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.

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Split comets and crater chains (catenae)

A. V. Sankaran

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 (Figure 1). 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.

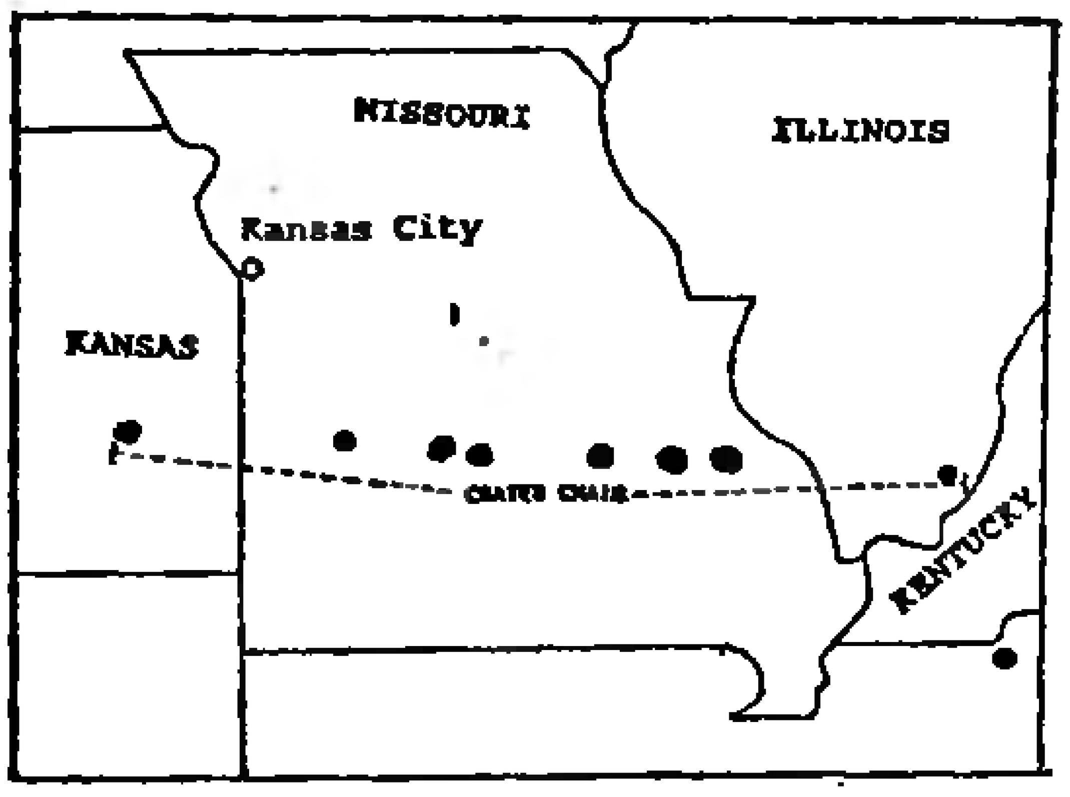

Figure 2. Crater chain extending for 700 km from Kansas to Illinois, USA.

Figure 3. A string of craters in Moon, the Davy crater chain, 47 km long.

battered by meteorites and asteroids in its early past[3], though the likelihood of their unweathered preservation over the intervening millions of years is rather uncertain. In spite of this major constraint, recently it has been possible to decipher crater chains, one in Africa and another in North America through the data gathered by NASA's Imaging Radar Space Shuttle and, also over Earth's moon, from the Apollo Lunar Orbiter photographs[4,5]. The African Aorounga Crater (12.6 km diameter) in northern Chad[3] is now found to have two more craters to its NNE, and probably, a suspected third one also, all hidden below the sands of Sahara desert. They stretch for about 100 km, the largest among them measuring about 17 km across. These craters are believed to have been made by a comet or asteroid which split into fragments up to 1 km diameter, shortly before impacting, some 360 million years ago.

The second discovery[5] in North America is a string of eight craters ranging in size from 3 to 17 km and extending for 700 km from southern Illinois through Missouri to eastern Kansas (Figure 2). Hitherto, they were believed to be volcanic craters, but in the absence of any volcanism in the area and presence of shock produced minerals[6] at the site, they are now considered as coeval impact craters, about 330–310 million years old and created by a 'string of asteroids or cometary objects produced by breakup within the inner solar system[5]'. One more proven impact crater about 6 km in diameter (estimated age <300 million years) lying further east, some 420 km away, in eastern Kentuky[6], is also suspected to belong to the same Kansas–Illinois chain. Though the African craters too are dated around the same time, evaluation of various other data indicates that the craters in these continents were made by two different comets or asteroids. The crater chains found on our moon (Figure 3) range in length from 50 km (Davy chain) to 250 km (near Abulfeda crater) and are supposed to have been generated by comets disrupted tidally when they passed close to Earth or by rubble-pile asteroids[7].

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