New Zircon U-Pb Ages for the Choiyoi Silicic Large Igneous Province of Argentina that Define a Strong Episodic History of Magmatism and Mass Extinction in the Permo-Triassic Time

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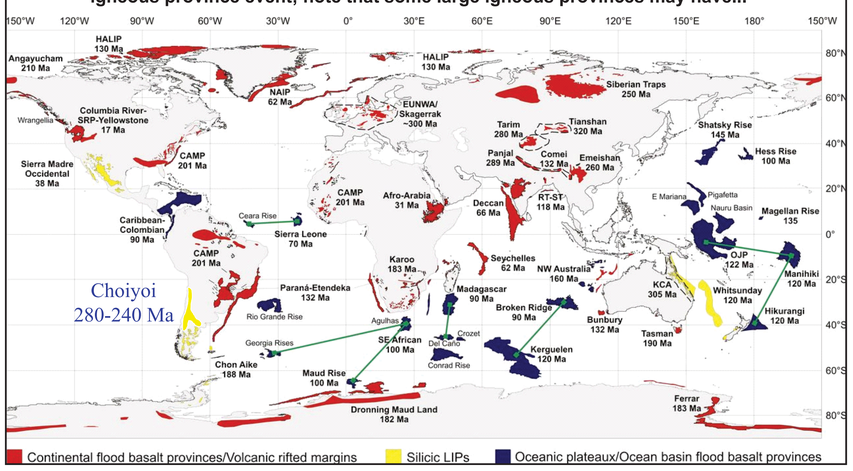
Abstract

The Choiyoi magmatic silicic large igneous province (SLIP) of central and southern Argentina and Chile (23°S-42°S) was emplaced along the eastern edge of Gondwana in Permo-Triassic time. This magmatic province qualifies as a SLIP due to: 1) aerial extent of ~500,000 km2 and variable thickness of at least two kilometers, 2) dominate rhyolite-ignimbrite composition, 3) the correlation of Choiyoi magmatism to widespread Permian ash falls, and 4) strong episodic magmatic record over ~30 m.y. The 26 new laser ablation ICP-MS zircon ages for Choiyoi rocks from two key transects in Mendoza (32°S) and San Juan (33°S) define strong bimodal age distribution with peaks at ~246 Ma and 266 Ma. The older peak dominates the distribution encompassing 20 of 26 ages that are statistically indistinguishable and which yield a weighted mean age of 265.9 ± 1.0 Ma (95% conf.). This 'flare-up' is documented strongly in a compilation of all available zircon U-Pb ages over the extent of the province (25°S–40°S) and the Neogene foreland basins. The ~266 Ma peak represents a short duration (1-6 m.y) of silicic volcanic activity that overlaps with several end-Permian events and extinctions, including Olson's extinction event marking the transition from basal synapsids to terapsids.

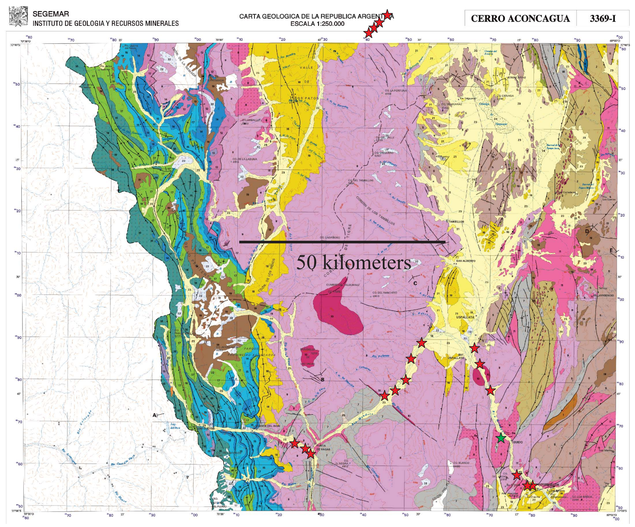
Introduction

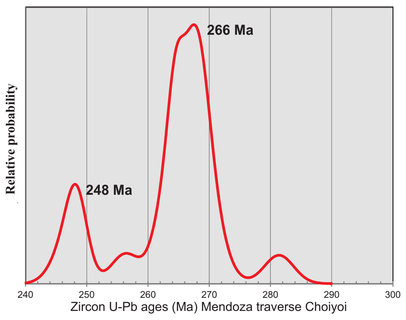
Major volcanic episodes have been accused of complicity in mass extinctions throughout geologic history. Four of the top five mass extinctions, as well as every minor crisis since the Permian have been correlated with major volcanic eruptions. These major volcanic events represent large igneous provinces, which are defined as magmatic provinces >100,000 km^2 in size, volumes of >100,000 km^3 and a maximum duration of 50 million years. Large igneous provinces are characterized by igneous pulse(s) of short duration (~1–5 m.y.), during which a large proportion (>75%) of the total volume is emplaced. The majority of LIPs are basaltic in composition, and the significance of rhyolitic (silicic) large igneous in the geologic record has not been extensively explored.

Global distribution of large igneous provinces (LIPs) following assembly of Pangea ca. 320 Ma. Annotated ages denote the onset of the main phase or first pulse of magmatism to the large igneous province event; note that some large igneous provinces may have...



Magmatic Zircon

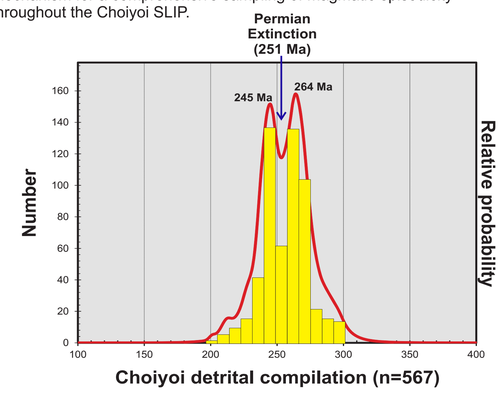


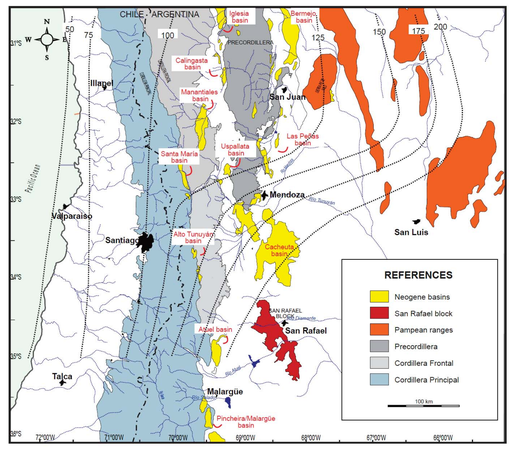


Geochronologic analysis of the Choiyoi Group was conducted along two transects perpendicular to the strike of the rhyolitic complex, and yield a distinctly bimodal age distribution.

Detrital Zircon

Neogene sedimentary basins flanking the Cordillera Frontal yield abundant PermoTriassic zircon from the Choiyoi Group, and provide an excellent mechanism for a comprehensive sampling of magmatic episodicity throughout the Choiyoi SLIP.

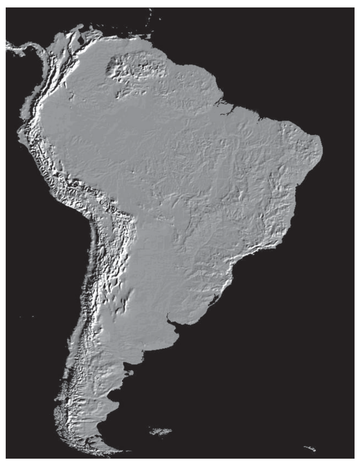


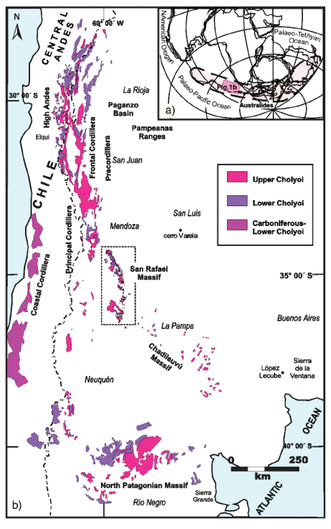


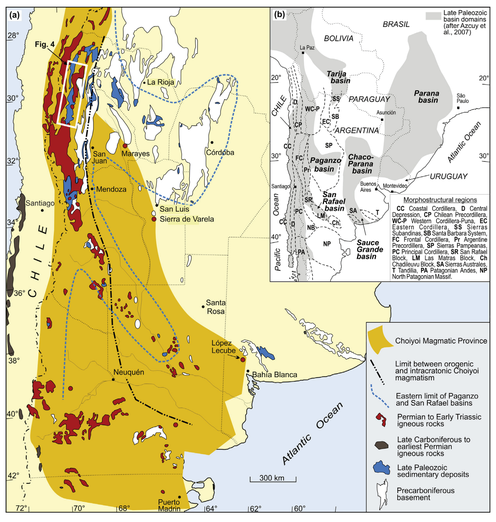
Detrital zircon probability chart and histogram from Neogene basins of the south-central Andes,displaying PermoTriassic ages derived from the Choiyoi Group. Note the distinct bimodal age distribution, with major peaks at 264 and 245 Ma, precisely bracketing the height of the Permian extinction.

Choiyoi Group

The Choiyoi Group is a major PermoTriasisc silicic large igneous province (SLIP) widely exposed in the Cordillera Frontal of the south-central Andes Mountains. The group is over 1500 km long, up to 100 km wide, and 3-5 km thick, and represents one of the largest rhyolitic volcanic complexes in the world. It is contains abundant caldera complexes believed to have widely distributed volcanic ash across much of southern Pangea.



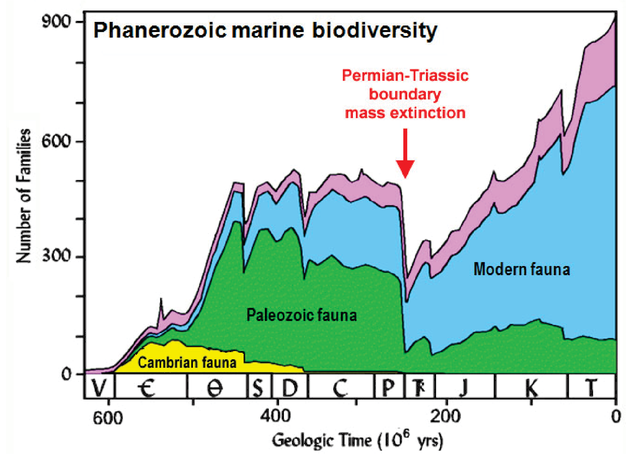


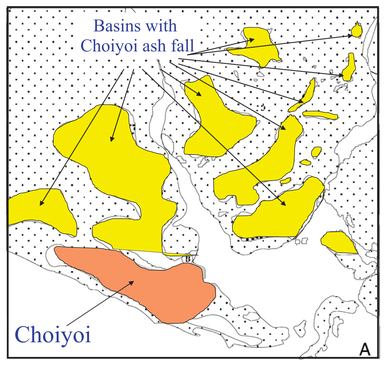


Geologic map of the distribution of the PermoTriassic Choiyoi Group in the southern Andes Mountains. Much of the Choiyoi Group is in the subsurface; exposed outcrop is shown in red.Note that this magmatic province, approximately 1800 x 600 km, would extend from southern California to northernWashington (diagram modified from Sato et al., 2015)

Link to Choiyoi Magmatism

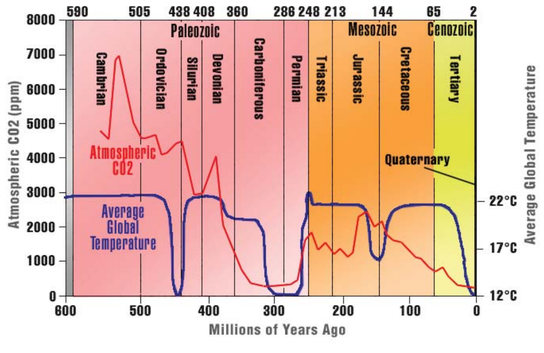
The largest extinction event in the history of the planet occurred at the end of the Permian, when over 95 percent of marine and 70 percent of terrestrial species were eliminated in a geologic instant (Erwin, 1994). Despite intensive research on the Permian-Triassic boundary interval for several decades, the cause of the end-Permian extinction remains controversial. The synchronicity between the end-Permian extinction and the eruption of the Siberian flood basalts has long been recognized, but the impact of these low volatile (<2%) magmas on atmospheric composition is debated. The influence of coeval, high volatile (>5%) silicic large igneous complexes, such as the PermoTriassic Choiyoi magmatic system of the southern Andes Mountains, on end-Permian environmental change has not been elucidated, and may represent an overlooked causative factor in PermoTriassic mass extinction.





Paleogeographic reconstruction of Pangea showing the distribution of PermoTriassic sedimentary basins that received abundant volcanic ash from the Choiyoi magmatic complex.

Permian-Triassic Extinction Event



Enormous caldera-forming eruptions, such as those documented in the Yellowstone hotspot system and those that probably typified the Choiyoi magmatic system, can eject 1000-2500 km^3 of volcanic ash, with measurable ash accumulations >3000 km away. These volatile-rich systems would also inject 10^{9-11} tons of H_2O, CO_2, SO_2, H_2S and HCl essentially instantaneously into the atmosphere, with potentially catastrophic environmental consequences. The distinctly bimodal age distribution within the Choiyoi Group, with major peaks of eruptive activity at 248 and 266 Ma, precisely brackets the peak Permian extinction event at 252 Ma. It is herein suggested that the presence of a major, actively erupting, silicic large igneous province in southern Pangea at the end of the Permian may have been a causative factor in the greatest mass extinction in geologic history.