

Atlas of Phanerozoic Upwelling Maps

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This Atlas of Phanerozoic Upwelling Maps shows the pattern of marine upwelling 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). The light blue shading represents areas of upwelling. The blue circles indicate the strength and persistence of the upwelling systems.

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 slight color differences between the symbols on the maps are due to the fact that the maps were made for four separate reports (Scotese et al., 2007; 2008; 2009; & 2011).

There are some notable patterns of upwelling illustrated by the maps. A strong upwelling system is always present along the Equator and along the west coasts of continents in the southern hemisphere and to a lesser extent along the east coasts of continents in the northern hemisphere. In addition, moderate zonal upwelling systems are present in temperate latitudes at 45 – 60 degrees (N&S). Broad regions of oceanic 'downwelling', are found in the northern and southern subtropics (23 – 40 degrees, N&S) and in the polar regions. The polar downwelling zones generate cold bottom water that chills the oceans during times when the Earth has polar icecaps.

The location of ancient upwelling systems is also a good predictor of world-class source rock deposits. This is especially true for times when continents, covered by shallow seas, cross the Equator. Extremely rich source rock deposits occur along the eastern edge of the Arabian platform because this area was located beneath the Western Tethys Equatorial Upwelling System for nearly 100 million years (mid-Triassic to mid-Cretaceous). Rich source rock deposits were similarly formed in Venezuela and Colombia when the vigorous westward moving Equatorial Current crossed the northernmost part of South America (Cretaceous, Maps 27-17).

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 Cambrian and Early Ordovician Paleogeographic Maps:

- 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 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., 2014. Atlas of Phanerozoic Upwelling Maps (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.

Scotese, C.R., Illich, H., Zumberge, J., and Brown, S., and Moore, T., 2008. The GANDOLPH Project: Year Two 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 Two: Miocene (10Ma), Aptian/Albian (120 Ma), Berriasian/Barremian (140 Ma), Late Triassic (220 Ma), and Early Silurian (430 Ma), July, 2008. GeoMark Research Ltd, Houston, Texas, 177 pp.

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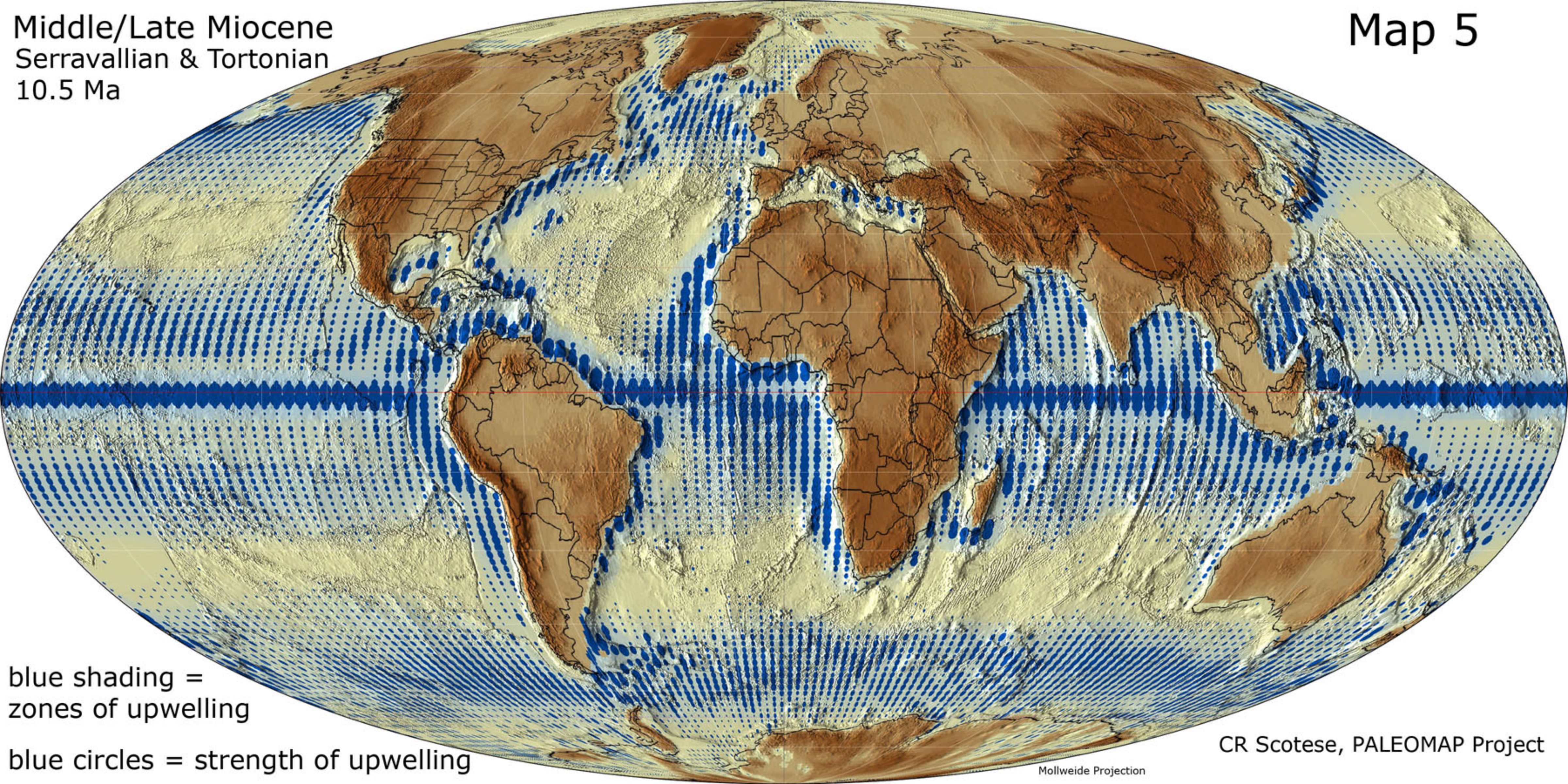
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Middle/Late Miocene
Serravallian & Tortonian
10.5 Ma

Map 5



blue shading =
zones of upwelling

blue circles = strength of upwelling

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Mollweide Projection

Early Miocene
Aquitanian & Burdigalian
19.5 Ma

Map 7

Map in Preparation

blue shading =
zones of upwelling

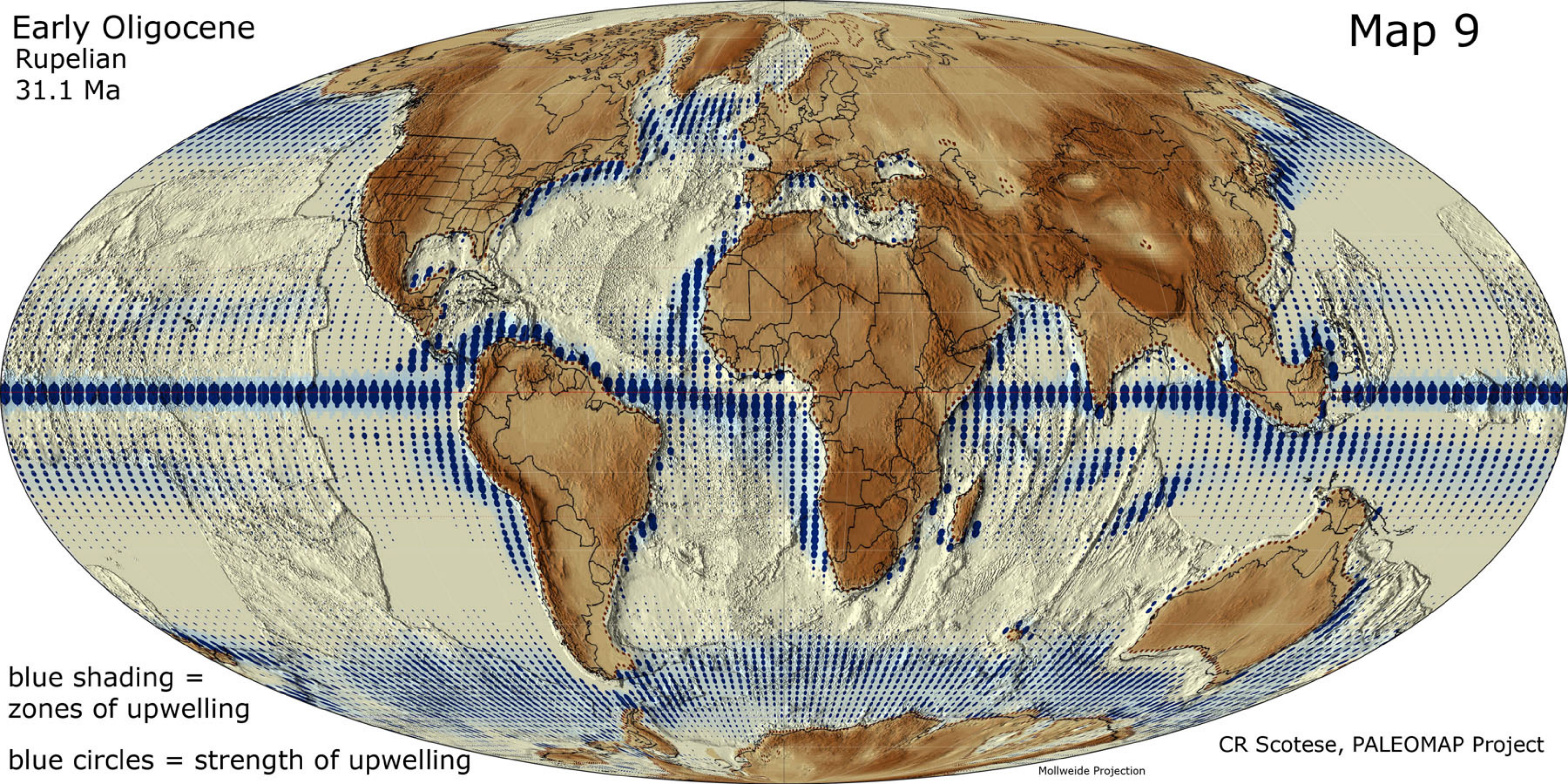
blue circles = strength of upwelling

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Mollweide Projection

Early Oligocene
Rupelian
31.1 Ma

Map 9



blue shading =
zones of upwelling

blue circles = strength of upwelling

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Mollweide Projection

early Middle Eocene
middle Lutetian
44.6 Ma

Map 12

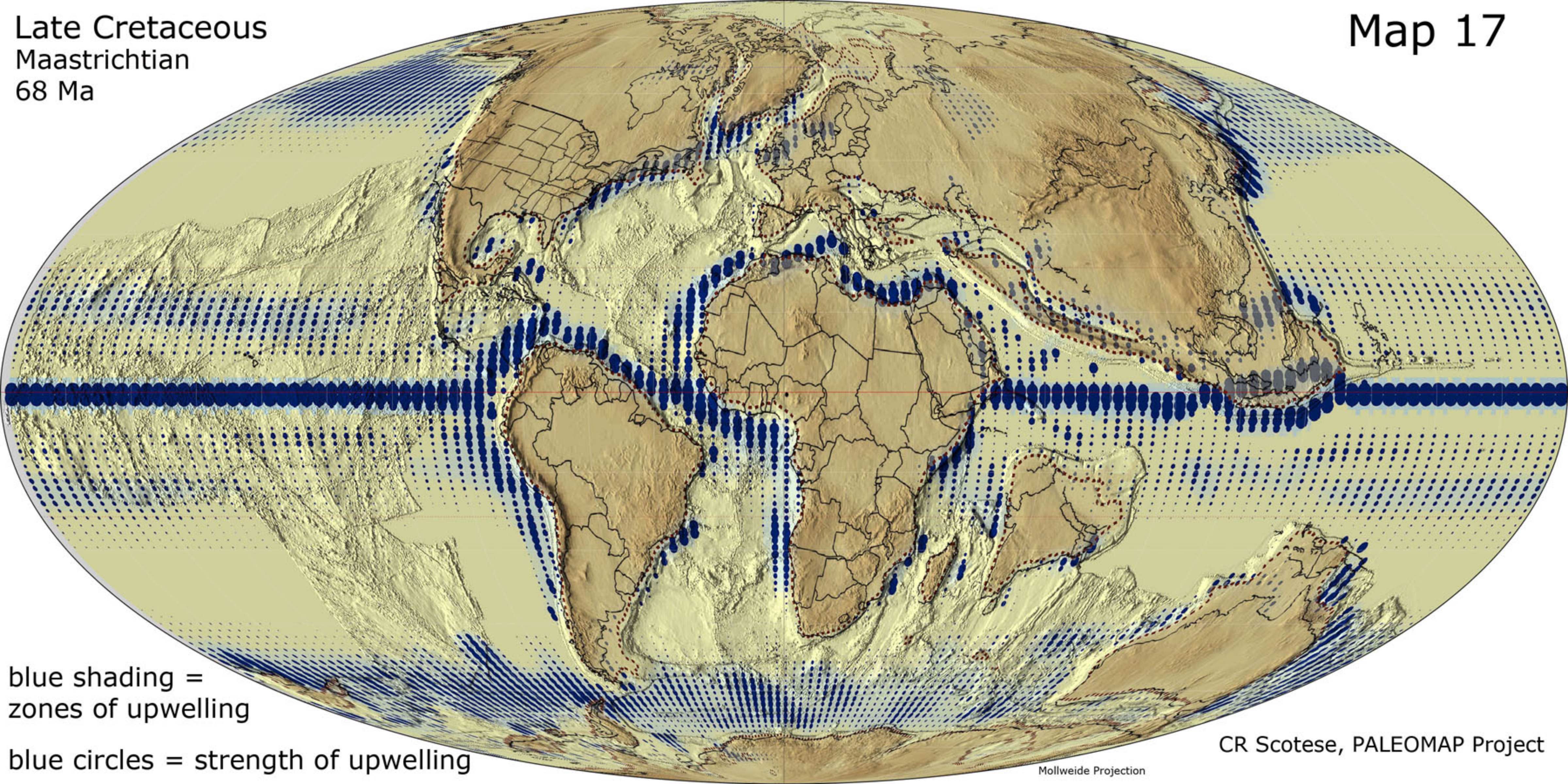
Map in Preparation

blue shading =
zones of upwelling

blue circles = strength of upwelling

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Mollweide Projection



Late Cretaceous
Maastrichtian
68 Ma

Map 17

blue shading =
zones of upwelling

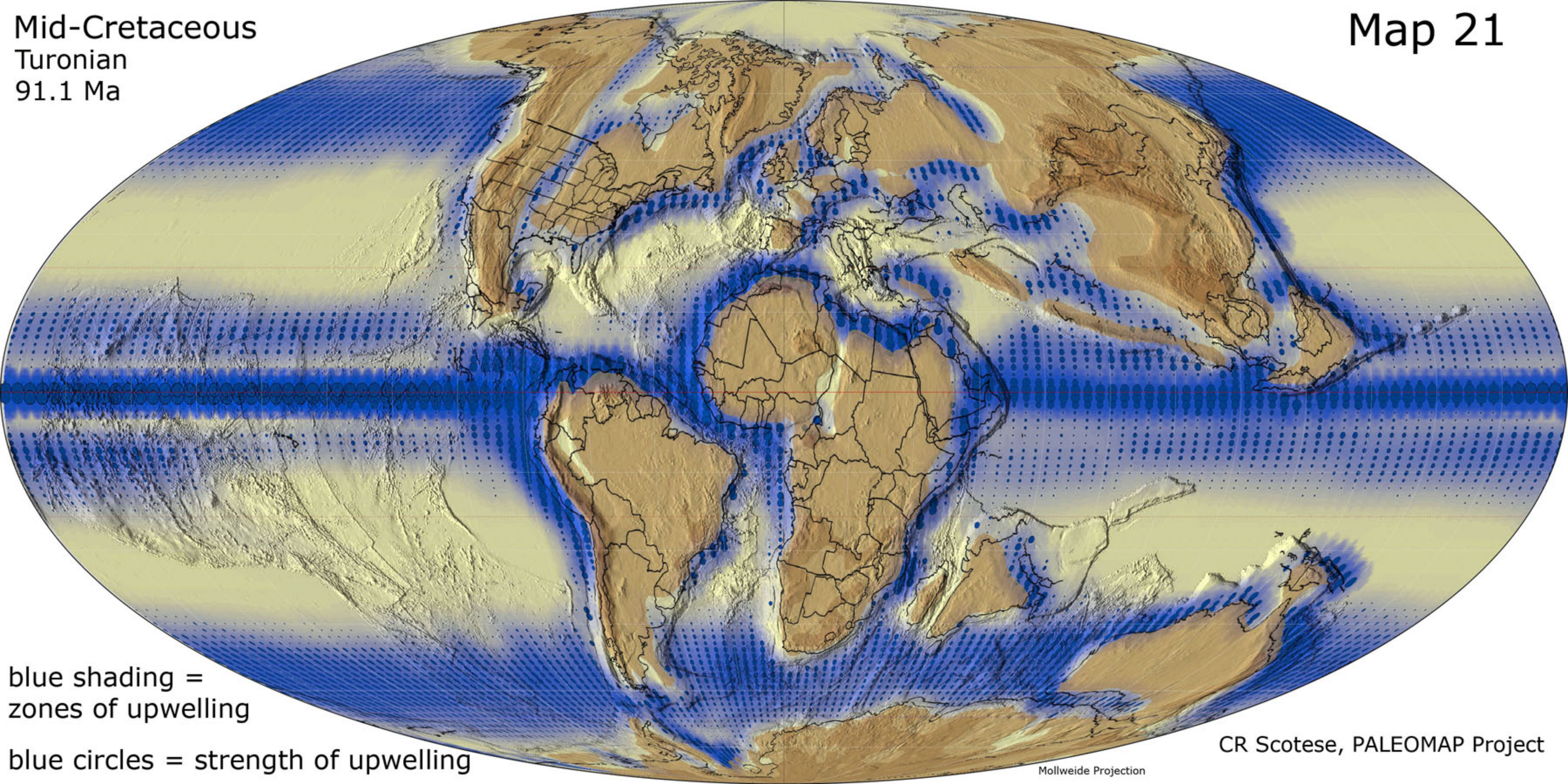
blue circles = strength of upwelling

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Mollweide Projection

Mid-Cretaceous
Turonian
91.1 Ma

Map 21



blue shading =
zones of upwelling

blue circles = strength of upwelling

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Mollweide Projection

Early Cretaceous
late Albian
101.8 Ma

Map 23

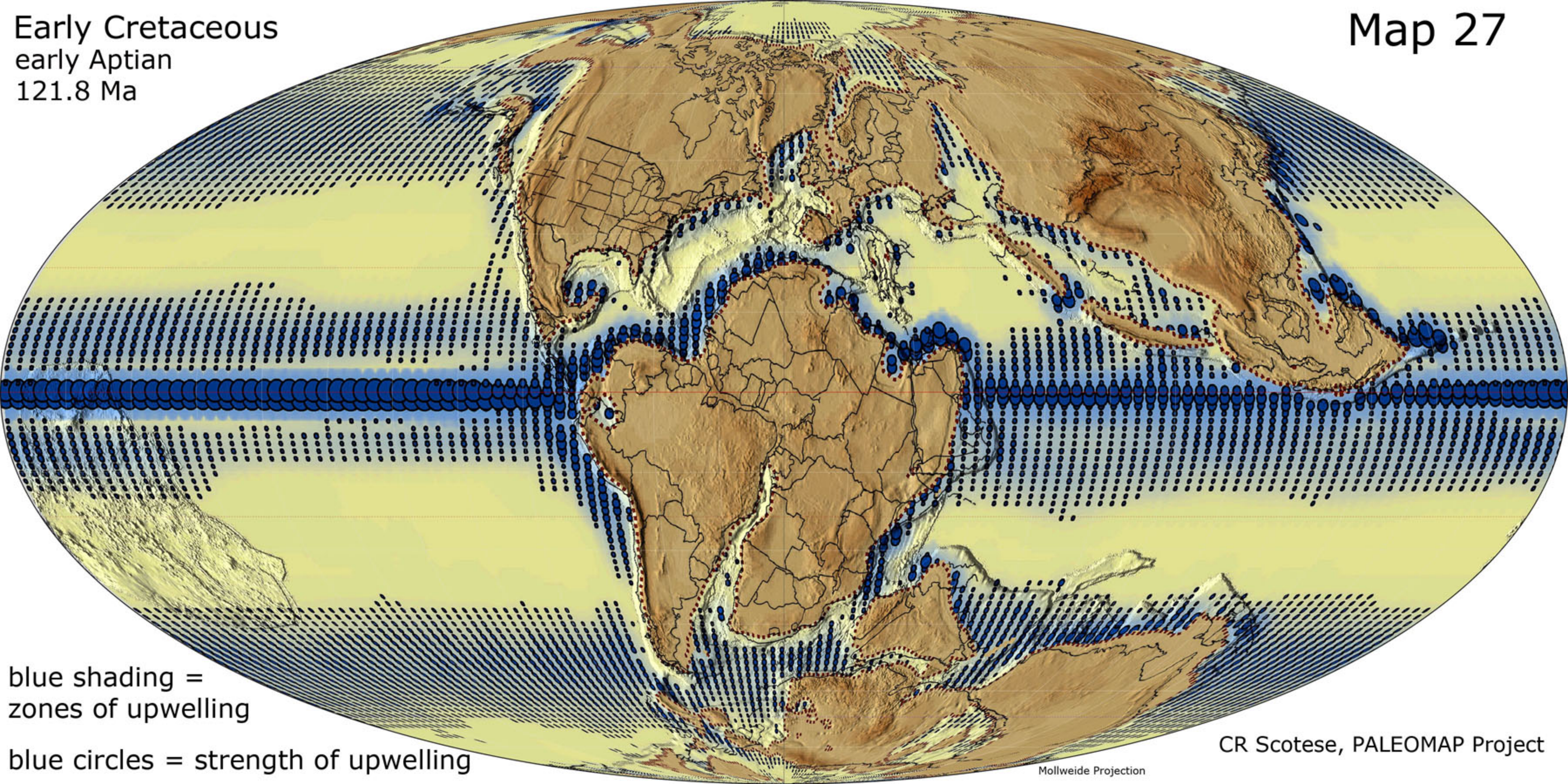
Map in Preparation

blue shading =
zones of upwelling

blue circles = strength of upwelling

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Mollweide Projection



Early Cretaceous
early Aptian
121.8 Ma

Map 27

blue shading =
zones of upwelling

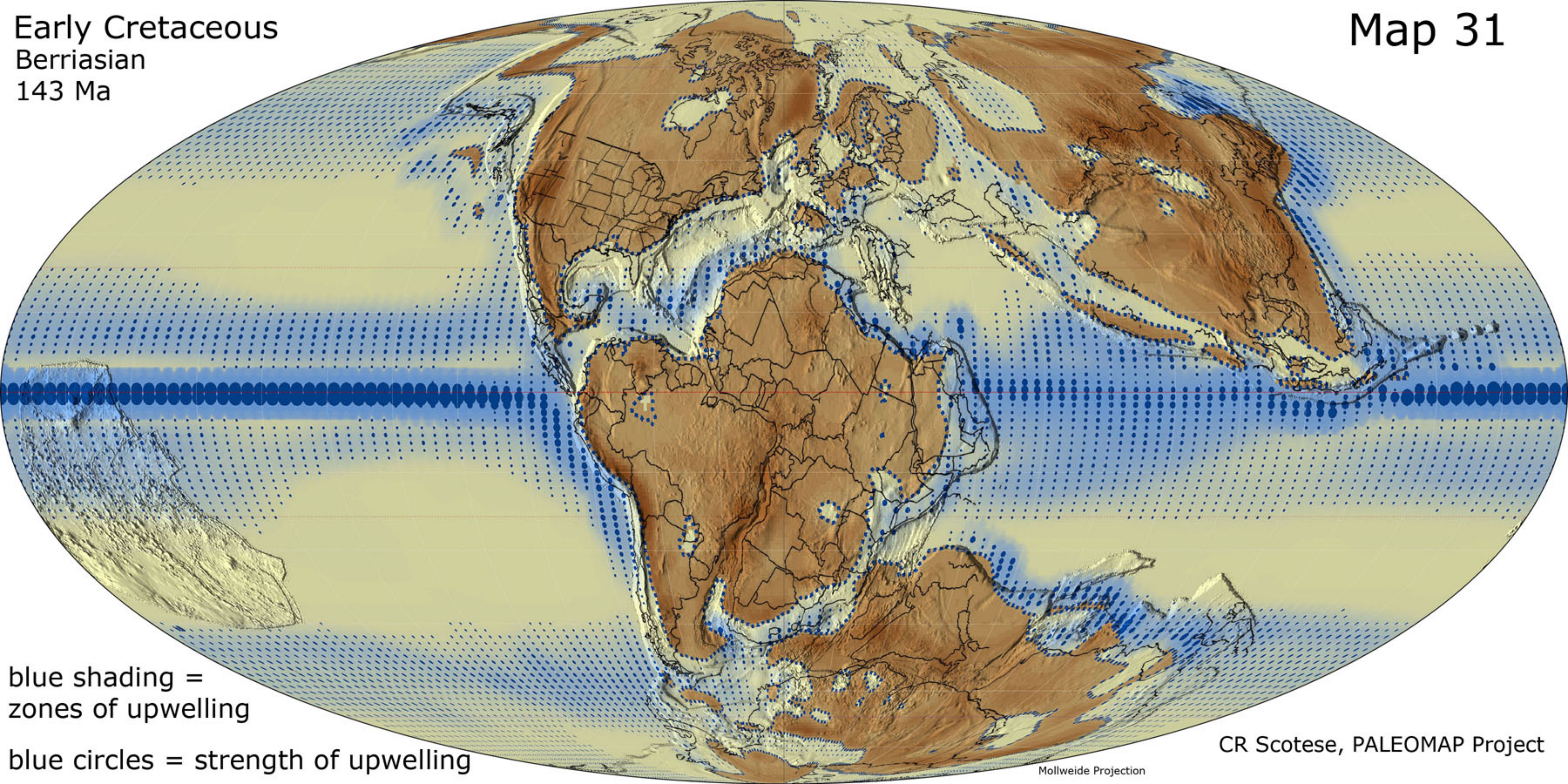
blue circles = strength of upwelling

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Mollweide Projection

Early Cretaceous
Berriasian
143 Ma

Map 31



blue shading =
zones of upwelling

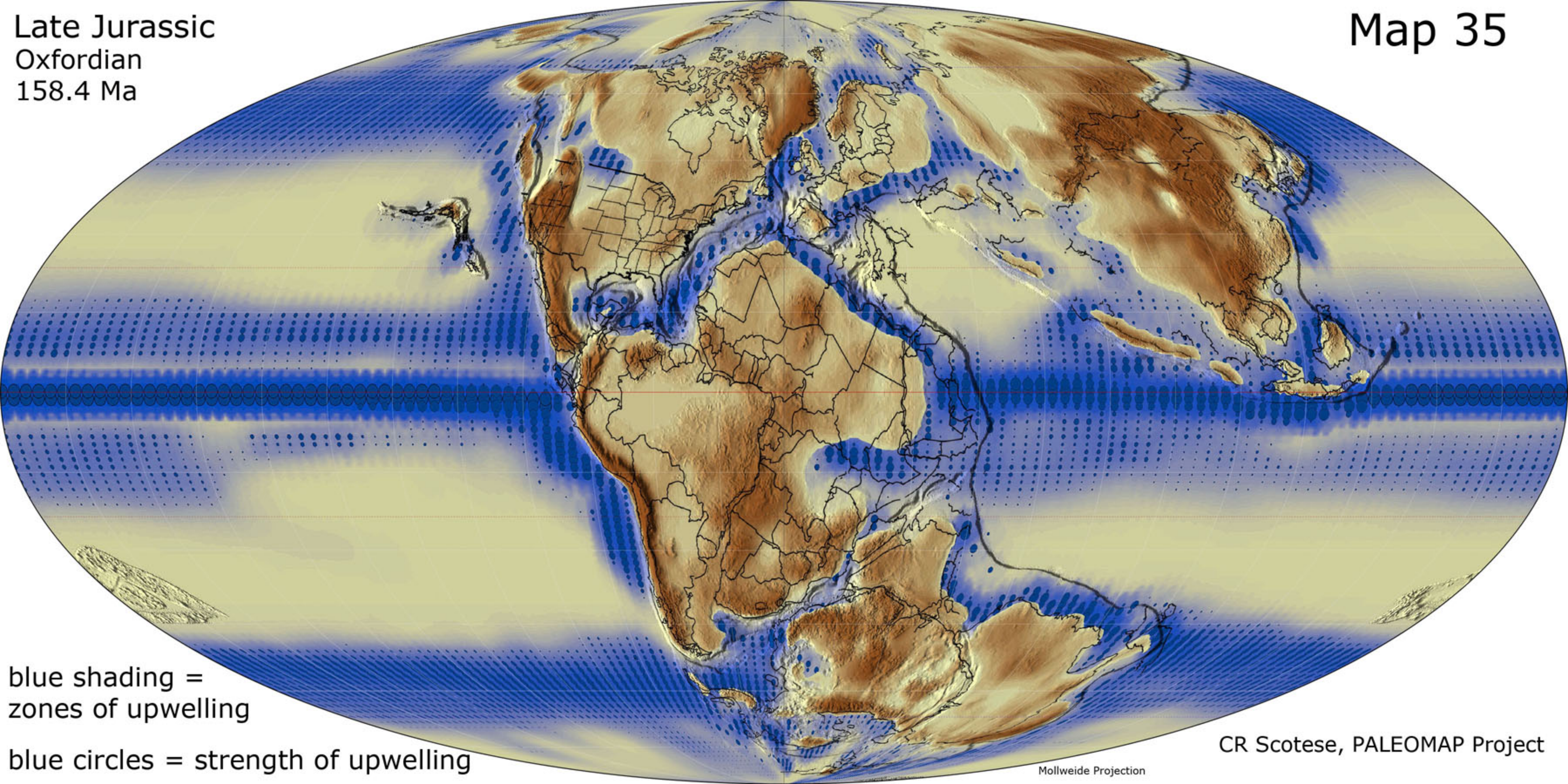
blue circles = strength of upwelling

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Mollweide Projection

Late Jurassic
Oxfordian
158.4 Ma

Map 35



blue shading =
zones of upwelling

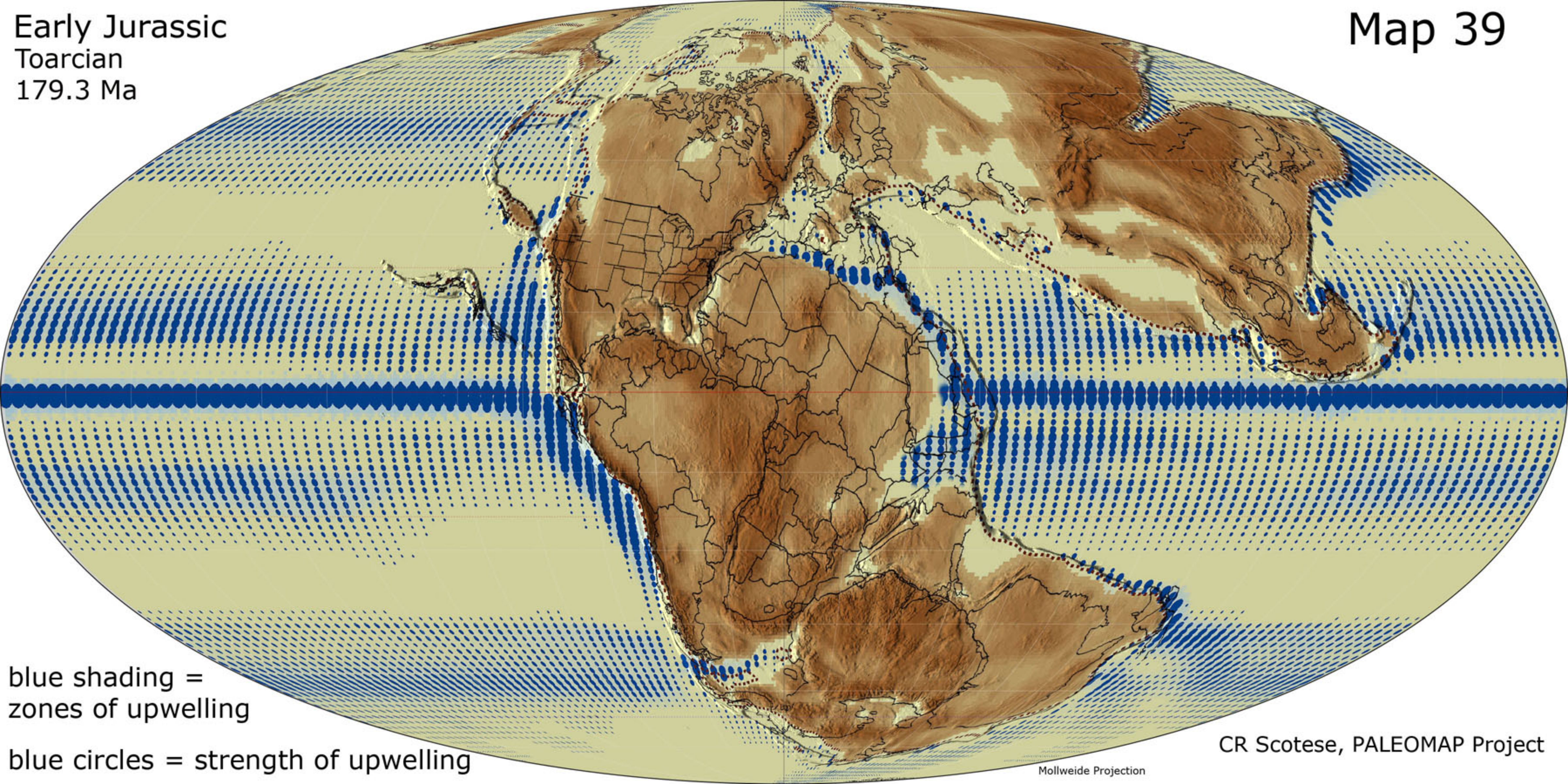
blue circles = strength of upwelling

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Mollweide Projection

Early Jurassic
Toarcian
179.3 Ma

Map 39



blue shading =
zones of upwelling

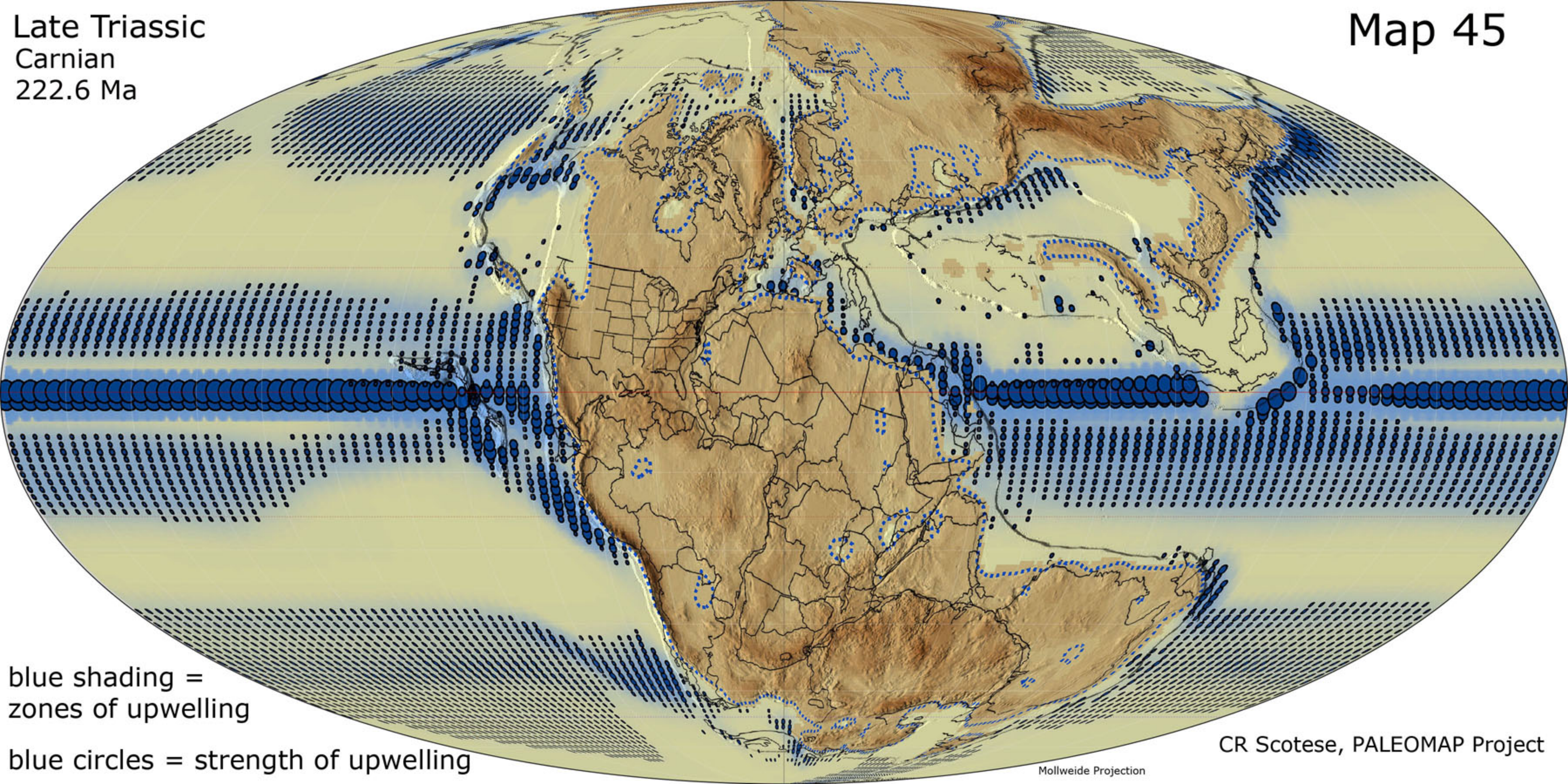
blue circles = strength of upwelling

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Mollweide Projection

Late Triassic
Carnian
222.6 Ma

Map 45



blue shading =
zones of upwelling

blue circles = strength of upwelling

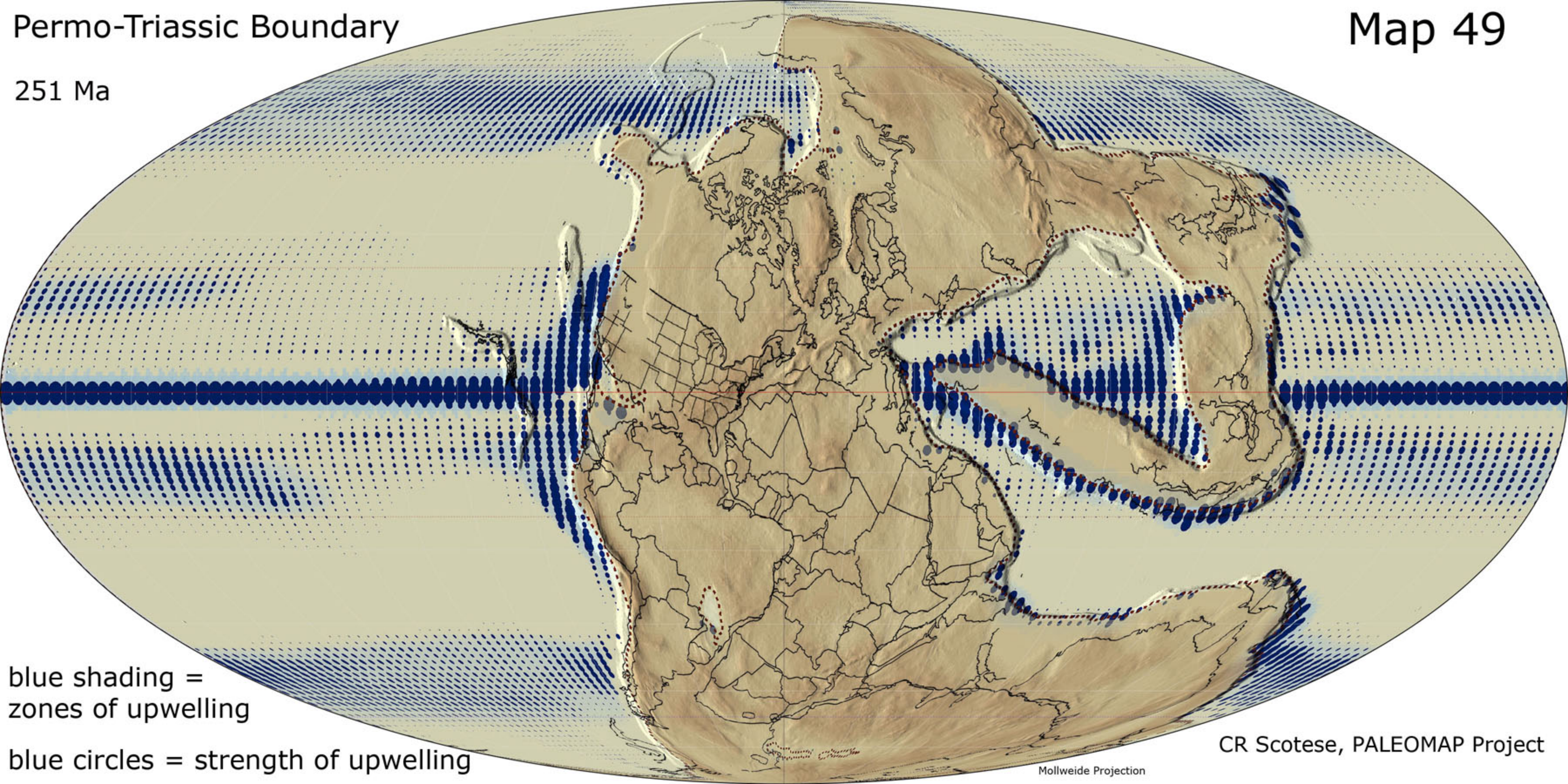
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Mollweide Projection

Permo-Triassic Boundary

Map 49

251 Ma



blue shading =
zones of upwelling

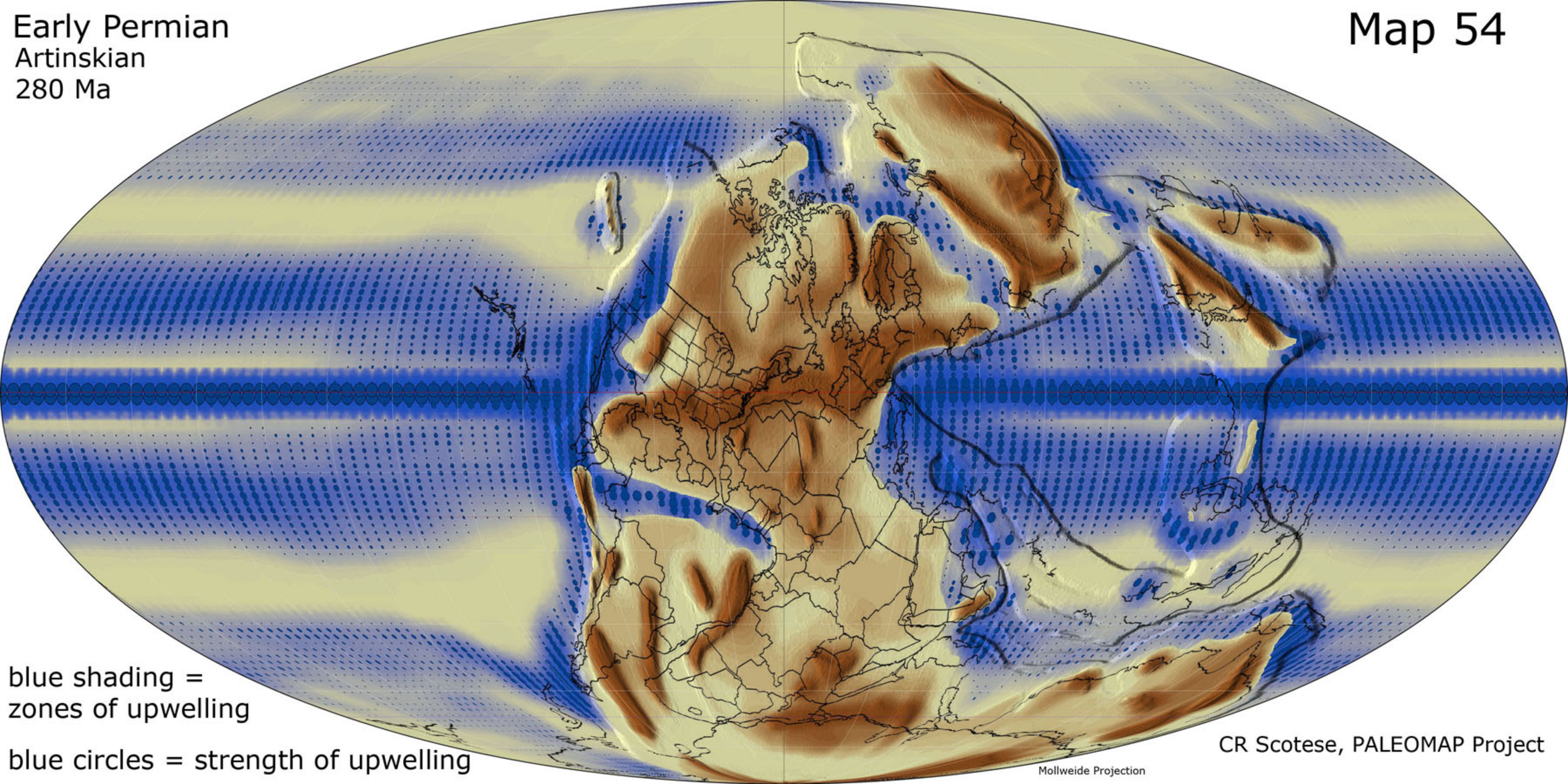
blue circles = strength of upwelling

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Mollweide Projection

Early Permian
Artinskian
280 Ma

Map 54



blue shading =
zones of upwelling

blue circles = strength of upwelling

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Mollweide Projection

Late Pennsylvanian
Gzhelian
301.2 Ma

Map 57

Map in Preparation

blue shading =
zones of upwelling

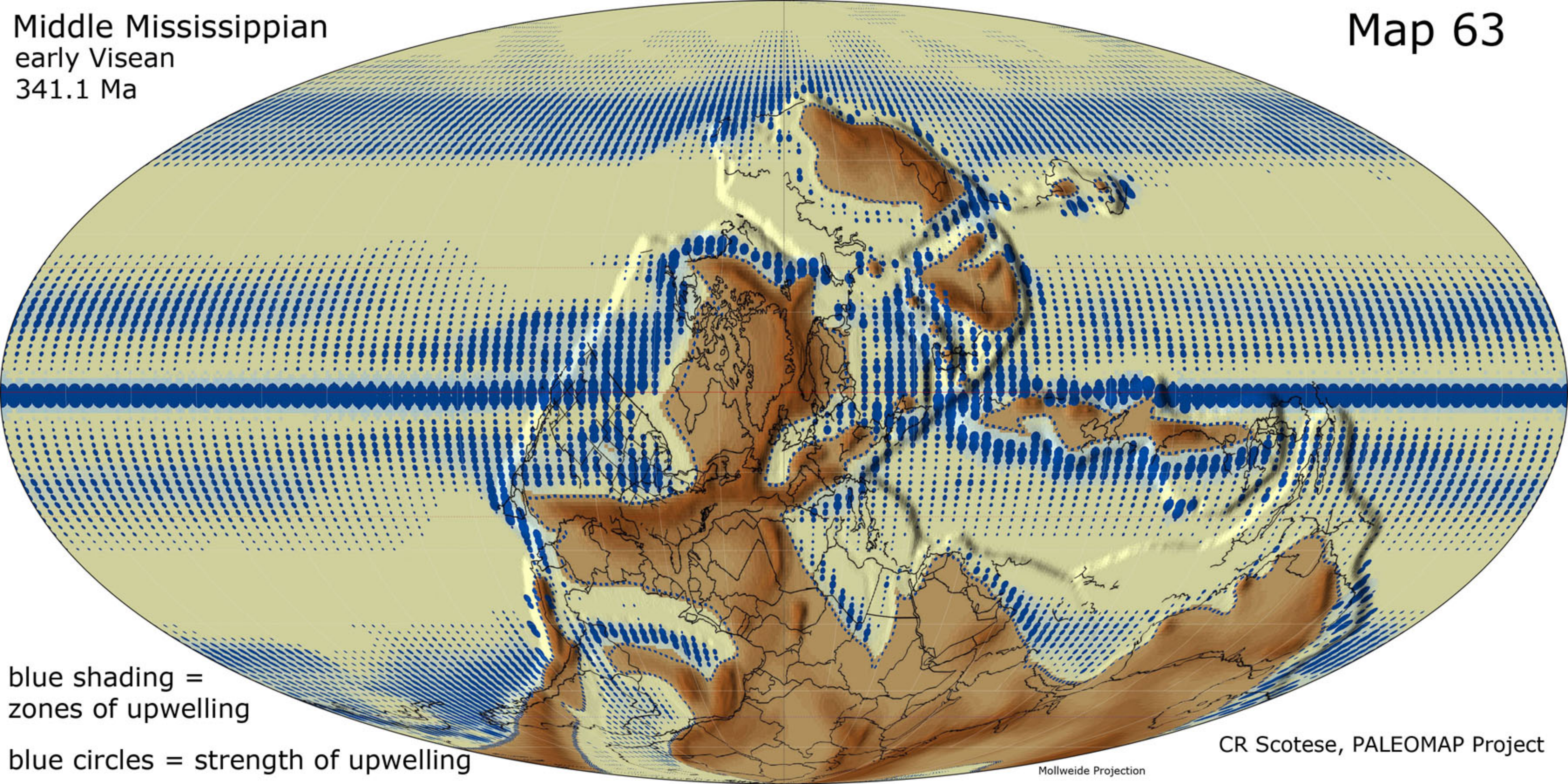
blue circles = strength of upwelling

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Mollweide Projection

Middle Mississippian
early Visean
341.1 Ma

Map 63



blue shading =
zones of upwelling

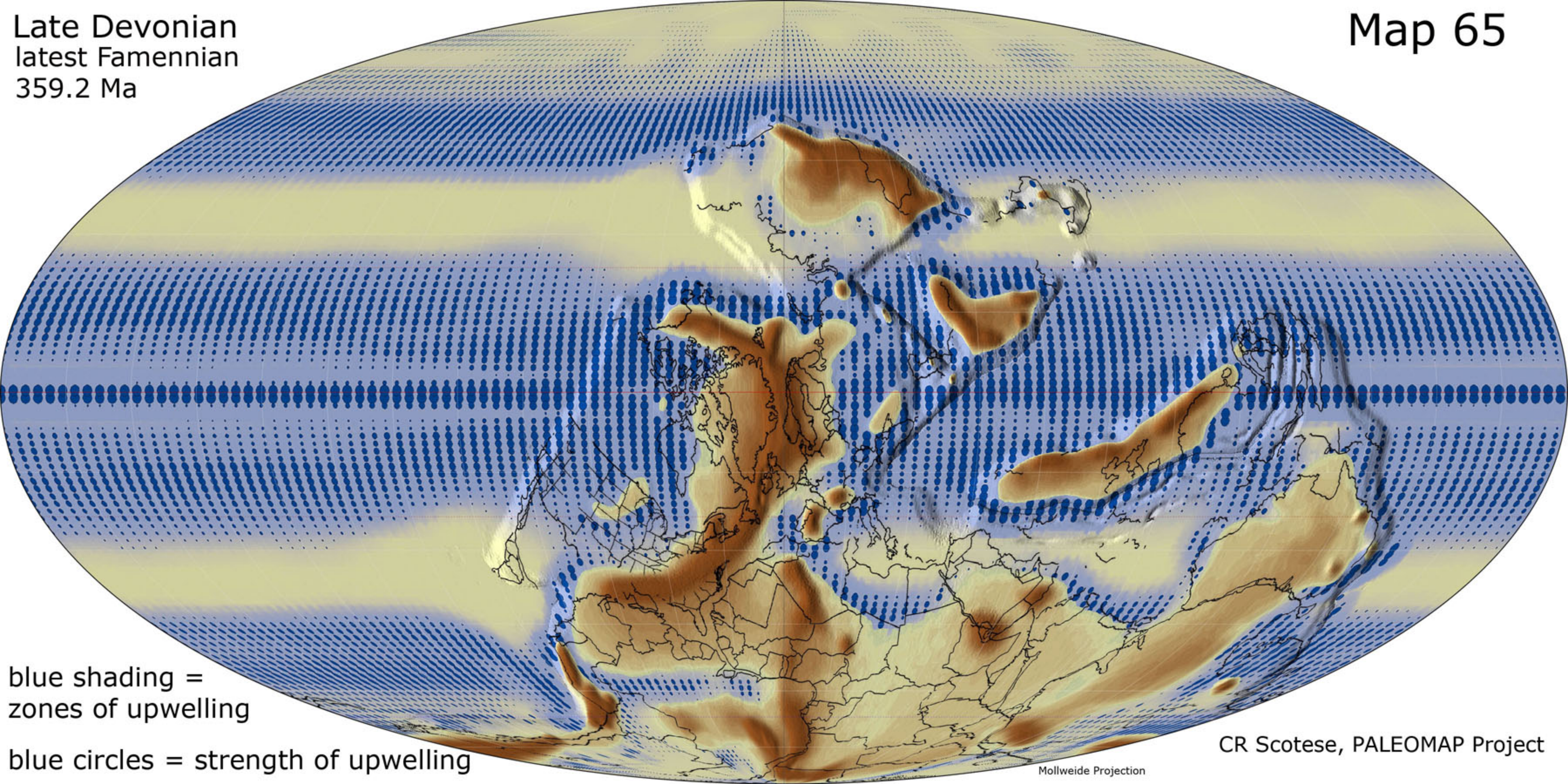
blue circles = strength of upwelling

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Mollweide Projection

Late Devonian
latest Famennian
359.2 Ma

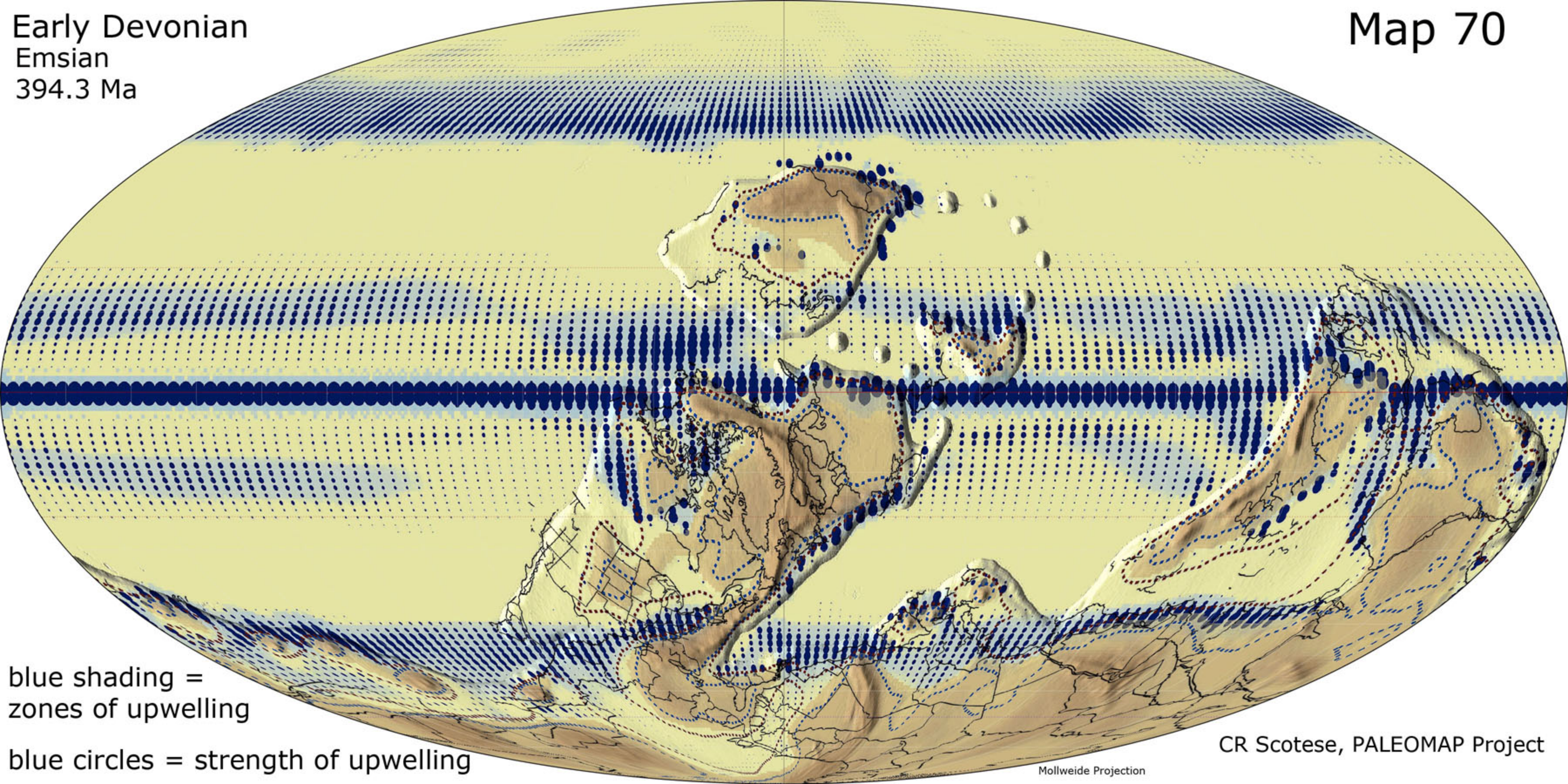
Map 65



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Early Devonian
Emsian
394.3 Ma

Map 70



blue shading =
zones of upwelling

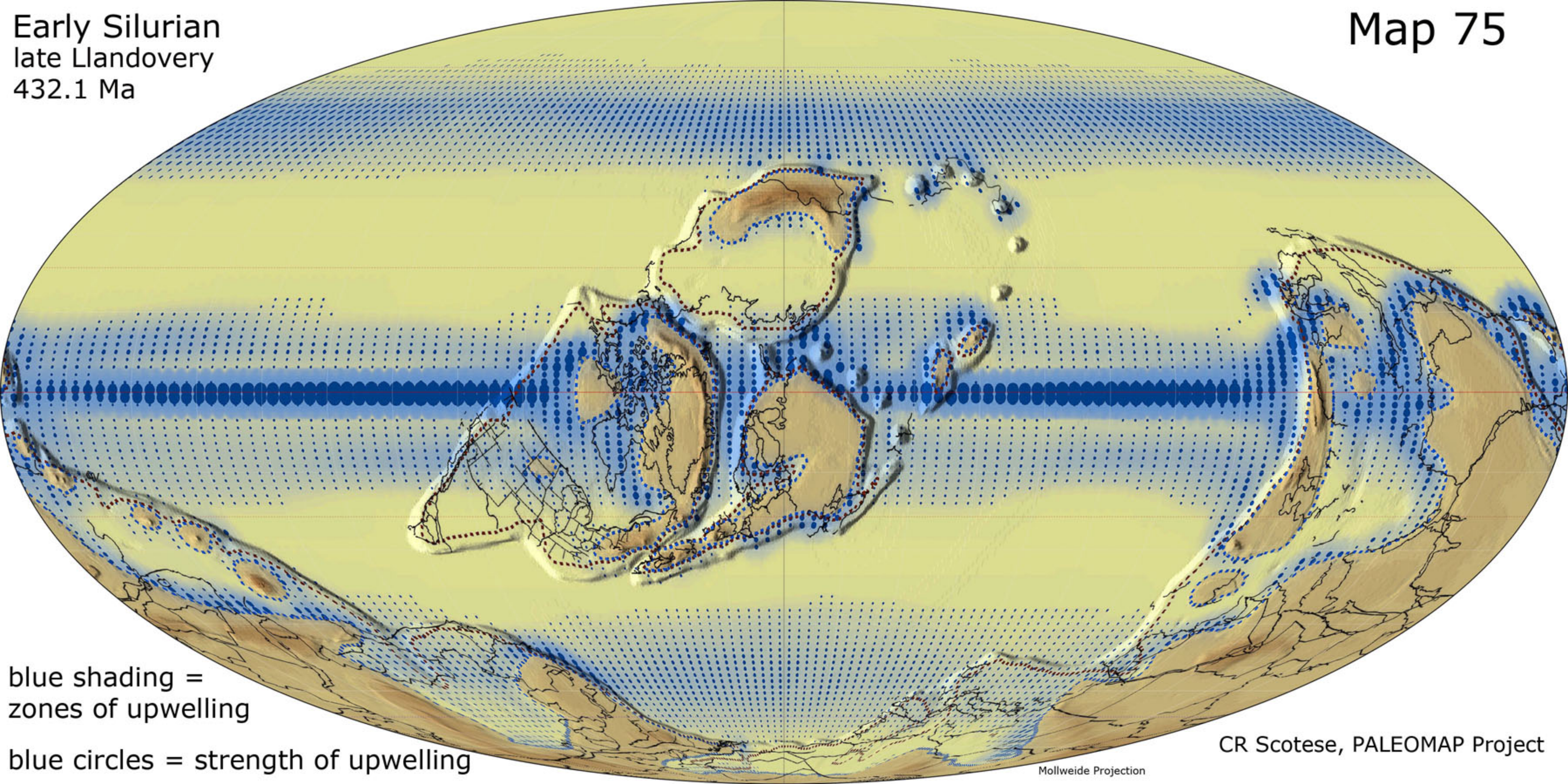
blue circles = strength of upwelling

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Mollweide Projection

Early Silurian
late Llandovery
432.1 Ma

Map 75



blue shading =
zones of upwelling

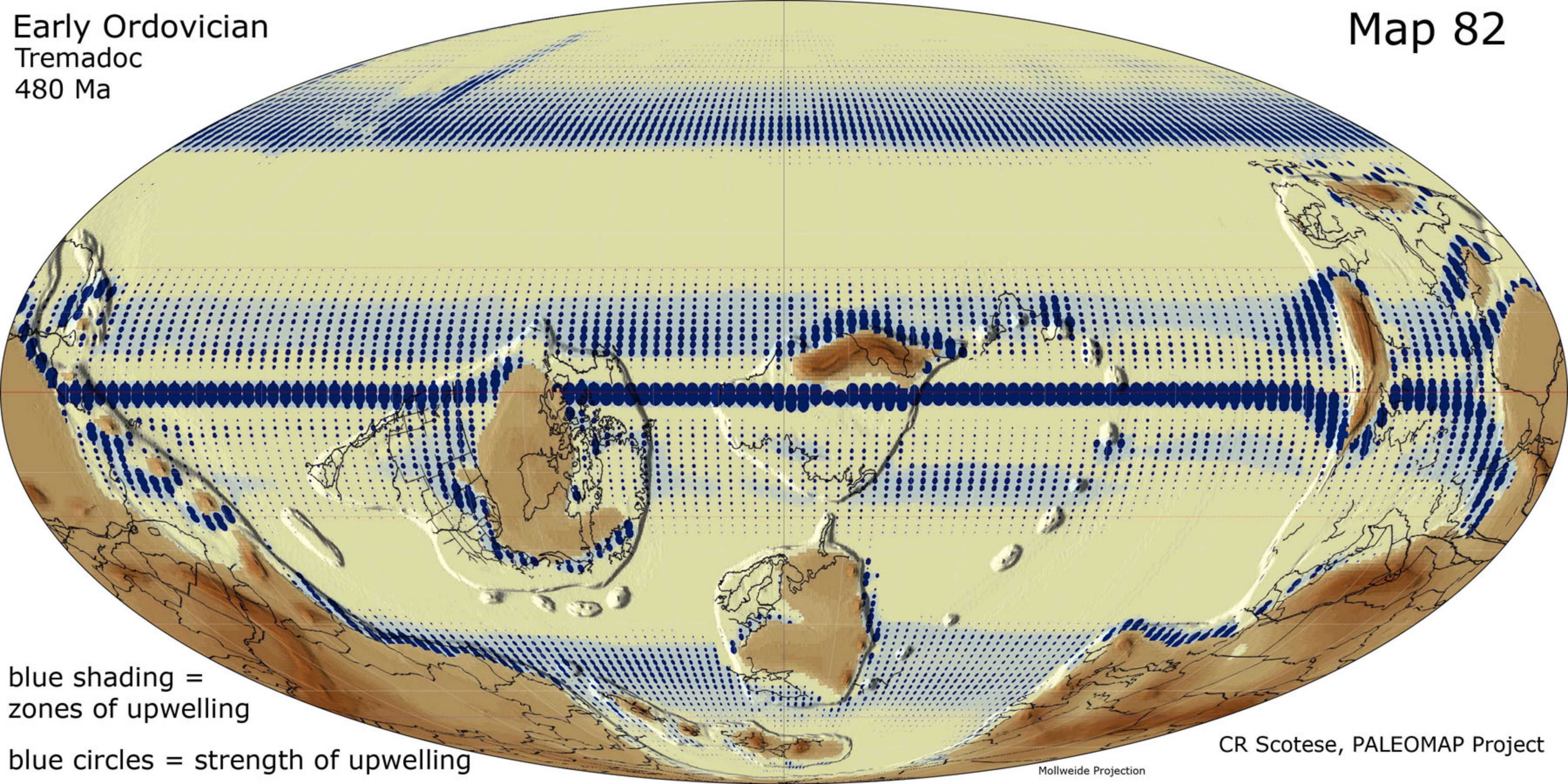
blue circles = strength of upwelling

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Mollweide Projection

Early Ordovician
Tremadoc
480 Ma

Map 82



blue shading =
zones of upwelling

blue circles = strength of upwelling

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Mollweide Projection

Map in Preparation

blue shading =
zones of upwelling

blue circles = strength of upwelling

Late Neoproterozoic
Middle Ediacaran
600 Ma

Map 90

Map in Preparation

blue shading =
zones of upwelling

blue circles = strength of upwelling

CR Scotese, PALEOMAP Project

Mollweide Projection