Iberian-Appalachian connection unveils a new and deep view of the interior of Pangea as it was amalgamated

February 19 2020, by Pedro Correia

Palaeogeographic and palaeotopographic constraints within Pangaea-A showing the continental linkage between eastern Laurentia and Iberia and uplift of the Appalachian and Variscan orogens in the late Gzhelian-early Permian. Credit: *Scientific Reports* (2020). DOI: 10.1038/s41598-020-59461-x

Recently, my team reported unprecedented evidence of a continental connection between the ancient landmasses Laurentia (North America) and Iberia (the northern margin of Gondwana) in the Late Pennsylvanian period (307-299 Ma), revealing a deep, new vision of the interior of the Pangaea supercontinent as it was amalgamated. This includes the first glimpse of a (paleo) geographic linkage between Iberia and the Appalachians of the eastern United States. As part of a larger puzzle, Iberia is a key piece for understanding how and when continental collision between Gondwana and Laurasia occurred during the amalgamation of Pangea, which was proposed for the first time by the German meteorologist and geophysicist Alfred Wegener in 1912.

This contribution addresses critical aspects about the timing of mountain uplift and climatic/environmental changes during the Gondwana-Laurasia collision within the heart of Pangea and final closure of the ancient Rheic Ocean.

In this study, detailed Pangea reconstructions are presented, with enlarged view of the interior of Pangea from paleoenvironmental, paleoclimatic and paleofloral (including biostratigraphic) constraints between Laurentia and Iberia, while also illustrating the paleogeography and paleotopography of the Appalachian and Iberian (Variscan) mountains as they developed.

We have provided paleofloral, biostratigraphic paleoenvironmental and paleoclimatic evidence of a geographic linkage between the Appalachians in the eastern United States and Iberia that happened at the Late Pennsylvanian, 307-299 million years ago. This late Paleozoic land connection reveals the timing of uplift of the Appalachian and Iberian (Variscan) orogens and shows the ancient landmasses Laurentia and Iberia sharing the same dryland environment and the consequent dispersal and migration of dry-climate-adapted flora during that time interval as a result of initial aridification in the interior of the Pangea during its final amalgamation.

Key highlights:

There is now a broad consensus that the late Paleozoic supercontinent, Pangea, is just the latest in a series of supercontinents whose amalgamation and dispersal have punctuated Earth history. Episodic recurrence of supercontinent assembly and breakup, i.e., the supercontinent cycle, has been linked to global-scale mountain building, crustal growth, rapid climate change, evolution of life, biogeochemical cycles, sea-level changes, large igneous provinces, deep mantle circulation, mantle-core dynamics and perturbations in Earth's magnetic field.

Although the existence of Pangea is a cornerstone of geology, there is much debate about its configuration. Two of the classical hypothesized configurations are Pangea-A (the "Wegenerian" configuration proposed by Alfred Wegener in 1912) and Pangea-B (configuration based on paleomagnetic data by Irving in a 1977 *Nature* paper). In the Pangea-A model, the supercontinent did not deform internally between amalgamation and breakup. By contrast, the Pangea-B configuration requires several thousand kilometres of dextral movement of Laurasia relative to Gondwana during the lifespan of Pangea. The validity of these reconstructions has been vigorously debated for more than 40 years.

Our data are not only key to resolving the longstanding Pangea-A versus Pangea-B controversy about the paleogeographic position of the Gondwana relative to Laurasia, they also illustrate the paleoclimate and paleogeography of both the Appalachian and Iberian (Variscan) mountains as they developed. In addition, our contribution addresses critical aspects of the timing of mountain uplift and climatic and environmental changes during the continental collision between Gondwana and Laurasia within the heart of Pangea.

1. Regarding the unprecedented evidence for this study—what are the datasets you're working with, and how did they reveal new features of this highly debated event?

For my Ph.D. thesis, I studied carboniferous sedimentary rocks (about 300 million years old) in the Douro Basin (Upper Pennsylvanian, northwestern Portugal) of Iberia that were deposited about the same time as Pangea formed by continental collisions between ancestral North America, Europe and Africa. I was looking at how plant life responded to the rise of these mountains. Our dataset is derived from new fossil discoveries I made in these rocks, among which are several new species of plants and insects.

In particular, we report the first occurrence of the seed plant Lesleya in the Iberian Massif. Lesleya is very rare pteridosperm (cycadopsid) genus and an enigmatic member of dry-climate-adapted plants (generally xeromorphic) that lived and were restricted to "dryland" environments located in the tropical regions of central Pangaea, and grew in both Laurentia and Iberia. Their fossil remains are an exceptional and valuable record of the paleoenvironmental and paleoclimatic conditions. Lesleya fossils have been widely documented in dryland basins of North America (e.g., Pennsylvania) which straddled the central Pangea at that time. The mountains formed by the continental collisions are thought to have acted as a physical barrier to their migration. The occurrence of Lesleya in Iberia suggests its dispersal and migration (and other dryland floras; see other examples in our article) occurred before uplift of the Appalachian and Iberian (Variscan) mountains (Figure 4 of article), placing it to the east of Pennsylvania at that time, and providing linkages between the ancient landmasses Laurentia and Iberia (located along the northern margin of Gondwana) along the paleoequatorial belt some 300 million years ago.

2. Data gives a "first glimpse" of the link between Iberia and the Appalachians—was this connection not previously believed to be present? What was past evidence that it was there?

Most of reconstructions show Iberia close to eastern Laurentia (eastern North America), but its exact paleo-geographic location was not known. Our dataset provides direct evidence of a geographic linkage between ancient land masses of the eastern of United States (Laurentia) and Portugal (Iberia), and sharing the same type of environment in the Late Pennsylvanian time (Figure 4 of article). A macrofloral biostratigraphic gap found in rocks of Upper Pennsylvanian from the Appalachian region in West Virginia and Portugal represents more clear, strong evidence of an "Iberian-Appalachian connection" for the same time (Kasimovian) interval (Figure 3 of article). This gap is thought to be attributed to a major glaciation in South Gondwana, which occurred in part of the paleo-equatorial belt during the Late Pennsylvanian. Based on these data, we now know that continental lands of Laurentia and Iberia shared the same "dryland" environment (Figure 4 of article) during the Late Pennsylvanian.

3. Does this new analysis change how we thought about the formation of the Appalachian and Iberian mountains?

It does not change models for how each of these mountains formed. It does constrain where they were located relative to one another and, equally importantly, how stable that connection was for over 100 million years, and precisely constrain the timing of uplift of the Appalachian and Iberian (Variscan) orogens and climatic (wet-to-dry and arid) and environmental (wetland-to-dryland) changes occurred during the amalgamation of Pangea and final closure of the ancient Rheic Ocean.

4. Regarding the issue of Pangea A vs B—does the data hint at one version or another? If not, how can this data be used to resolve the debate?

Pangea began to form about 380 million years ago, and began to break up about 200 million years ago. Pangea-A is the classical "jigsaw" fit of continents proposed by Alfred Wegener. Everyone agrees with a Pangea-A configuration at the time it began to break up. Those who advocate the Pangea-B model claim that Pangea changed its configuration over the previous 180 million years due to internal stresses. This model requires that Gondwana was located about 3000 km farther east relative to North America, compared to the Pangea-A configuration. Our data show that Iberia and Pennsylvania lay along the same paleo-equatorial belt 300 million years ago, which is precisely where they would sit on a Pangea-A reconstruction. This implies that the central part of Pangea had essentially the same configuration from 300 to 200 million years ago.

This story is part of Science X Dialog*, where researchers can report findings from their published research articles.* Visit this page *for information about ScienceX Dialog and how to participate.*

More information: Pedro Correia et al. Iberian-Appalachian connection is the missing link between Gondwana and Laurasia that confirms a Wegenerian Pangaea configuration, *Scientific Reports* (2020). DOI: 10.1038/s41598-020-59461-x

Bio:
I am a Ph.D paleontologist and naturalist from Portugal. My research is focus on paleobotany, paleoentomology, paleoclimate, paleogeography,

tectonics in Iberia and North America.