Late Cretaceous-Paleogene Foreland Sediment-Dispersal Systems in Northern and Eastern Mexico: Interpretations from Preliminary Detrital-Zircon Analysis*

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Abstract

Upper Cretaceous-Paleogene stratigraphy of the Mexican foreland-basin system broadly resembles that of the Alpine foreland basin in that both contain initial deepwater (flysch) deposits overlain by younger molasse-type deposits. In the Parras and La Popa basins of northern Mexico, Turonian-Santonian deepwater successions are overlain by shallow-marine and continental deposits of the Maastrichtian-Eocene Difunta Group. Similar molasse deposits are absent above deformed turbidites in the Mesa Central of north-central Mexico, where shallow-water strata may have been eroded from the thrust orogen. In the Tampico-Misantla basin of eastern Mexico, deepwater deposition persisted into the early Eocene, but molasse deposition never took place. Sediment delivery among these broadly correlative successions, the extent of their drainage basins, and locations of their depositional termini in and near the Gulf of Mexico basin are critical unresolved questions regarding the Cretaceous paleogeography of Mexico. New detrital-zircon data indicate that sediment sources for Mesa Central flysch deposits lay as far away as the SW United States, but that those sediment-delivery systems never connected as far south as the Tampico-Misantla basin. Detrital zircon populations in a single sample of flysch in Zacatecas and six Difunta samples from the Parras and La Popa basins contain 1.7–1.6 Ga and 1.4 Ga zircon populations characteristic of SW Laurentian basement. These preliminary data suggest that Turonian-Santonian axial rivers debouched SSE into deep water of the Mexican seaway basin prior to late

Campanian time, when the advancing orogen deflected axial drainage eastward along the Sierra Madre foredeep toward Monterrey. Flysch deposits of central Mexico, recorded by a sample of the Soyatal Fm, lack Laurentian grains, indicating local derivation from accreted terranes directly to the west. A sample of Paleocene turbidites from the Puskon #1 well in the distal part of the Tampico-Misantla basin similarly lacks Laurentian zircons, and is dominated by grains ranging 1.3–1.1 Ga and 144–66 Ma, likely derived from exposed Grenville basement and the Cretaceous magmatic arc of southern Mexico, respectively. Because axial drainage recorded by the Difunta Group did not deliver Laurentian sediment into the Tampico-Misantla basin, it is likely that this voluminous Wilcox-equivalent dispersal system instead spilled eastward across the Tamaulipas arch into the NW Gulf of Mexico.

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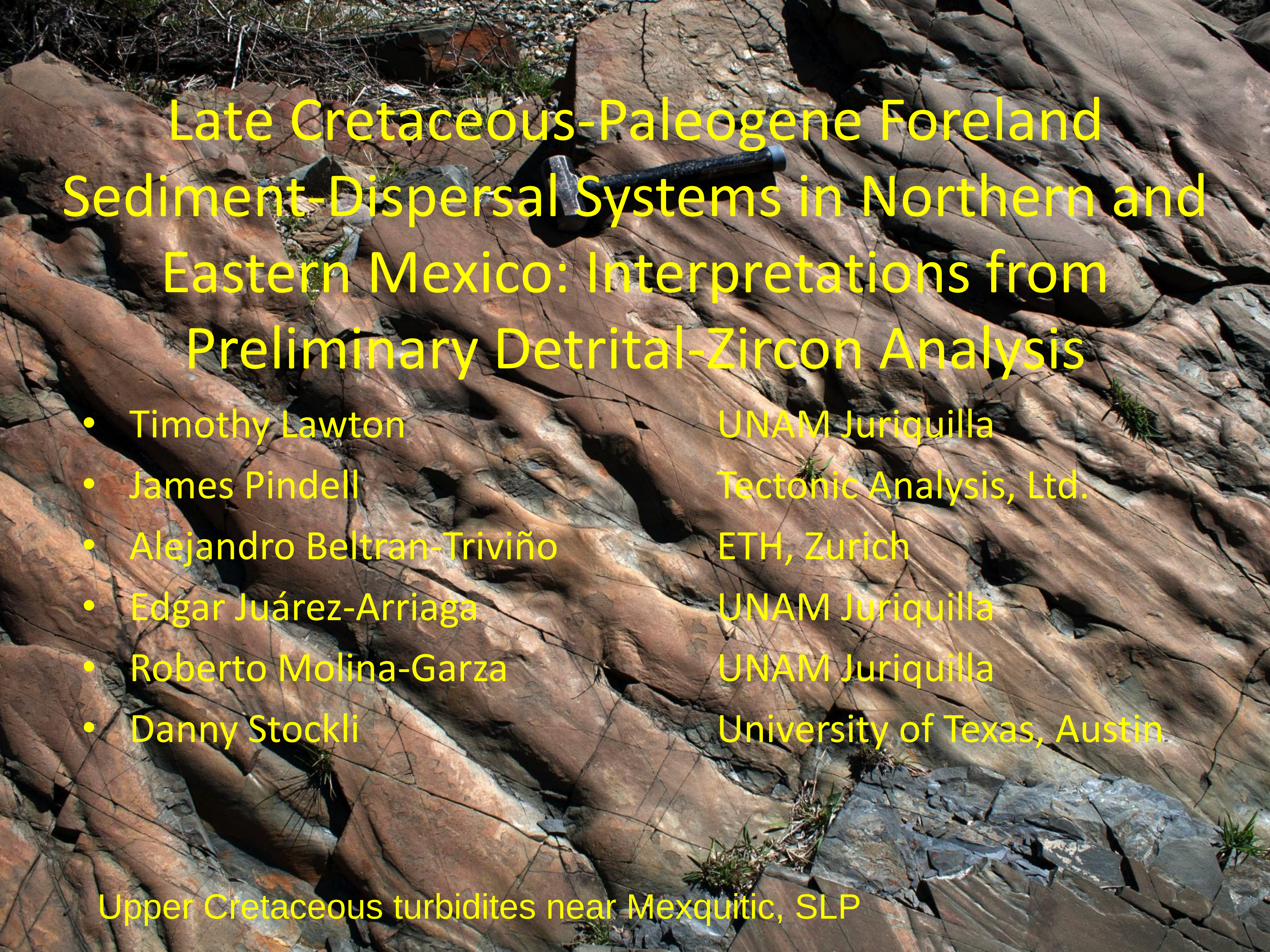

Upper Cretaceous turbidites near Mexquitic, SLP

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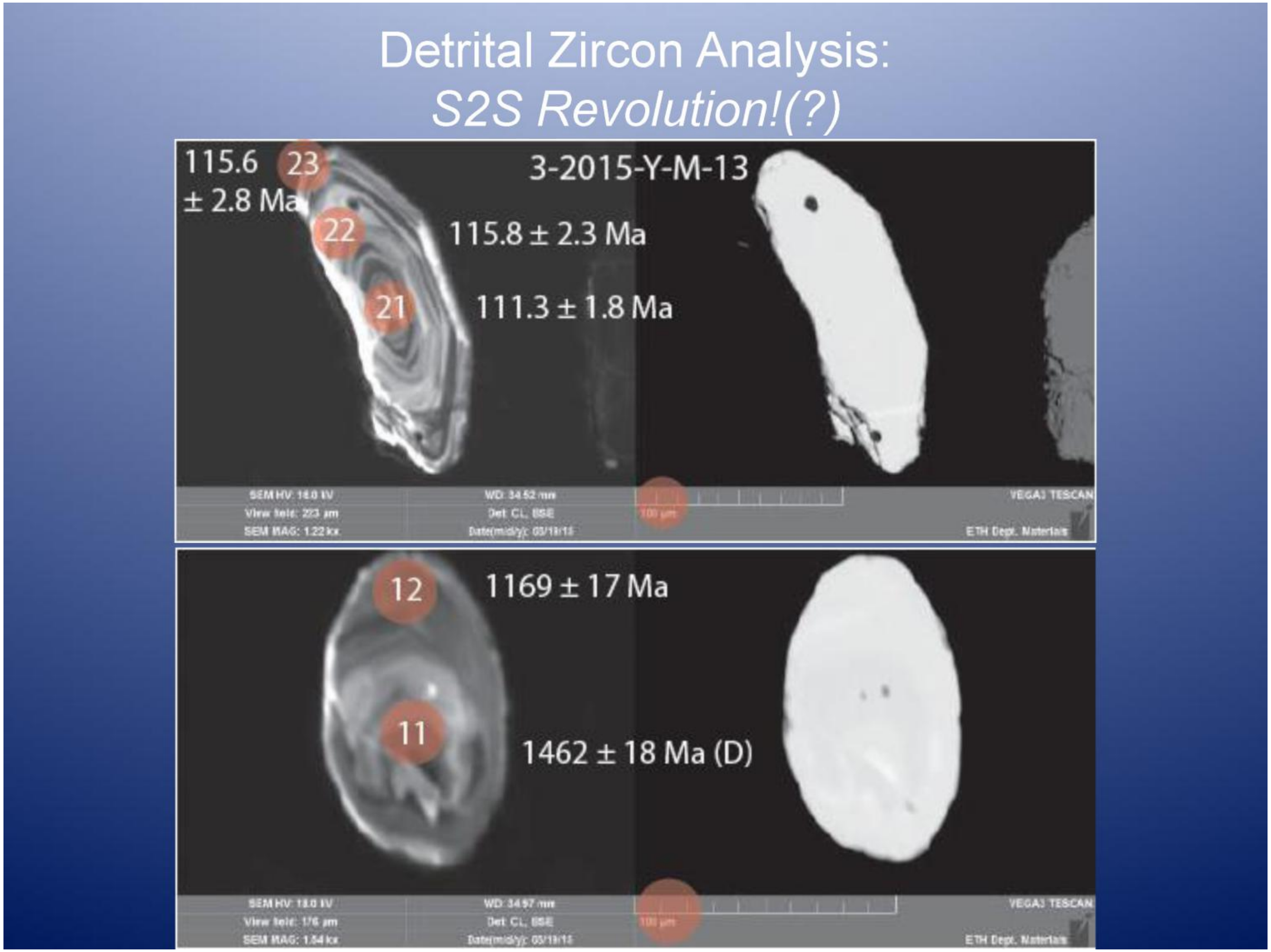
Presentation Organization

1. Detrital zircons in source to sink analysis
2. Introduction to Cretaceous-Paleogene foreland stratigraphy of northern Mexico
3. Detrital zircon characteristics of Upper Cretaceous-Paleogene strata
4. Interpretation of sediment sources, dispersal systems, and sediment sinks

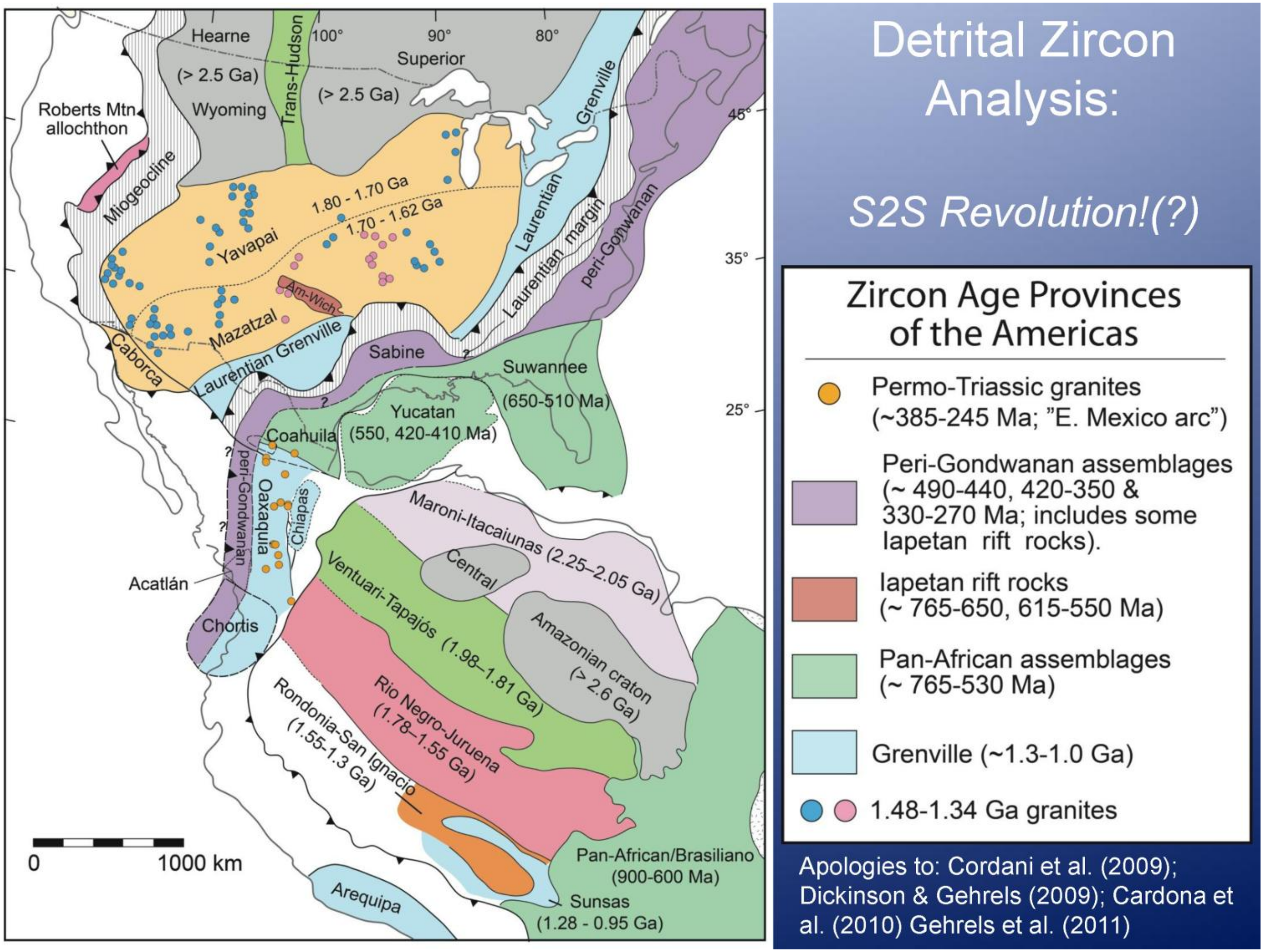
Presenter’s notes: The primary topics of this talk are to briefly discuss the utility of Uranium lead dating of individual detrital zircons in source to sink analysis, and then to apply the technique to a case study in the Upper Cretaceous and Paleogene of Mexico. My principle goal is to describe how preliminary detrital zircon data can be used to interpret the evolution of the Sierra Madre foreland basin and the pathways that sediment took to get to the basin. Steps three and four will be repeated four times to link detrital zircon characteristics of progressively younger strata to a corresponding sediment-dispersal model.



Presenter's notes: Dating of individual zircon grains is the most important analytical tool for evaluation of ultimate sediment sources and possible dispersal pathways since the development of paleocurrent analysis and petrographic determination of sandstone composition. In this method, individual zircons are analyzed with a laser linked to a (Presenter's notes continued on next slide)

(Presenter's notes continued from previous slide)

mass spectrometer, which measures the ration of Uranium to lead in the grains and permits a determination of the time since crystallization of the zircons, in short, zircon age. Here are cathodoluminiscence images of two zoned detrital zircons analyzed by Alejandro from the Chicontepec Formation and indicating changes in age between cores and rims of an Early Cretaceous grain (above) and a Proterozoic grain (below). Scale bars are 100 microns and laser spot size is 23 microns.

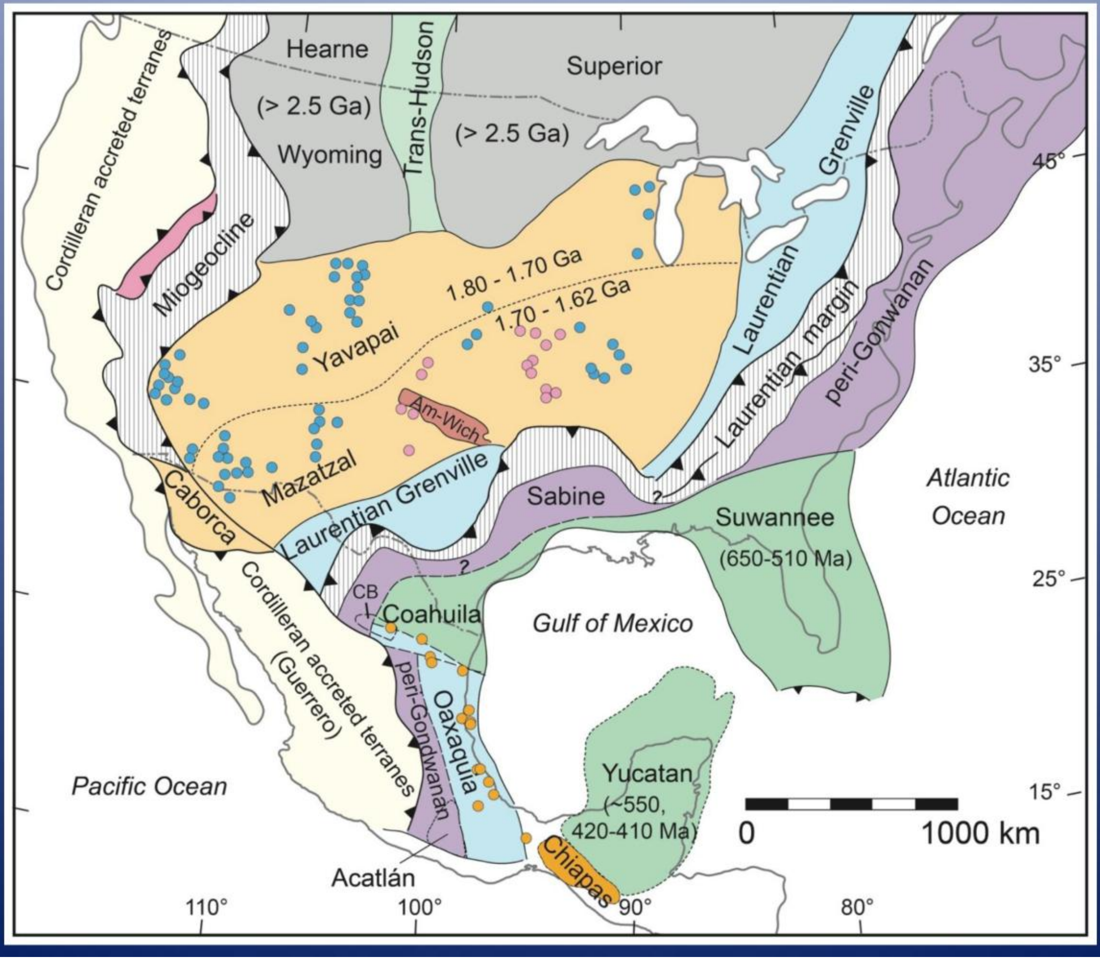


Presenter's notes: There are obvious and subtle analytical uncertainties associated with the technique that I'm not going to discuss, one must have some idea of possible basement sources as indicated on the map above, and zircons are prone to multiple stages of recycling after their initial release from a basement terrane. Seldom are basement (Presenter's notes continued on next slide)

(Presenter's notes continued from previous slide)

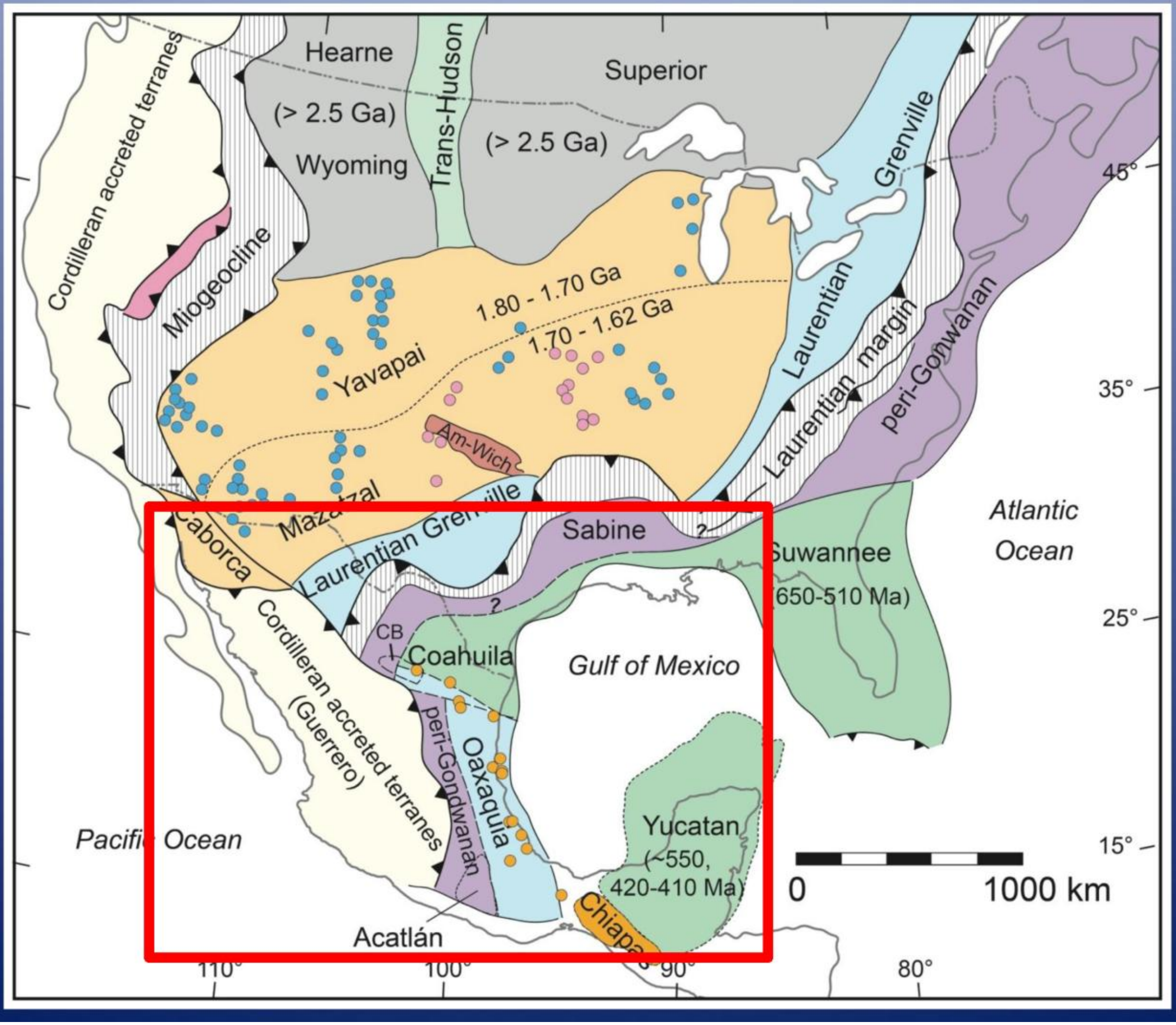
ages unique, for example, the Archean shields of North and South America, and the age equivalent Trans-Hudson and Ventuari-Tapajos provinces. There is much age overlap between Yavapai-Mazatzal and these southwestern Amazonia provinces, but 1.5 Ga grains are comparatively rare in North America. Mexico was positioned to receive detritus from both continents prior to the opening of the Gulf of Mexico.

Post-Jurassic Laurentian Zircon Age Provinces and Possible Sources for Gulf of Mexico Sediment

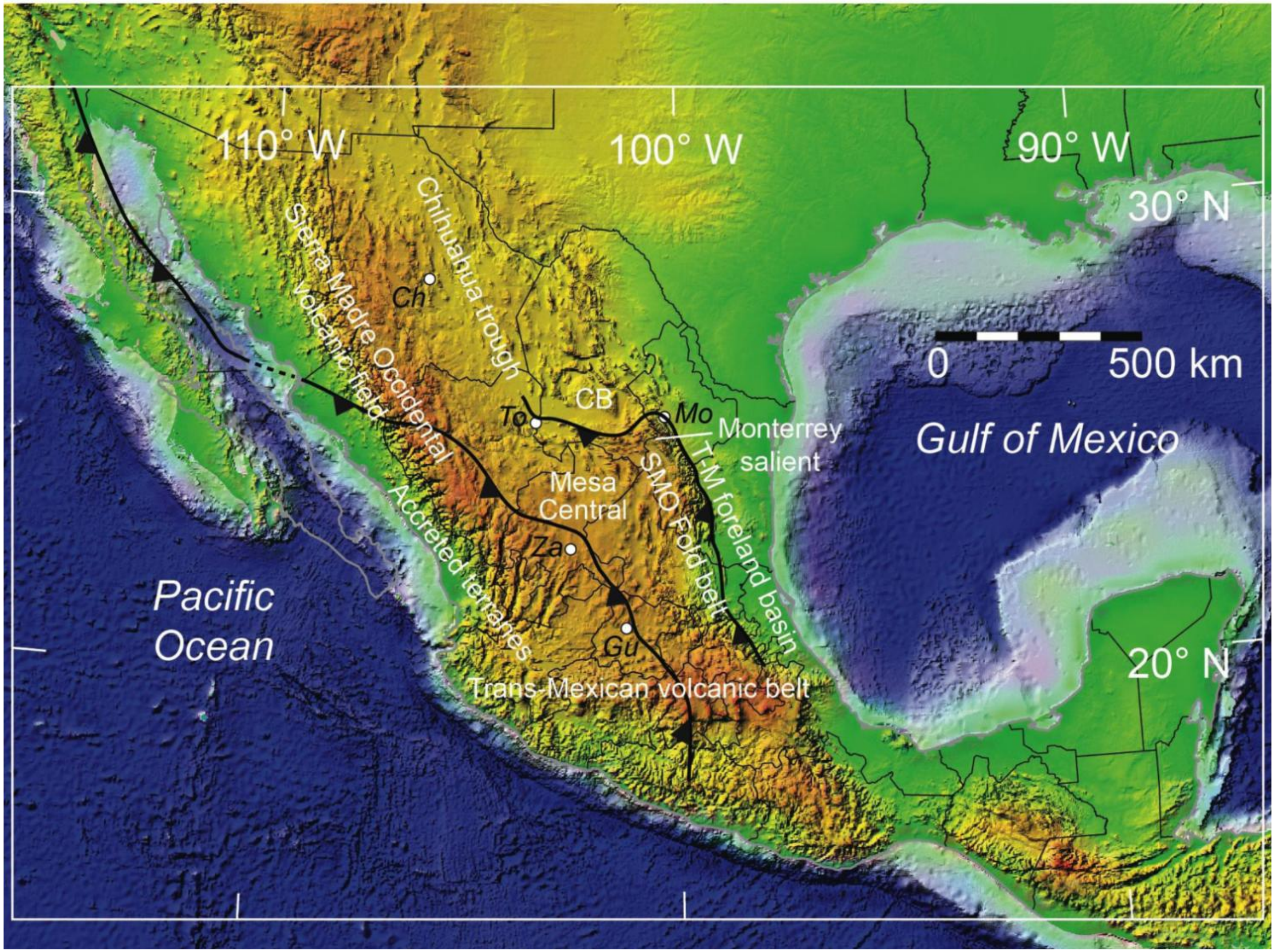


Presenter's notes: By the end of the Early Cretaceous, basement sources were a bit more restricted in terms of nearby basement, but by then, accreted terranes were present along the length of the Cordillera, and along with continental-margin magmatic arcs, were important sources for zircons, both from igneous rocks and from thrust belts containing uplifted sedimentary and metamorphic rocks.

Post-Jurassic Laurentian Zircon Age Provinces and Possible Sources for Gulf of Mexico Sediment



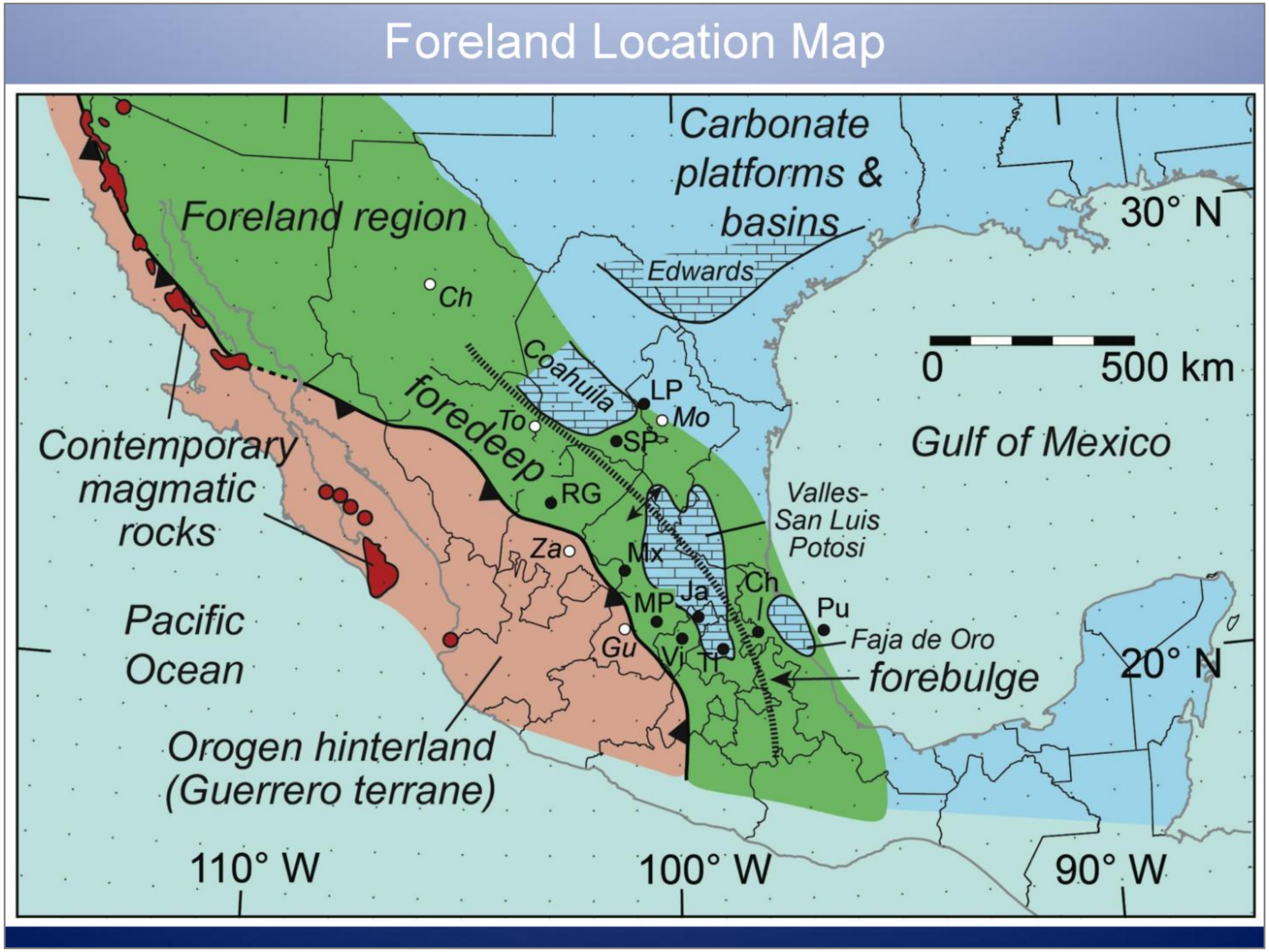
Presenter's notes: The area I will describe for the rest of the talk is indicated by the rectangle



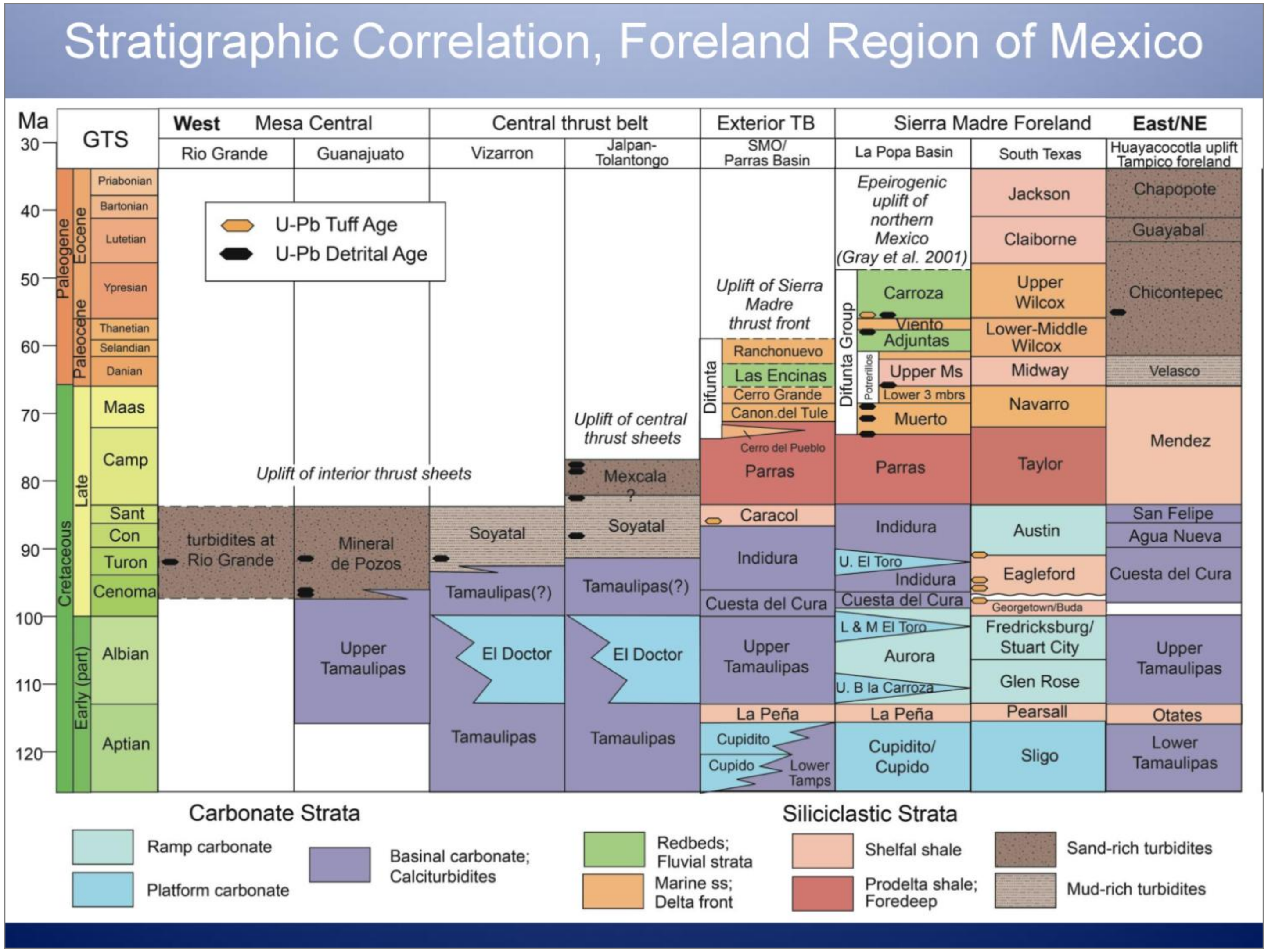
Presenter's notes: Physiographic provinces of Mexico important to this talk are indicated on this slide. These include the low-relief but high standing Mesa Central, underlain by folded and thrusted Cretaceous turbidites, the Sierra Madre fold and thrust belt and its current structural front, and the Tampico Misantla basin. The Chihuahua trough is an (Presenter's notes continued on next slide)

(Presenter’s notes continued from previous slide)

inverted Jurassic-Early K basin, and the Sierra Madre fold belt is a complex of inverted basins. Much of the foreland south of Texas was deformed by detachment folds and block uplifts in the Eocene. The Sierra Madre Occidental and Trans-Mexican volcanic belt are younger volcanic features that conceal much of the Cretaceous geology, particularly in the orogenic hinterland of the fold thrust belt.



Presenter's notes: The key to the following paleogeographic maps is indicated here. Brown-orogenic hinterland, which consists of accreted oceanic and arc terranes; green—foreland, which will change in shape and width with time, and blue—dominantly Early Cretaceous carbonate platforms of northern and eastern Mexico and the Gulf Rim, some of which persisted into the Late Cretaceous as indicated by composition of some of the foreland basin sandstones.



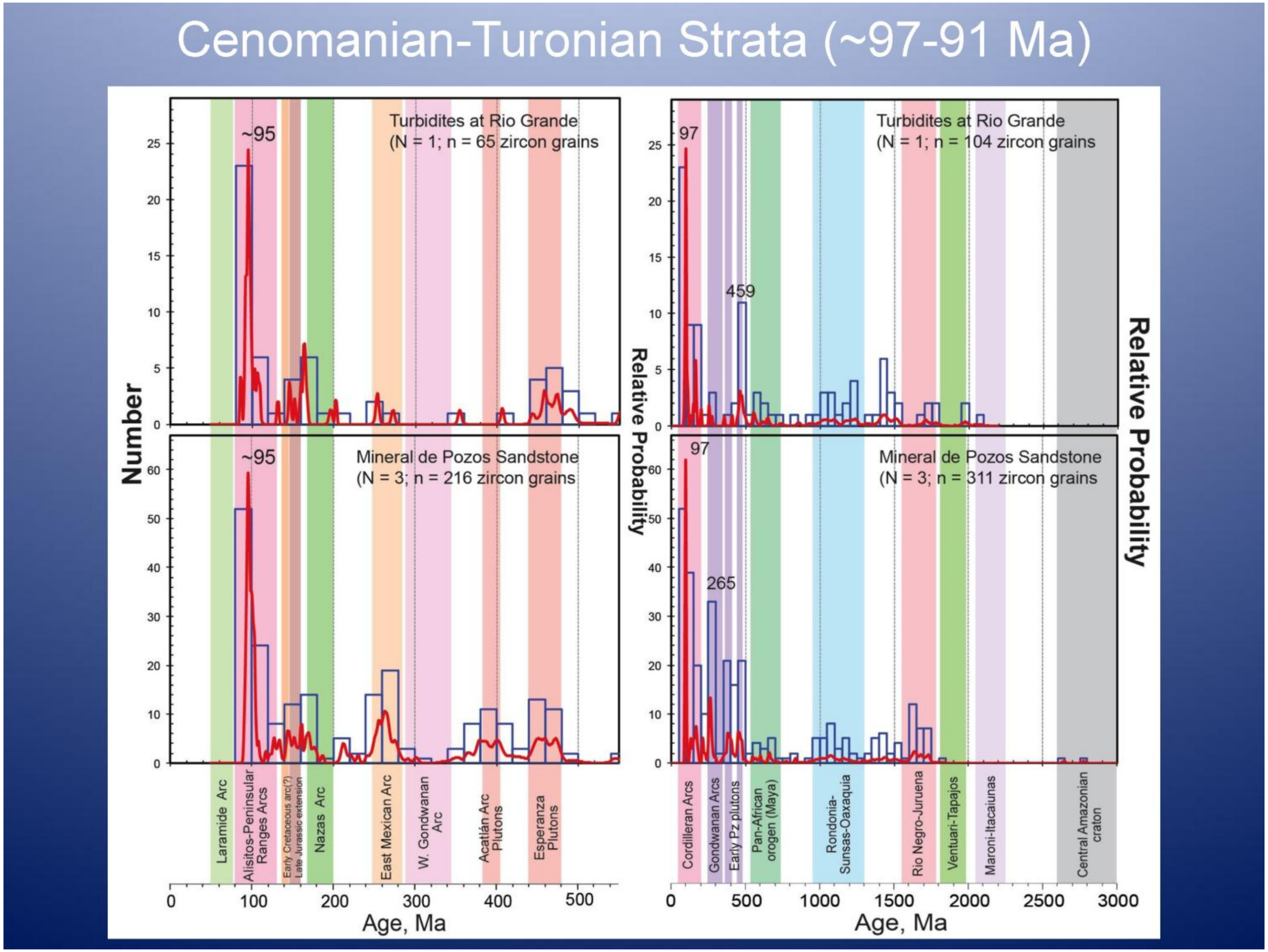
Presenter's notes: The purple and blue colors of this correlation chart indicate the Carbonate platforms and basins of the Early Cretaceous plus some transgressive shales. These carbonate environments persisted into the Upper Cretaceous in the east and northeast, at the same time as they were replaced in Cenomanian time by turbidites (Presenter's notes continued on next slide)

(Presenter’s notes continued from previous slide)

of the foreland basin in the west, nearer the hinterland. Calciturbidites of the older carbonate successions interfinger with the lower parts of the interior turbidites, a relation not recognized in lower siliciclastic units farther east and northeast. The siliciclastic environments migrated eastward with time, to what is now the central part of the thrust belt in Coniacian and Santonian time, and in Campanian time into the exterior part of the Sierra Madre orogen and the Tampico Misantla basin. The upper age limits of the foreland basin successions are not well known in the west, and are truncated erosionally by uplift of the earlier basin sequences by east-progressing thrust uplift.

Presenter's notes: The turbidites of the orogen's interior are locally well exposed along arroyos and in highway cuts. This is an unusually good exposure near Mexquitic in turbidites that have been termed Caracol, incorrectly I think, because they are 4 or 5 million years older. Their structural complexity impedes stratigraphic understanding—these beds are overturned.

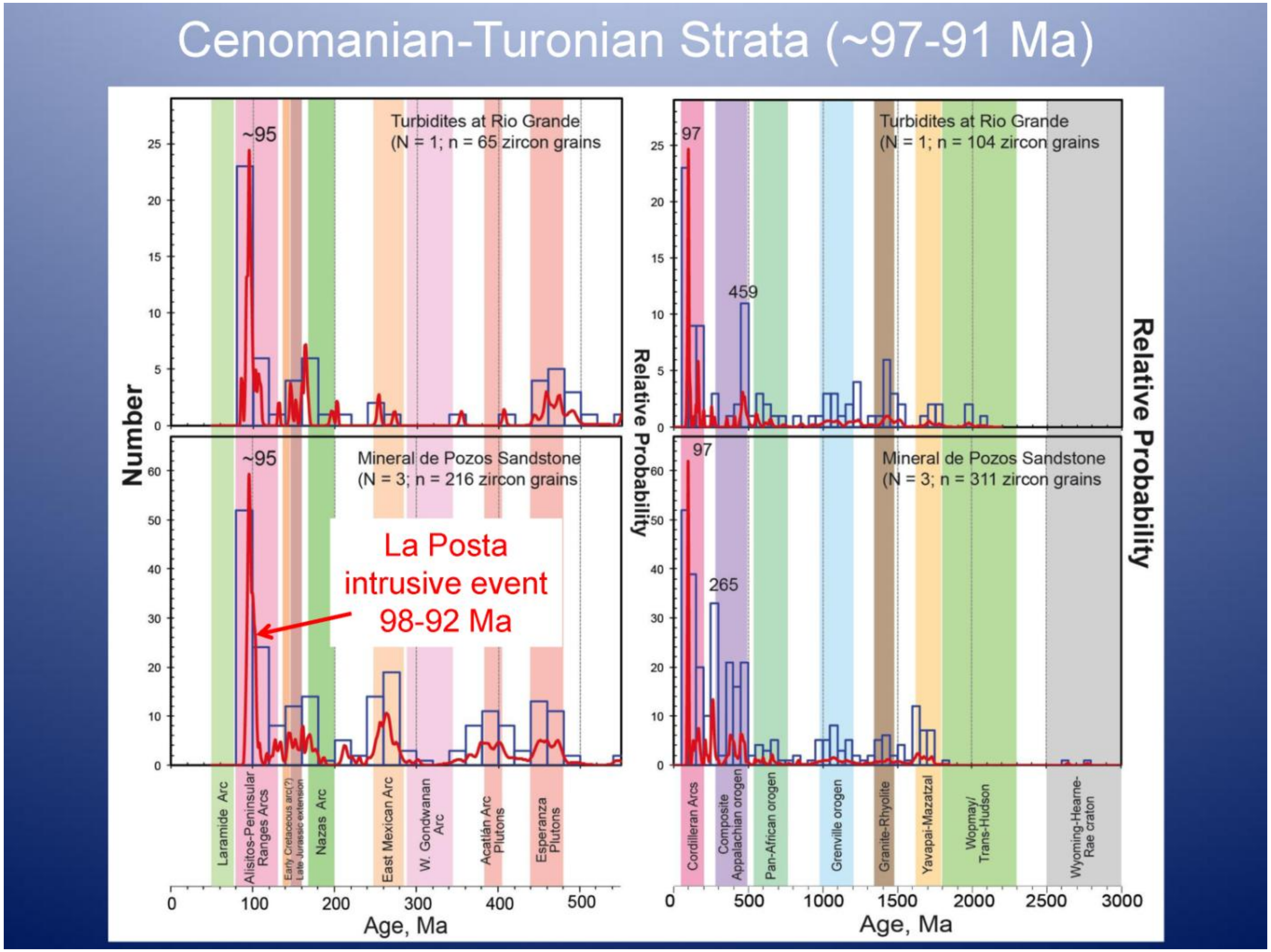
Presenter’s notes: However, it is great for paleocurrent work. Corrected flow directions here are SE, parallel to the basin foredeep.



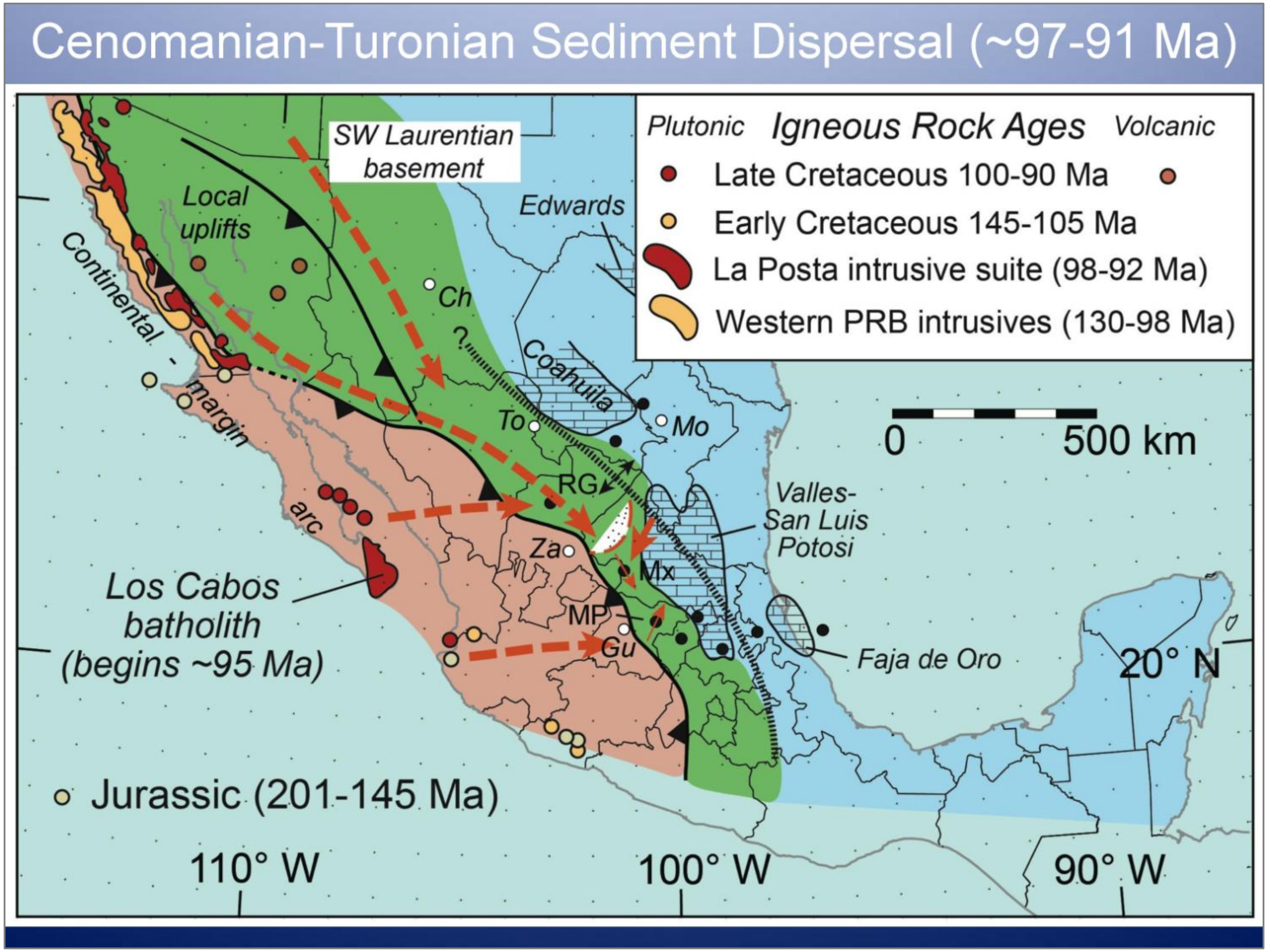
Presenter's notes: This figure illustrates detrital zircon analyses from four turbidite samples nearest the orogenic hinterland, the two left hand columns on the correlation chart, and evidently the oldest deposits of the foreland basin. These plots are not normalized, but rather simply show age probability curves in red, with key age peaks labeled, and (Presenter's notes continued on next slide)

(Presenter’s notes continued from previous slide)

histograms that indicate the number of grains in 50 m.y. bins for the right hand plots, which show all grain ages, and 20 m.y. bins for the left hand plots, which show only Phanerozoic grains. The color bands on the left will be constant and basically represent Mexican source rocks, particularly ages of magmatic arcs on the west edge of Mexico, whereas the color bands will shift between South American Gondwanan sources, as shown here, which seem to lack the population between 1.4 and 1.5 billion years, and...



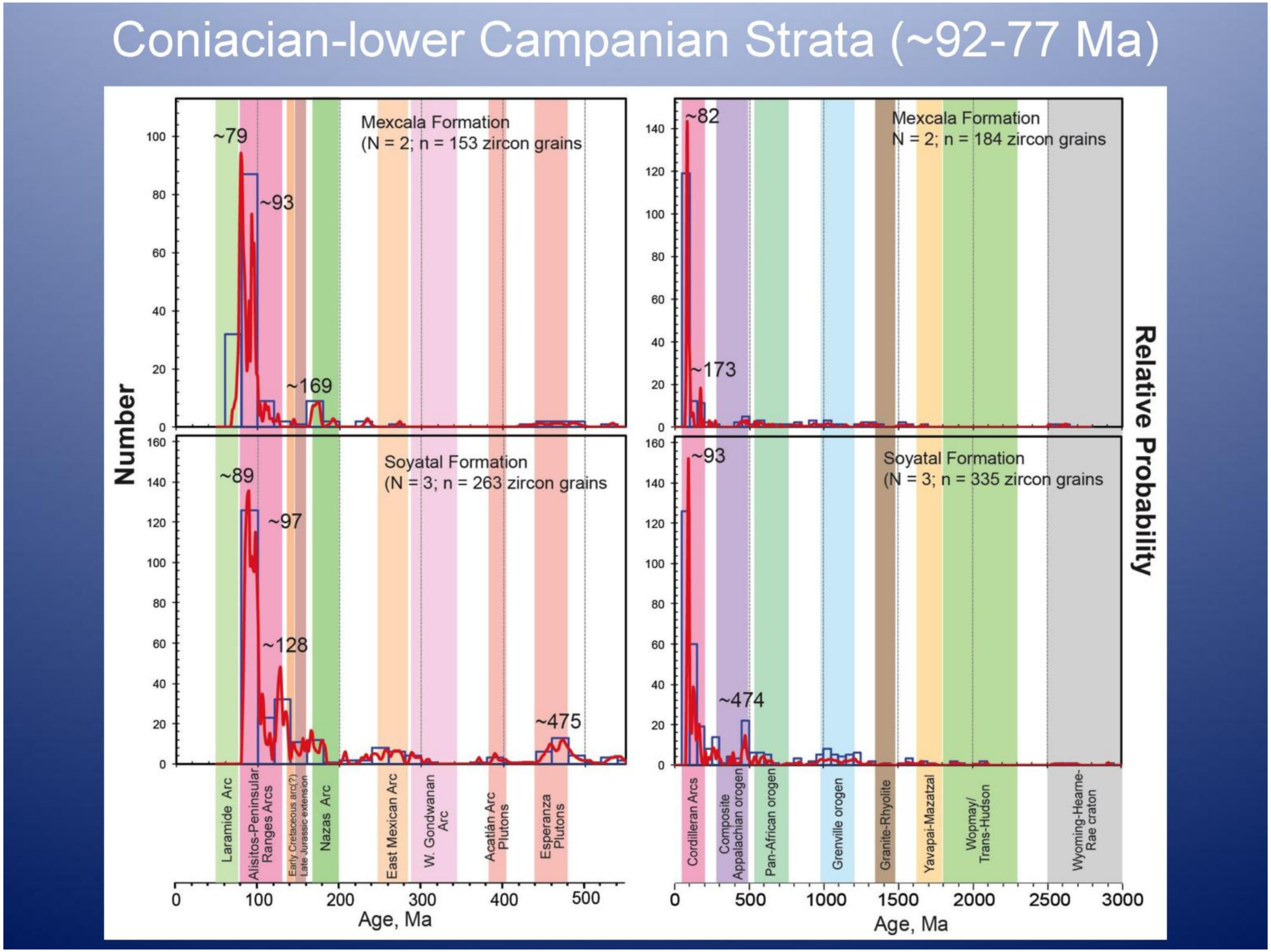
Presenter's notes: …Laurentian sources, which seems to show a better match for these samples. Note the three-fold Laurentian age distribution. Grains attributable to Mesozoic arc sources are also exceedingly common in these sandstones, and the voluminous La Posta intrusive event of southernmost California and the northern Baja Peninsula is perhaps the best-recorded grain population in these sandstones. The other Phanerozoic age groups are probably the result of recycling of grains from sedimentary units uplifted in the thrusted hinterland rocks.



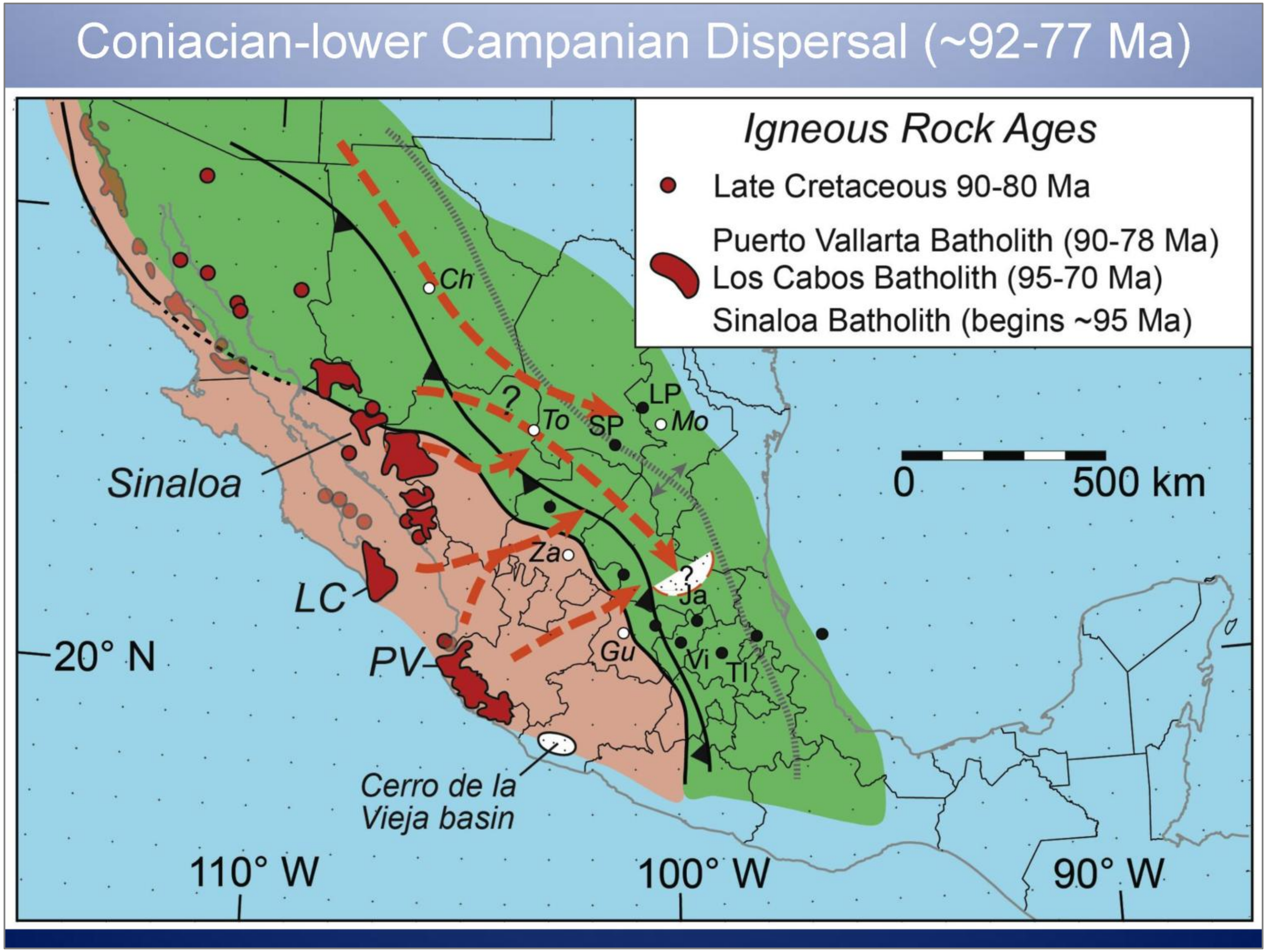
Presenter's notes: The initial foreland-basin deposits occupied a narrow trough that was bordered on the east and northeast by remnant carbonate platforms. The magmatic arc that resulted from subduction of the Farallon slab was well underway and is represented by the intrusive belts of the Baja Peninsula. Arc grains could be derived from (Presenter's notes continued on next slide)

(Presenter's notes continued from previous slide)

longitudinal transport or from closer parts of the arc that peek out from under younger volcanic rocks farther SE along strike of the margin. The three-fold distribution of zircon grains from Laurentian basement must have come along strike. The deltaic terminus is estimated to be about here in the Turonian, but there is little data, and the sink of this time was distributed along the foredeep in San Luis Potosí. Note that the postulated foredeep runs through the monster Valles-San Luis Potosí platform, which was in its waning days at this time. This can explain (1) the interbedding of calciturbidites derived from the platform in the siliciclastic deposits of the foredeep, which absolutely lack zircons not expected from purely limestone sources, and (2) multiple Cenomanian-Turonian unconformities on the platform described by Wilson and Ward (1993).



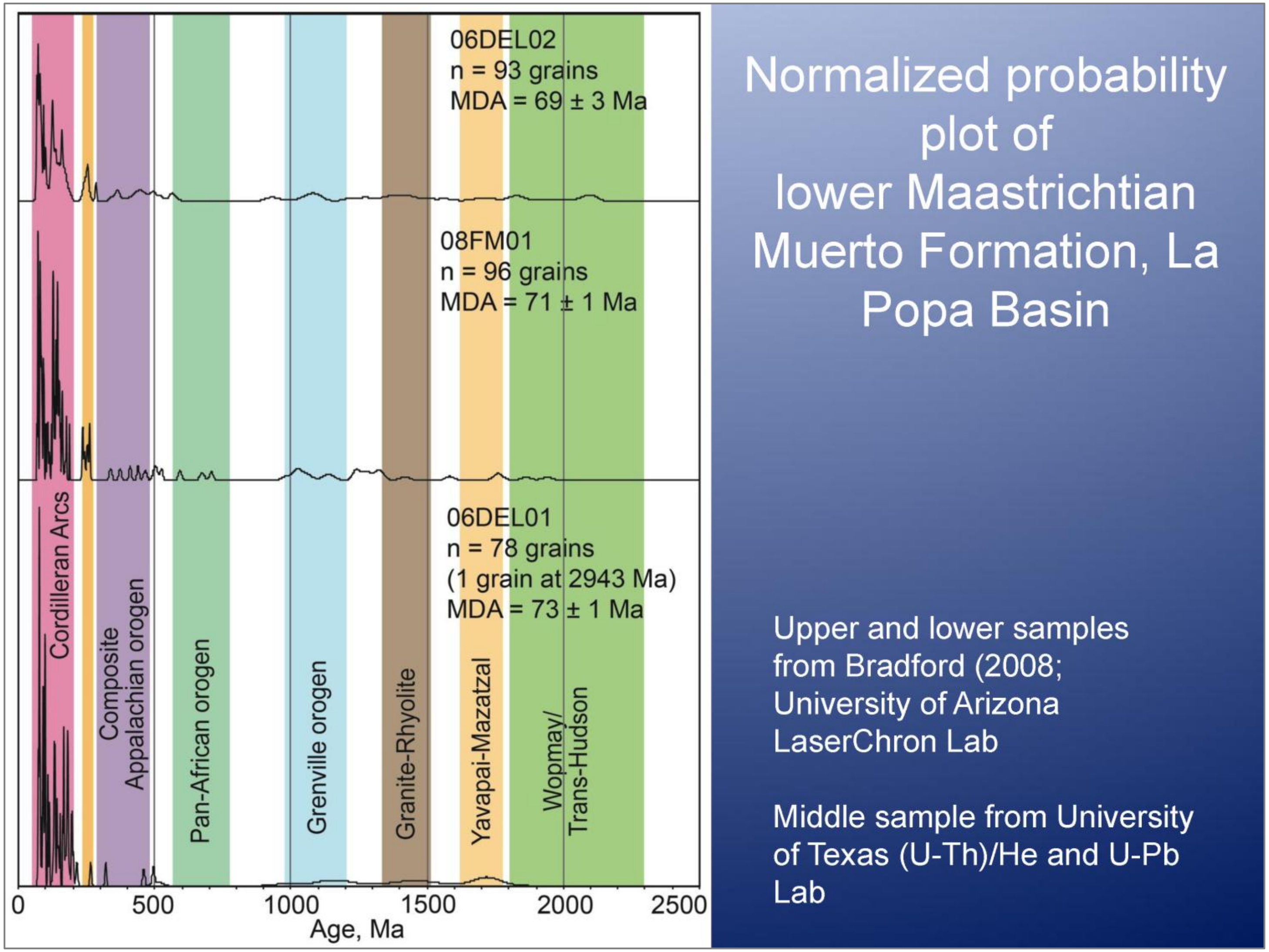
Presenter’s notes: Slides of the same data indicates that the three-fold Laurentian zircon signature is missing from these sandstones.



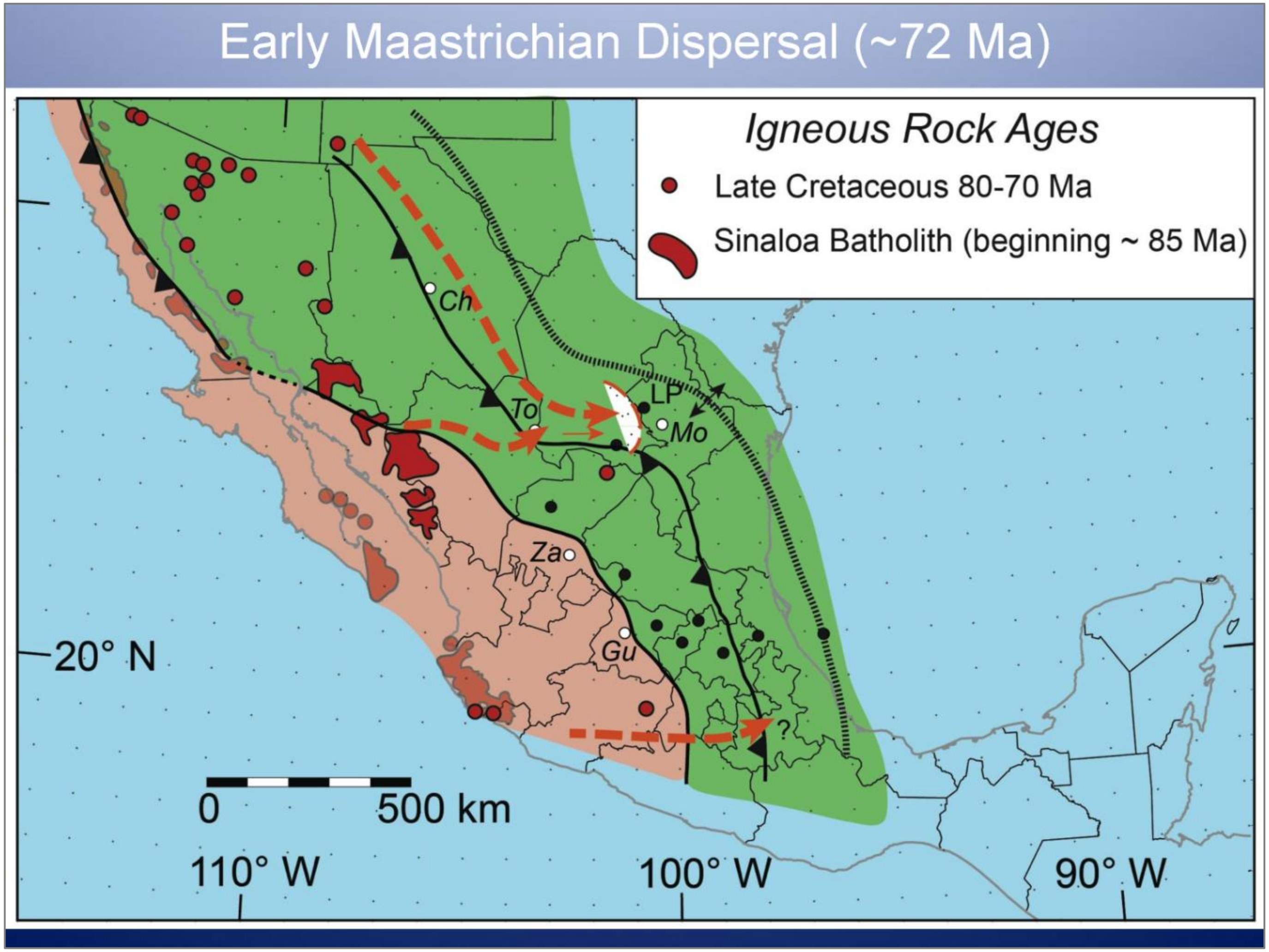
Presenter's notes: Now the carbonate platforms were buried by the advancing sediment wedge by this time. In order to explain the absence of Laurentian grains in the units at Ja, Vi, and Tl, I have simply deflected the northern drainage by an unspecified divide. I have no data for rocks of this age in the Parras Basin, but this drainage is present in (Presenter's notes continued on next slide)

(Presenter's notes continued from previous slide)

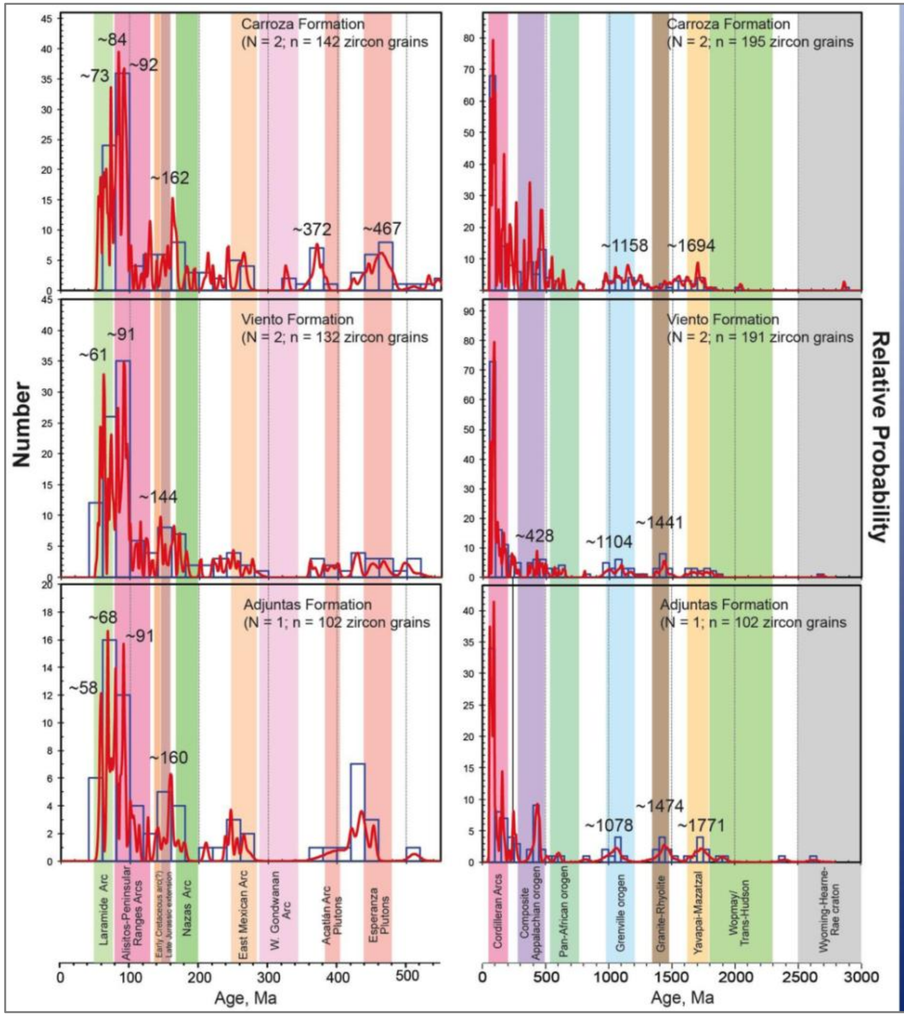
younger strata. Perhaps I should advance the thrust sheet here, but it could be done by inverted Jurassic basins in the Torreón area. The forebulge probably passed right through mudstone-rich deposits of the Caracol Formation in the Sierra de Parras at about 85-86 m.y. The sandstone sink at this time is probably north of mudstone-rich turbidites at the labeled sites in east-central Mexico. The young limit of this map is the onset of major Laramide deformation in the Colorado Plateau.



Presenter's notes: The lowermost sandstone deposits of La Popa basin, which I showed earlier, in the current foreland of the Sierra Madre oriental, contains a mix of Laurentian basement grains and arc-derived grains. The latter could have come from anywhere along the arc, so could have been contributed by tributaries to a long basin-axial fluvial system.

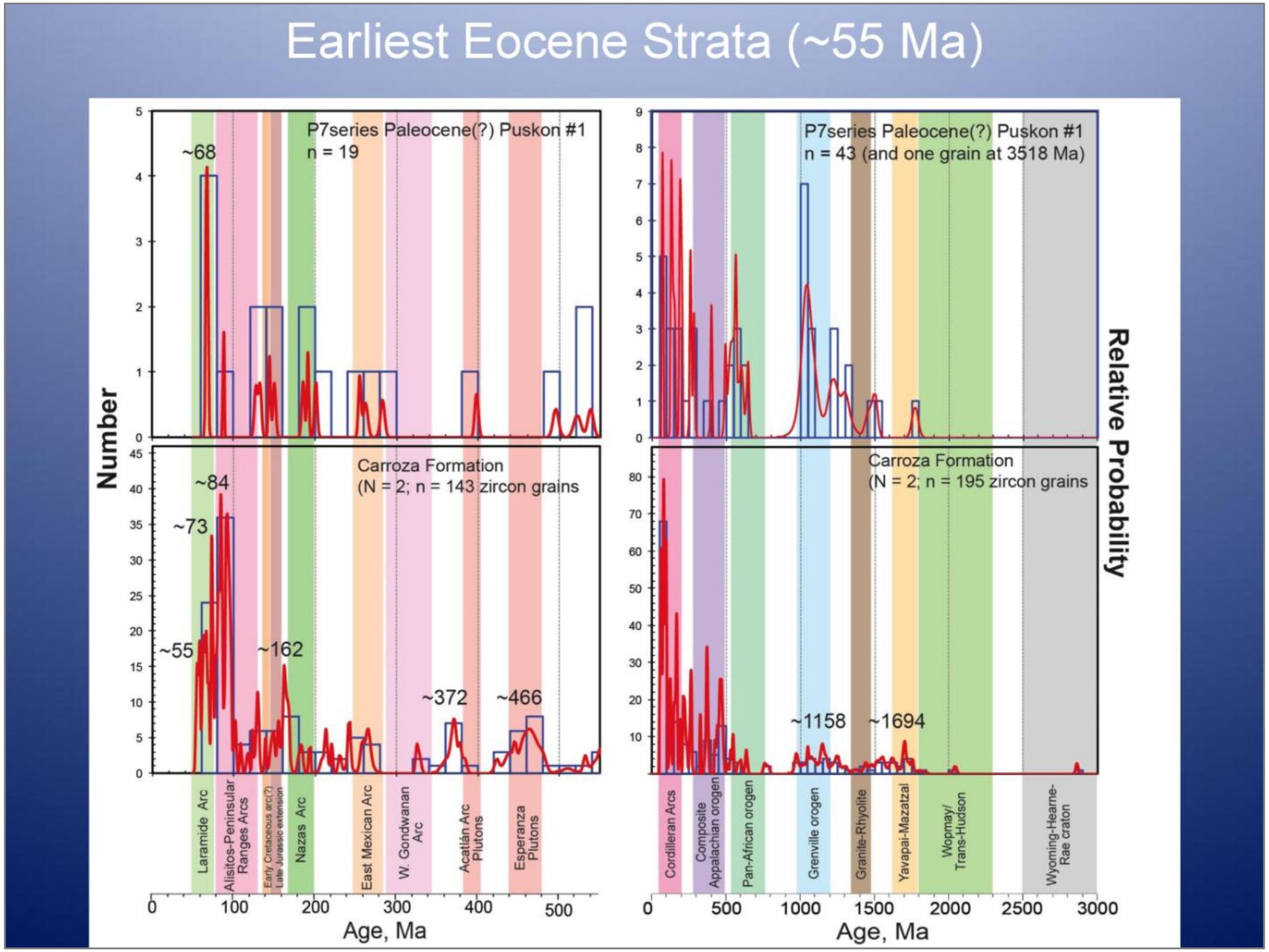


Presenter's notes: At the beginning of the Maastrichtian, thick deltaic and tidal successions in the Muerto Formation represent the sink and sources lay as far away as the SW United States. Deformation had inverted the triangular area of the Jurassic Mexican seaway and had begun to shorten the former carbonate platforms. An axial river system carrying Laurentian detritus was deflected eastward along this new deformation front and was probably joined by tributaries that transported sand across the fold-thrust belt.



Upper Paleocene-Lower Eocene part of Difunta Group, equivalent to the Wilcox Group

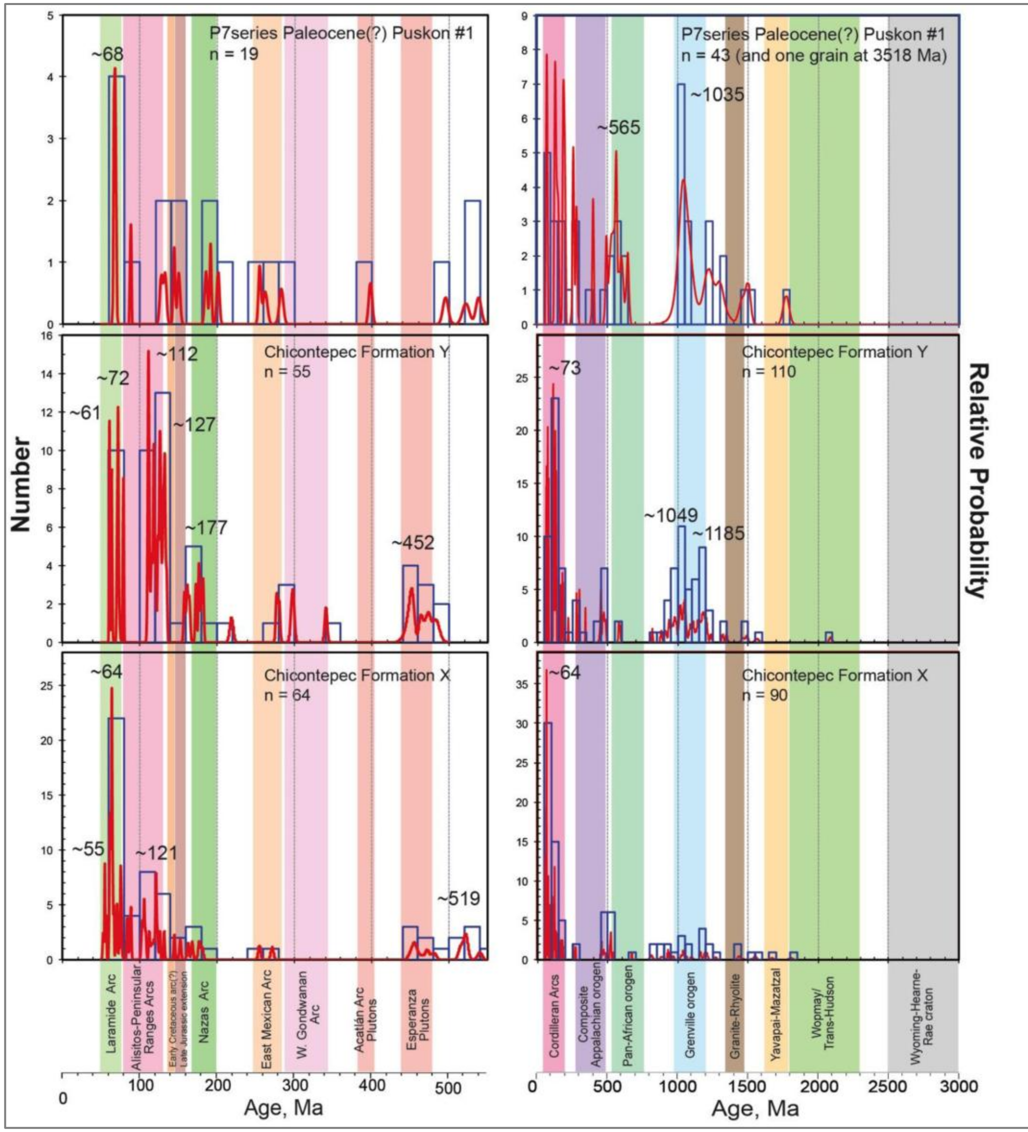
Presenter's notes: The upper three units of the Difunta Group, equivalent to most of the Wilcox Group, have a strong Laurentian signature, and also contain arc-derived grains that span the interval of Cordilleran arc magmatism up to that time, with abundant young grains that could represent reworked tuffs that fell in the foreland. These young grains yield consistent syndepositional ages, as calibrated by a tuff in the upper part of the section and consistent younging of maximum depositional ages upsection.



Presenter's notes: Finally, here is what you have been waiting for. This slide compares the Chicontepec formation in the Puskon well in the western Gulf with its approximate equivalent in the Difunta Group. Are they part of the same dispersal system? I think not. There is a major component of Pan-African and Grenville grains in the offshore (Presenter's notes continued on next slide)

(Presenter's notes continued from previous slide)

Chicontepec. The Laurentian triad is missing. The arc grains are present, but the Chicontepec assemblage can be explained by recycling of older Gondwana-derived sediment uplifted in the Sierra Madre, as has been inferred for Chicontepec sandstones in the past. This means the likelihood of a local source in Mexico than for the Difunta Group, whose sources tapped all the way into SW Laurentia of the United States.



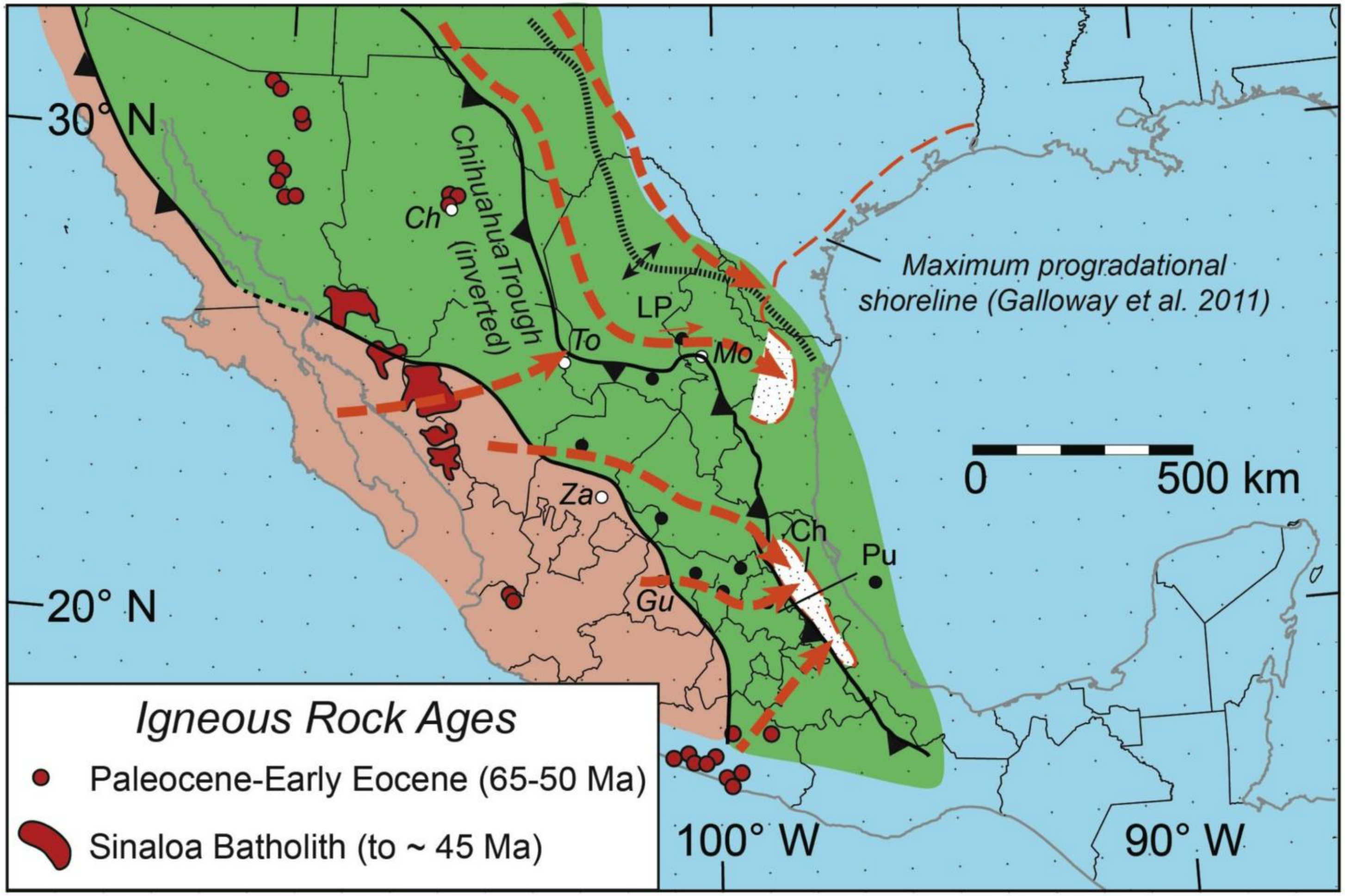
Chicontepec Samples, Offshore Well (upper plot)

and outcrop (lower 2 plots)

Laurentian sources shown for the right plots of all grains

Presenter’s notes: Using the Gondwanan color bands does not help much in characterizing sources for the older grains.

Paleocene-Early Eocene Dispersal (~55 Ma)



Presenter's notes: By the beginning of the Eocene, the deformation front had moved to its current location along the Sierra Madre Oriental and the Jurassic-Early Cretaceous Chihuahua trough was inverted, pushing the axial drainage system eastward. It still transported some SW Laurentian grains to the Sierra Madre Foreland as indicated by DZ (Presenter's notes continued on next slide)

(Presenter's notes continued from previous slide)

in the Carroza Formation, and was separated from the main Wilcox drainage to the east, as drawn by Bill Galloway. The topographic separation between the two northwestern drainages, indicated schematically by a forebulge element, was probably in reality created by foreland uplifts formed as Laramide deformation stepped into the former foreland. The wide spread of arc-derived grains in both the Carroza Formation and Chicontepec formation may in part be the result of recycling zircons from uplifted strata of the earlier foreland basin in the Mesa Central, but the youngest grains indicate that there must have been some primary arc feed. Nevertheless, the absence of Laurentian grains indicates that the Chicontepec, at least the part we sampled, was not connected with the Difunta Group, and further suggests the presence of a sink east of La Popa basin (paleocurrrent indicated), perhaps in the western Gulf of Mexico.

Summary-1

- The foreland basin migrated eastward, adjacent to an advancing thrust orogen

- Forebulge uplift initially contributed to sediment feed from carbonate platforms east of the basin and isolated foreland dispersal systems from the Gulf of Mexico

Summary-2

- Dominant sources of detrital zircons lay in the arc terrane of western Mexico and basement of the SW United States

- The zircon sources in turn indicate the importance of sand-rich international axial fluvial systems and shorter Mexican tributaries with headwaters in the arc

Summary-3

- The Chicontepec Formation is variable in composition, derived from a variety of southern and western Mexico sources, and was not connected to Laurentian fluvial systems

Presenter's notes: The Chicontepec Formation was not connected to the larger drainage systems that flowed south from Laurentia. This has implications for the ultimate volume of its conventional reservoir facies.