# New views on Andes mountains and South American plate movements

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Mountain chains like the Himalayas, according to existing theories, are formed due to plate collisions, like the Indo-Australian continental plate pushing against Asian plate and folding up the intervening area as the lofty Himalayas. However, this theory fails to explain the rise of Andes along the west coast of South America or the Rocky mountains in North America as these continents had no opposing plate to collide against. Two geophysicists, R. M. Russo and P. G. Silver, have recently postulated[1,2] that the geologic forces in the mantle zone below South America is responsible for the rise of the Andes mountains. This view was a sequel to the unusual changes they noticed in the seismic wave propagation, while studying movement of mantle below the western edge of South America. Here the Pacific seafloor, the Nazca plate, subducts eastward (6 cm/year) into the Peru–Chile trench beneath the South American plate, while the latter glides westward (3 cm/ year) over the subducting plate. Contrary to the expected eastward movement of the mantle currents below the Nazca plate, the seismic data revealed movements of these currents, north and south, parallel to the western edge of the South American plate, i.e. at right angles to the expected orientation or flow direction (Figure 1).

The two geophysicists compared this anomalous movement of the mantle currents to that of water swept around a square-fronted boat pushing its way through the sea, implying thereby that the migration of the South American plate westward makes the mantle current flow north-south around the broad front edge of the plate. This motion, as if ploughing through the mantle, generates enormous pressures along the continent's western edge, enough to buckle the region up as Andes mountains. This upheaval is further facilitated by sofi ing of the rocks present along this e due to volcanic heat from the mantle caping along the the Nazca plate's si ing edge.

These views received support w similar mantle current movements v observed in their computer experim simulating a broad-edged contir coursing through mantle. They fur found that in both simulated and continents, the mantle forces exe maximum impact at the junction wl these currents split northward southward (Figure 1), and as a coı

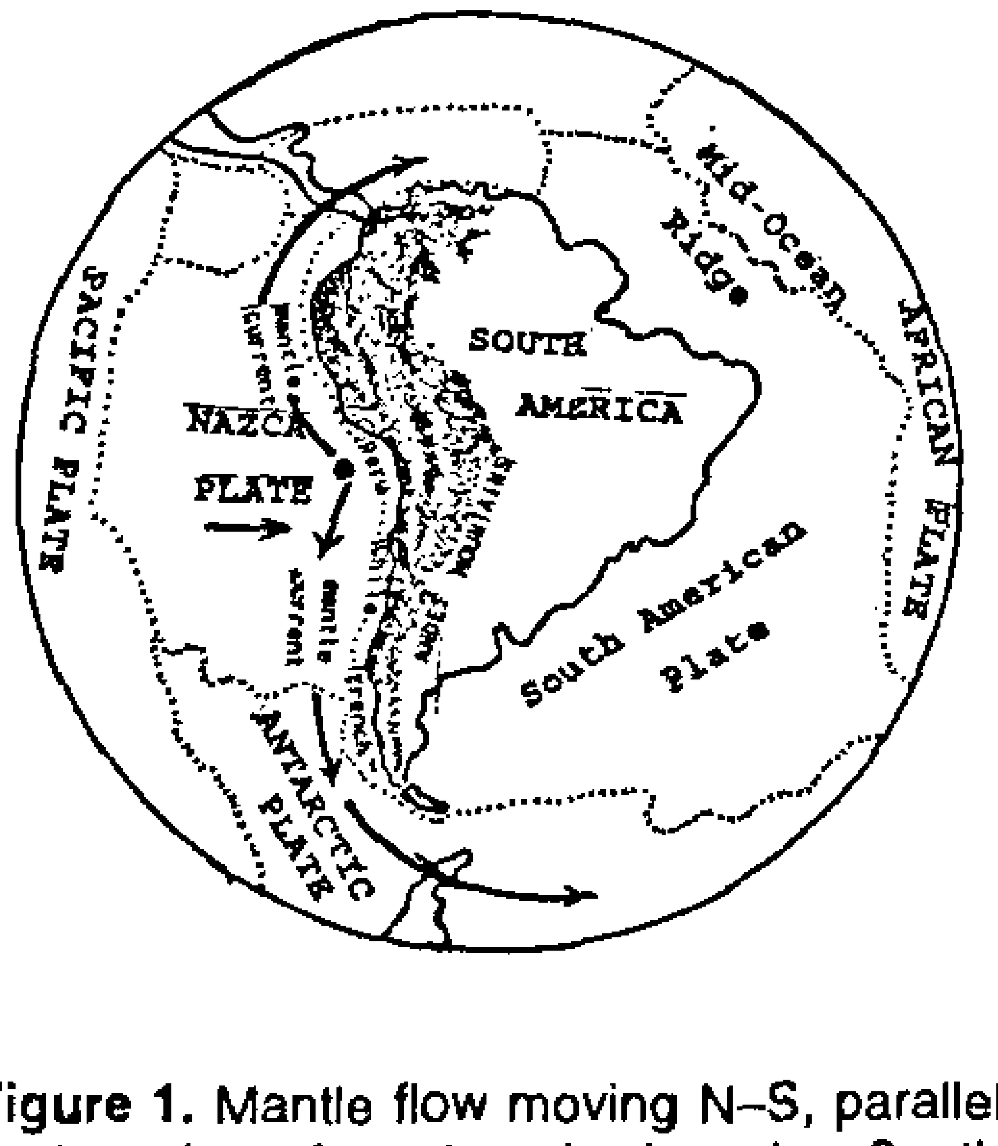


**Figure 1.** Mantle flow moving N–S, parallel to the edge of westward advancing South American plate. The Nazca plate is subducting into the Chile–Peru trench eastwards.

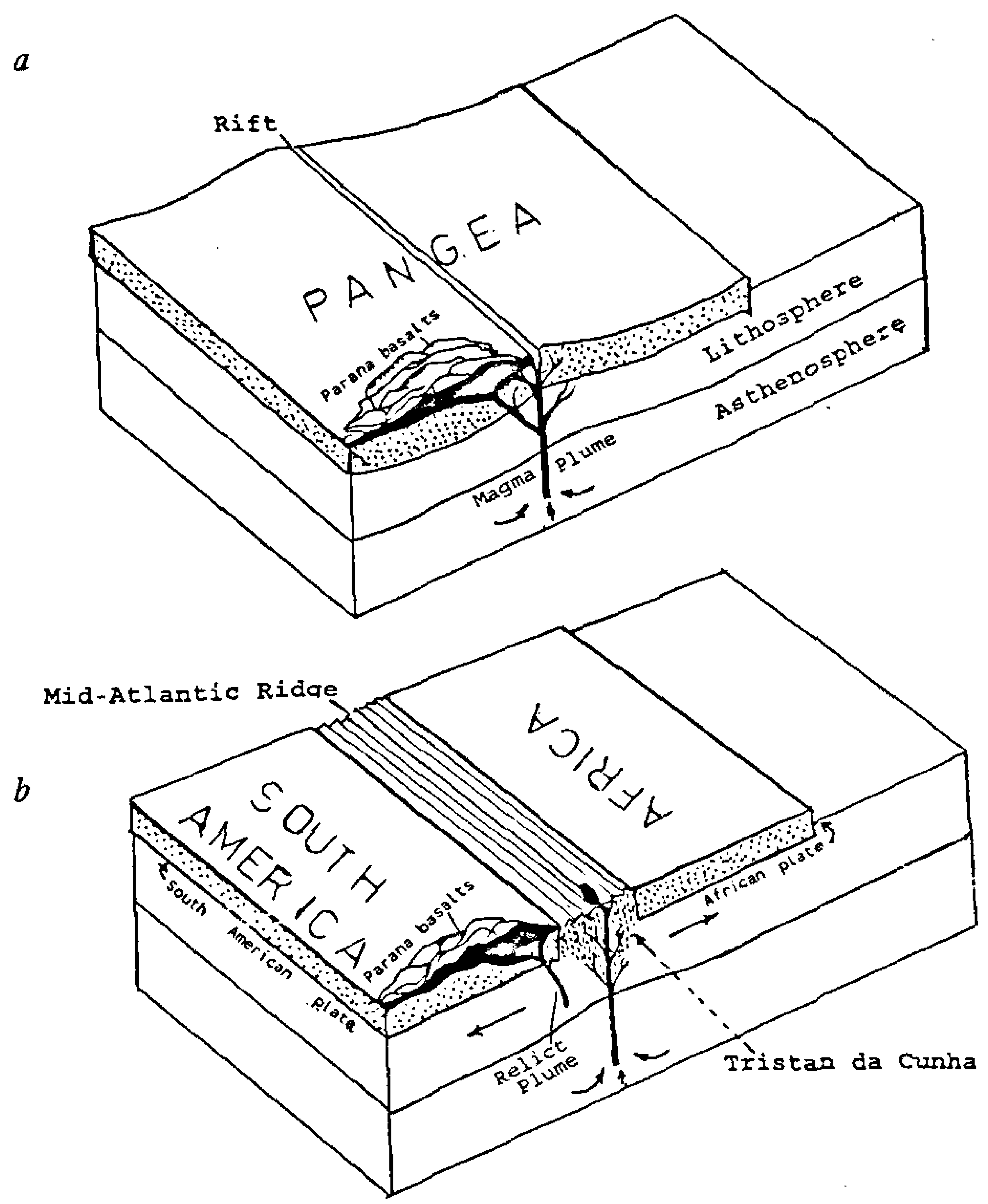


**Figure 2. a**, Rifting of Pangea and eruption of Parana Basalts flooding ancient Brazil Westward drift of rifted South American continent carrying relict magma plume. L eruptions continue along the mid-Atlantic ridge today at the island of Tristan da Cunha.

quence, the Andes mountains are found to attain their widest extent at this midpoint, known as Altiplano. Further, these simulations indicated an eastward curving of the northern and southern tips of the continent, which indeed, they exhibit. The two found parallels in the rise of the North American Rocky mountains, as they too, 100 million years ago, had a similar subduction zone off their west coast, and likewise, exhibit the typical eastward bend, and a wide midsection.

As for the forces driving South American plate, both Russo and Silver are emphatic that this continent is swept westward by deep, wide, mantle currents from beneath the Atlantic Ocean. This view, no doubt, runs counter to the prevailing models of plate movements according to which the low viscosity layer, asthenosphere, separating crustal plates from the mantle, impedes mantle currents to carry the crustal plates along. While the Nazca plate is dragged eastwards by its sinking (subducting) edge, the South American plate is pushed from the rear, westwards, over the Nazca plate, by the emerging new crust – the mid-Atlantic ridge. This conventional 'ridge-push' view is very much doubted by both Russo and Silver who consider these forces alone are too inadequate for the build up of stresses and feel that these are augmented by the underlying mantle currents pulling to the west. But according to Richardson and Coblentz of University of Arizona, Tucson, the magnitude of drag forces from the mantle, invoked by Russo and Silver, are too small to carry the plate westwards[2]. According to their finite analysis calculations of stress measurements within the South American plate and also in the absence of any E–W stress-build expected if drag forces were significant, they feel that the movement of the South American plate should be essentially due to ridge-push force.

However, the theory, that mantle currents were the driving force received support from new data presented at last year's meeting of the American Geophysical Union, by geophysicists John Van Decar and David E. James of Carnegie Institution, Washington (DC). Using seismic tomography, a sort of CAT scan of the mantle below South America, they evaluated the seismometer recordings of earthquakes, worldwide, over a three year period. From these data on travel times of the waves which are influenced by the composition and temperature of the rock or zone through which they travel, the two were able to detect below Brazil presence of a relict or fossil structure of a magma plume which was once the conduit for the vast basalts (Parana basalts) that erupted in that country 130 million years ago (Figure 2 *a*). Obviously, this relict structure had moved 3000 kms westwards along with the South American plate from the original site (Figure 2 *b*). This is a strong indication that 'deep mantle currents carried both the mantle shaft and South American continent' together, though the eruptive source had still remained fixed as is evident from present day volcanic eruptions at Trista da Cunha in the middle of South Atlantic.

1. Russo, R. M. and Silver, P. G., Symposium of the American Geophysical Union, Baltimore, 1995.
2. Monastersky, R., *Sci. News*, 1995, **148**, 124–125.

# Split comets and crater chains (catenae)

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There is hardly any planet in the Solar System which is not pock-marked by impact craters. Only about three years back, in July 1994, there was a live spectacle of the Shoemaker–Levy 9 comet (S–L9) crashing over Jupiter, an extremely rare celestial event that had mobilized scientists around the world to test some of their theoretical speculations about impacting bodies as well as impacted planets (or satellites). This comet had split into over twenty pieces during its close approach to Jupiter in 1992; these pieces, however, remained in the same orbit, though at some distance apart. Finally, one after another, two years later, they plunged on to this planet's thick gaseous surface, in a rare display of multiple impacts, generating huge plumes or clouds and leaving scars which gradually diffused into the planet's atmosphere.

While these were the outcome of the multiple crash over a gaseous planet like Jupiter, an event of similar nature by fragmented comets or rubble-asteroids over solid planets like Earth or Mars can result in carving of chain of craters (catenae). In fact, such crater chains produced by comets disrupted by tidal forces when they swept past Jupiter[1,2] have been spotted by the spacecraft *Voyager* on two of this planet's moons – Callisto and Ganymede. The craters on Callisto extend over a distance of 360 km with an average diameter of 24 km, while those on Ganymede are lesser in extent and sizes (Figure1). Now, after witnessing the crashes of S–L9 fragments, the origin of these crater chains, long considered enigmatic, no longer remain a mystery.

Recognition of crater chains on Callisto and Ganymede spurred searches for detecting similar ones on Earth and its moon also. Scientists consider their presence on Earth highly likely since our planet is known to have been severely

**Figure 1.** Crater chain on Callisto, the outermost moon of Jupiter, photographed by Voyager Spacecraft. This chain extends for 360 km and contains craters up to 24 km across. The origin of this chain was enigmatic until the impact of S–L9 fragments over Jupiter in 1994.