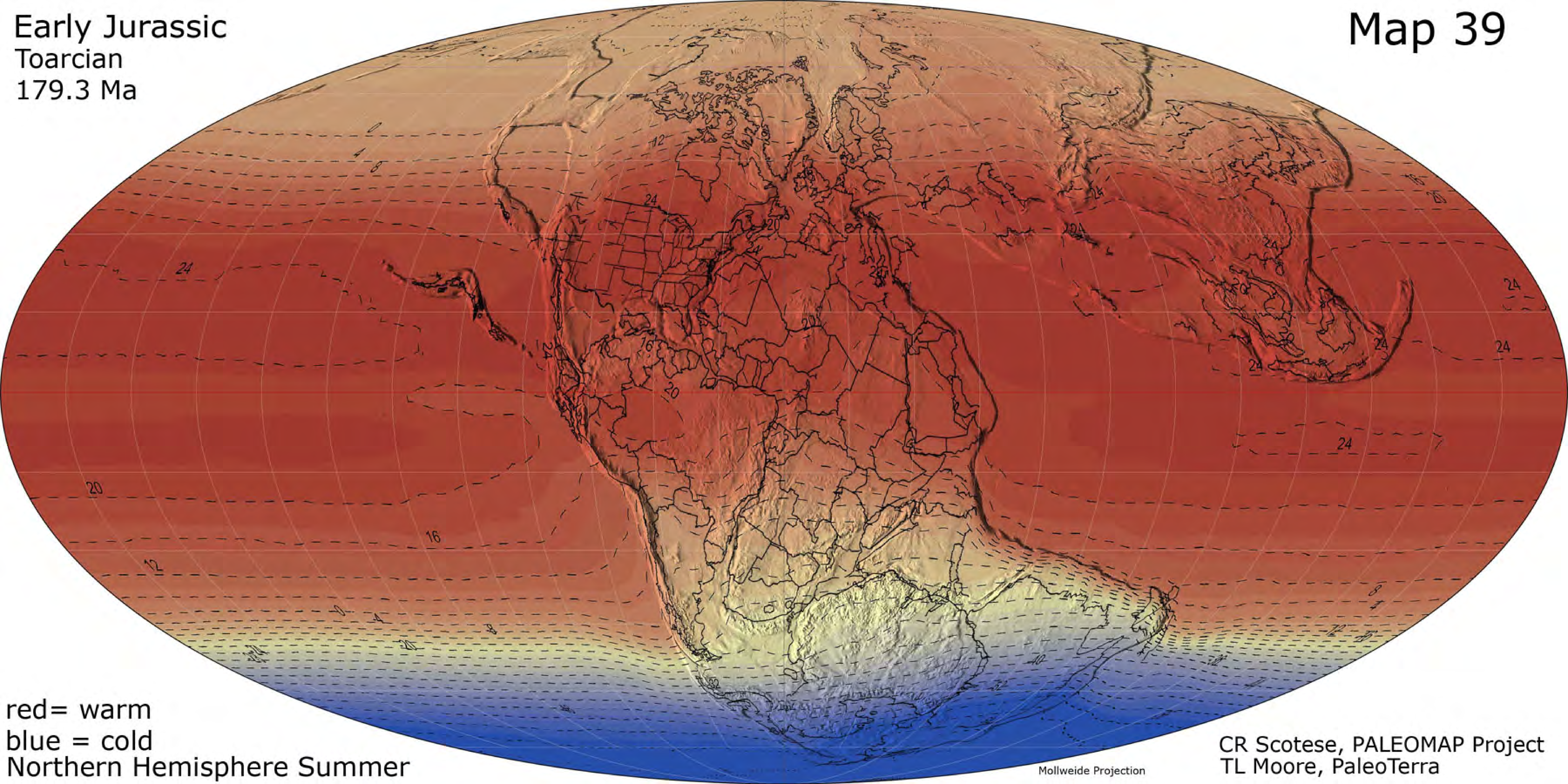
red= warm
blue = cold
Northern Hemisphere Summer

Mollweide Projection

CR Scotese, PALEOMAP Project
TL Moore, PaleoTerra

Early Jurassic
Toarcian
179.3 Ma

Map 39



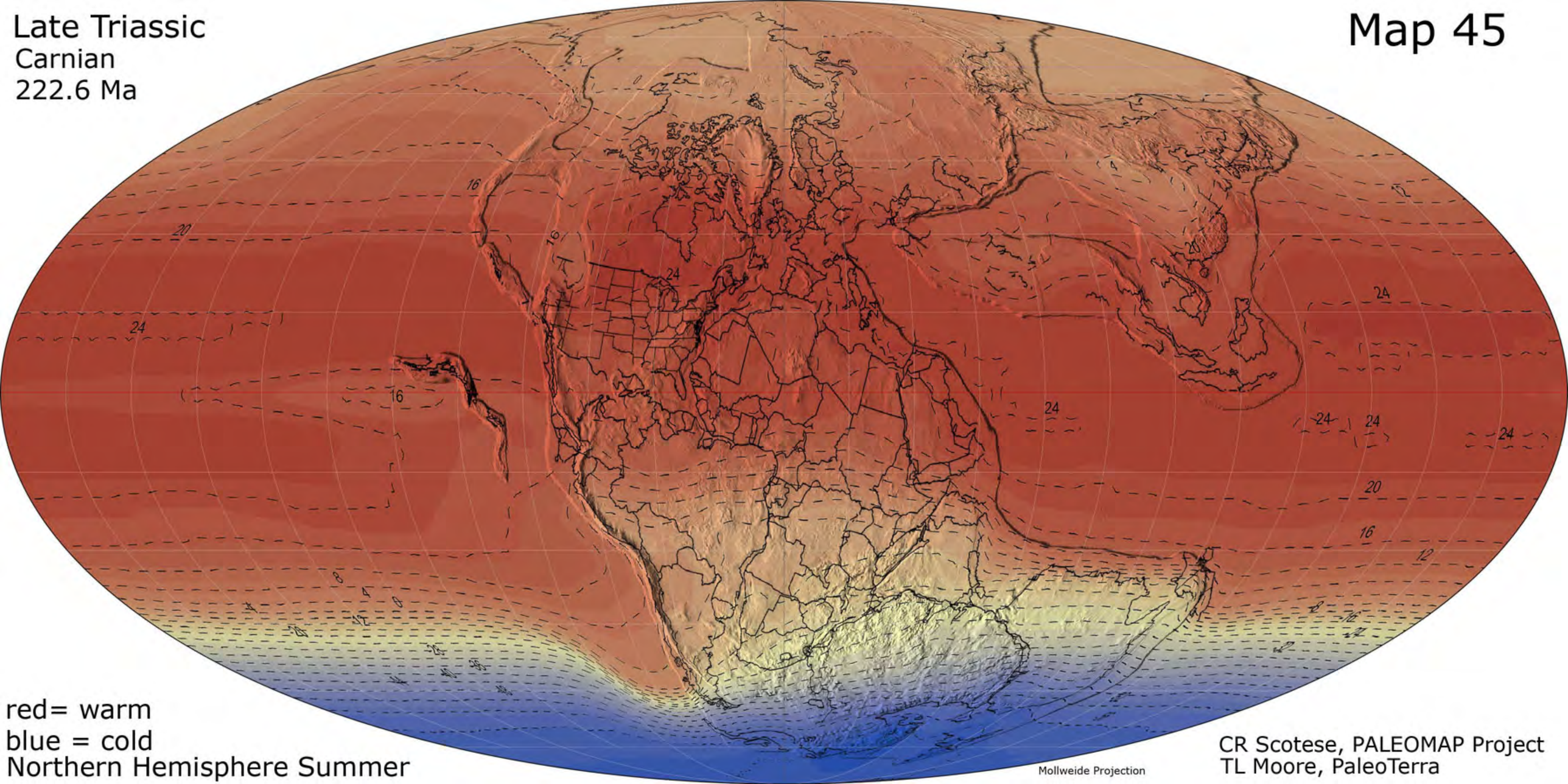
red= warm
blue = cold
Northern Hemisphere Summer

Mollweide Projection

CR Scotese, PALEOMAP Project
TL Moore, PaleoTerra

Late Triassic
Carnian
222.6 Ma

Map 45



red= warm
blue = cold
Northern Hemisphere Summer

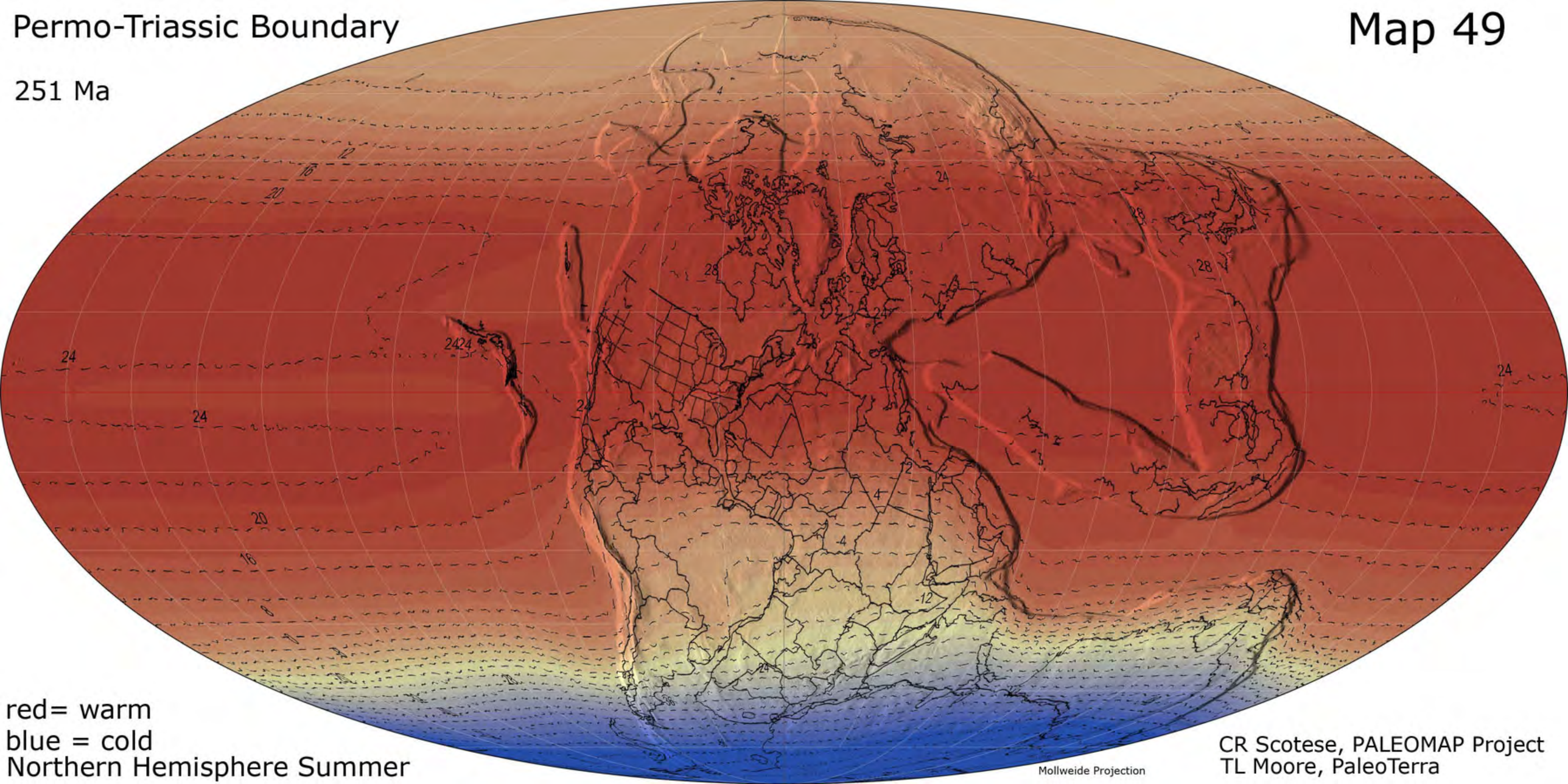
Mollweide Projection

CR Scotese, PALEOMAP Project
TL Moore, PaleoTerra

Permo-Triassic Boundary

251 Ma

Map 49



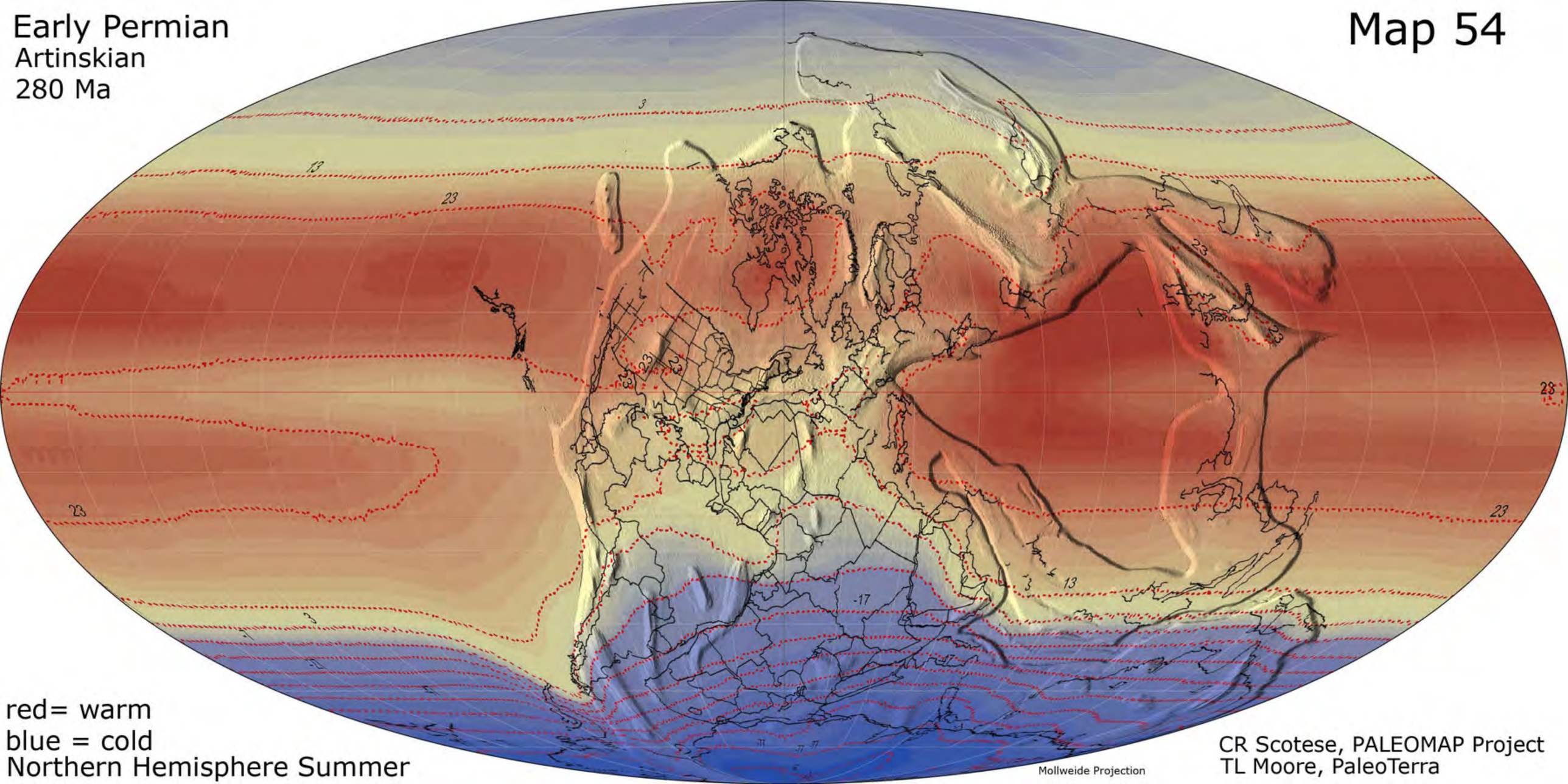
red= warm
blue = cold
Northern Hemisphere Summer

Mollweide Projection

CR Scotese, PALEOMAP Project
TL Moore, PaleoTerra

Early Permian
Artinskian
280 Ma

Map 54



red= warm
blue = cold
Northern Hemisphere Summer

Mollweide Projection

CR Scotese, PALEOMAP Project
TL Moore, PaleoTerra

Late Pennsylvanian
Gzhelian
301.2 Ma

Map 57

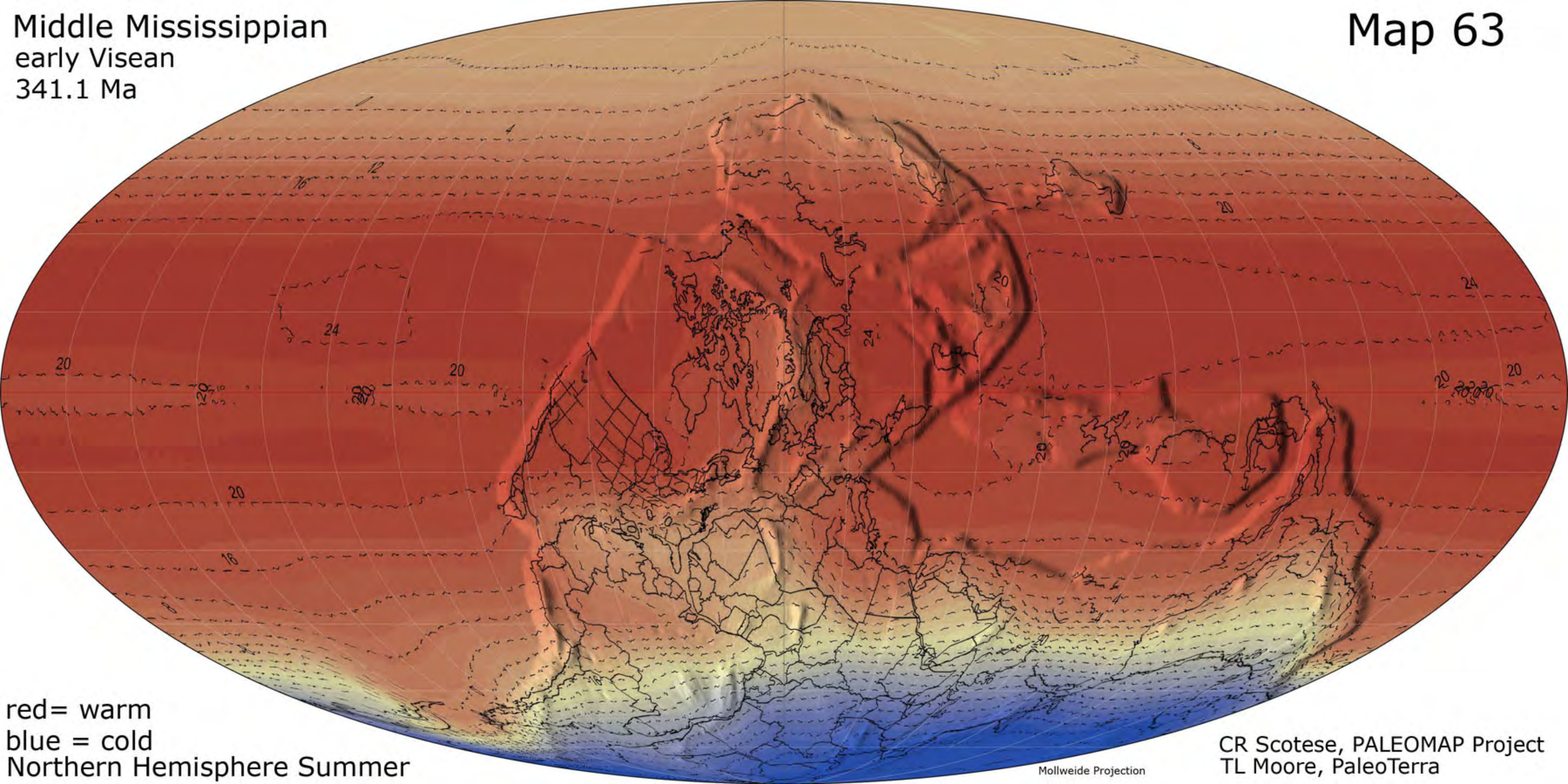
red= warm
blue = cold
Northern Hemisphere Summer

Mollweide Projection

CR Scotese, PALEOMAP Project
TL Moore, PaleoTerra

Middle Mississippian
early Visean
341.1 Ma

Map 63

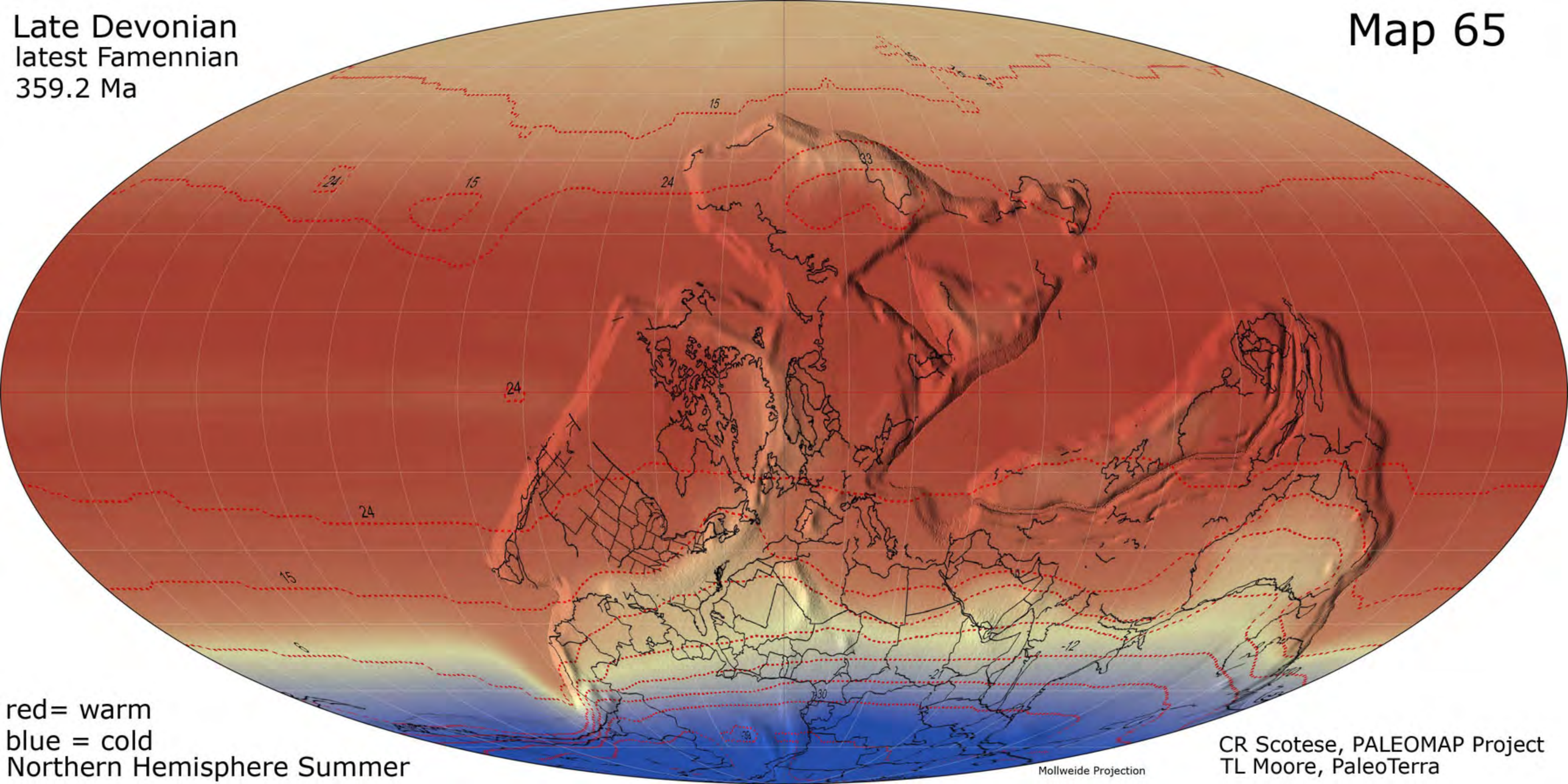


red= warm
blue = cold
Northern Hemisphere Summer

CR Scotese, PALEOMAP Project
TL Moore, PaleoTerra

Late Devonian
latest Famennian
359.2 Ma

Map 65



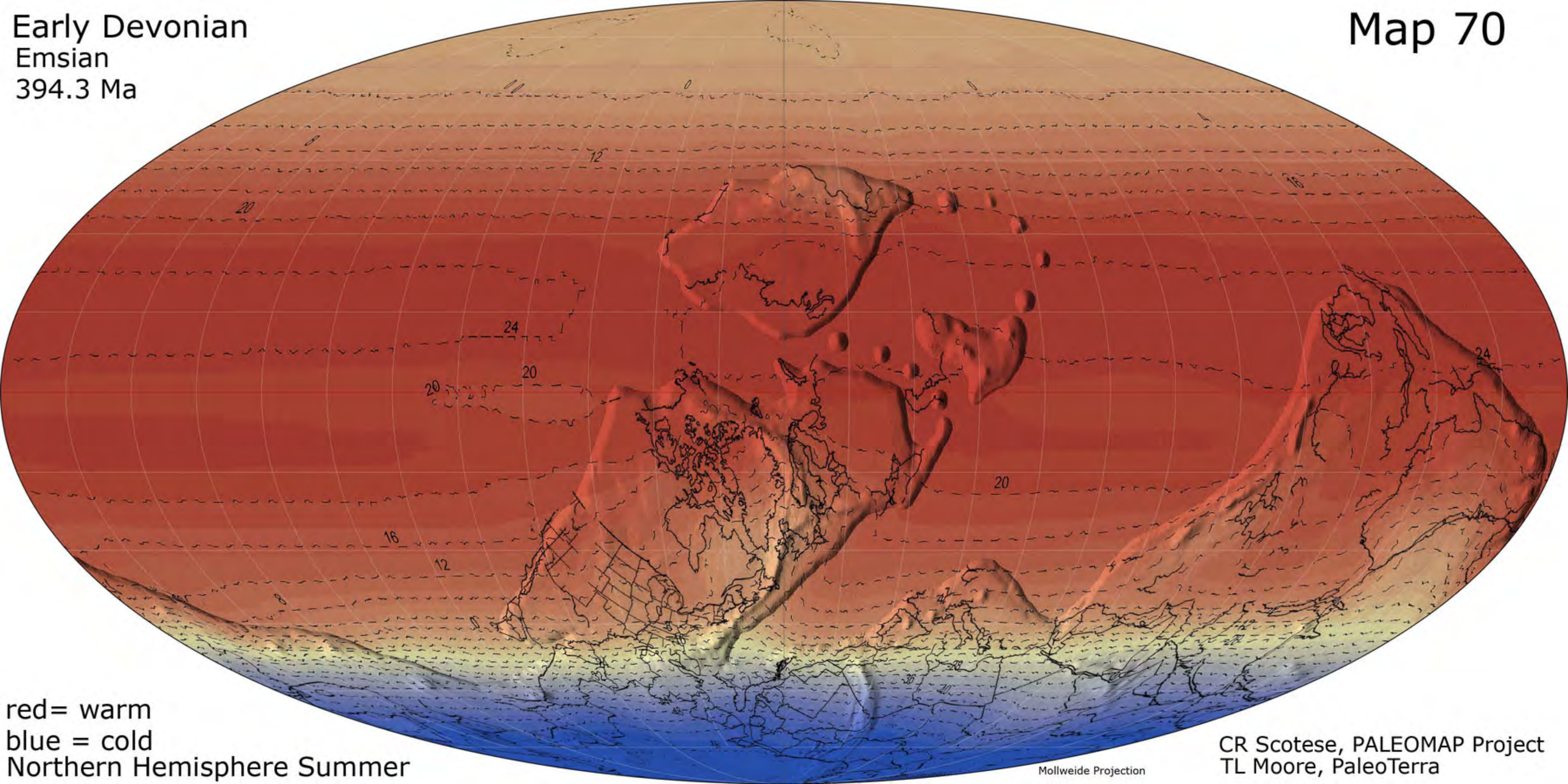
red= warm
blue = cold
Northern Hemisphere Summer

Mollweide Projection

CR Scotese, PALEOMAP Project
TL Moore, PaleoTerra

Early Devonian
Emsian
394.3 Ma

Map 70



red= warm
blue = cold
Northern Hemisphere Summer

Mollweide Projection

CR Scotese, PALEOMAP Project
TL Moore, PaleoTerra

Early Silurian
late Llandovery
432.1 Ma

Map 75

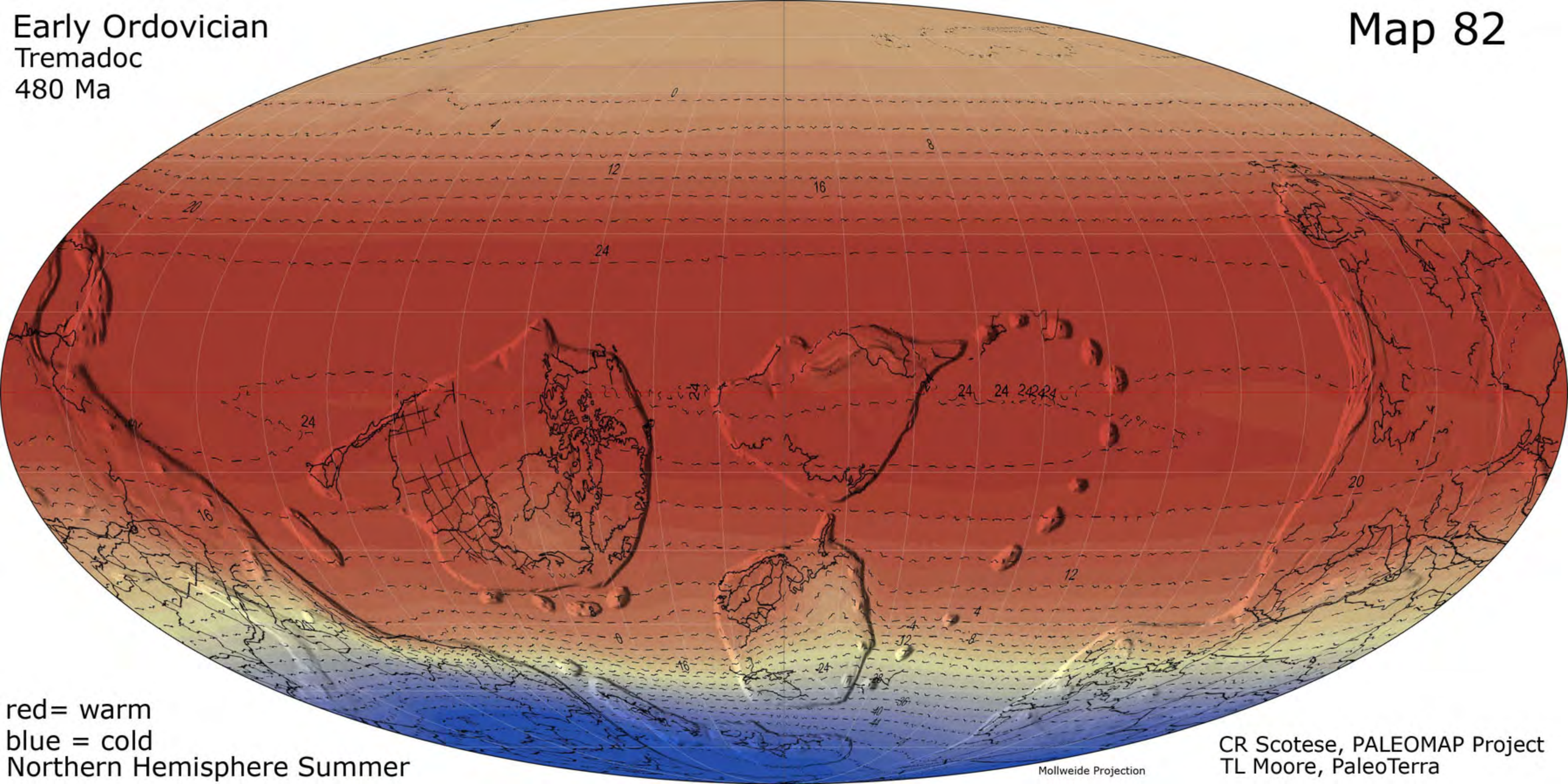
red= warm
blue = cold
Northern Hemisphere Summer

Mollweide Projection

CR Scotese, PALEOMAP Project
TL Moore, PaleoTerra

Early Ordovician
Tremadoc
480 Ma

Map 82



red= warm
blue = cold
Northern Hemisphere Summer

Mollweide Projection

CR Scotese, PALEOMAP Project
TL Moore, PaleoTerra

Cambrian-Precambrian Boundary

542 Ma

Map 88

red= warm
blue = cold
Northern Hemisphere Summer

Mollweide Projection

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TL Moore, PaleoTerra

Late Neoproterozoic
Middle Ediacaran
600 Ma

Map 90

Map in Preparation

red= warm
blue = cold
Northern Hemisphere Summer

Mollweide Projection

CR Scotese, PALEOMAP Project
TL Moore, PaleoTerra