

## Myth and catastrophic reality: using myth to identify cosmic impacts and massive Plinian eruptions in Holocene South America

W. BRUCE MASSE<sup>1</sup> & MICHAEL J. MASSE<sup>2</sup>

<sup>1</sup>*ENV-EAQ Ecology and Air Quality Group, Mailstop J978, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA (e-mail: wbmasse@lanl.gov)*

<sup>2</sup>*Mail Drop SW308, Scripps Green Hospital, La Jolla, California 92037, USA*

**Abstract:** Major natural catastrophes such as floods, fire, darkness, and 'sky falling down' are prominently reflected in traditional South American creation myths, cosmology, religion, and worldview. Cosmogonic myths represent a rich and largely untapped data set concerning the most dramatic natural events and processes experienced by cultural groups during the past several thousand years. Observational details regarding specific catastrophes are encoded in myth storylines, typically cast in terms of supernatural characters and actions. Not only are the myths amenable to scientific analysis, some sets of myths encode multiple catastrophes in meaningful relative chronological order. The present study considers 4259 myths, including 284 'universal' (perceived in the narratives to be worldwide) catastrophe myths, from 20 cultural groups east of the Andes. These myths are examined in light of available geological, palaeoenvironmental, archaeological, and documentary evidence. Our analysis reveals three likely major Plinian volcanic eruptions in Columbia and the Gran Chaco. We also identify a set of traditions that are probably linked to the well-known Campo del Cielo iron meteorite impact in northern Argentina around 4000 years ago, along with a separate set of traditions alluding to a possible airburst in the Brazilian Highlands. These impacts apparently triggered widespread mass fires. There are hints of cosmic impacts in the mythologies for other locations in South America.

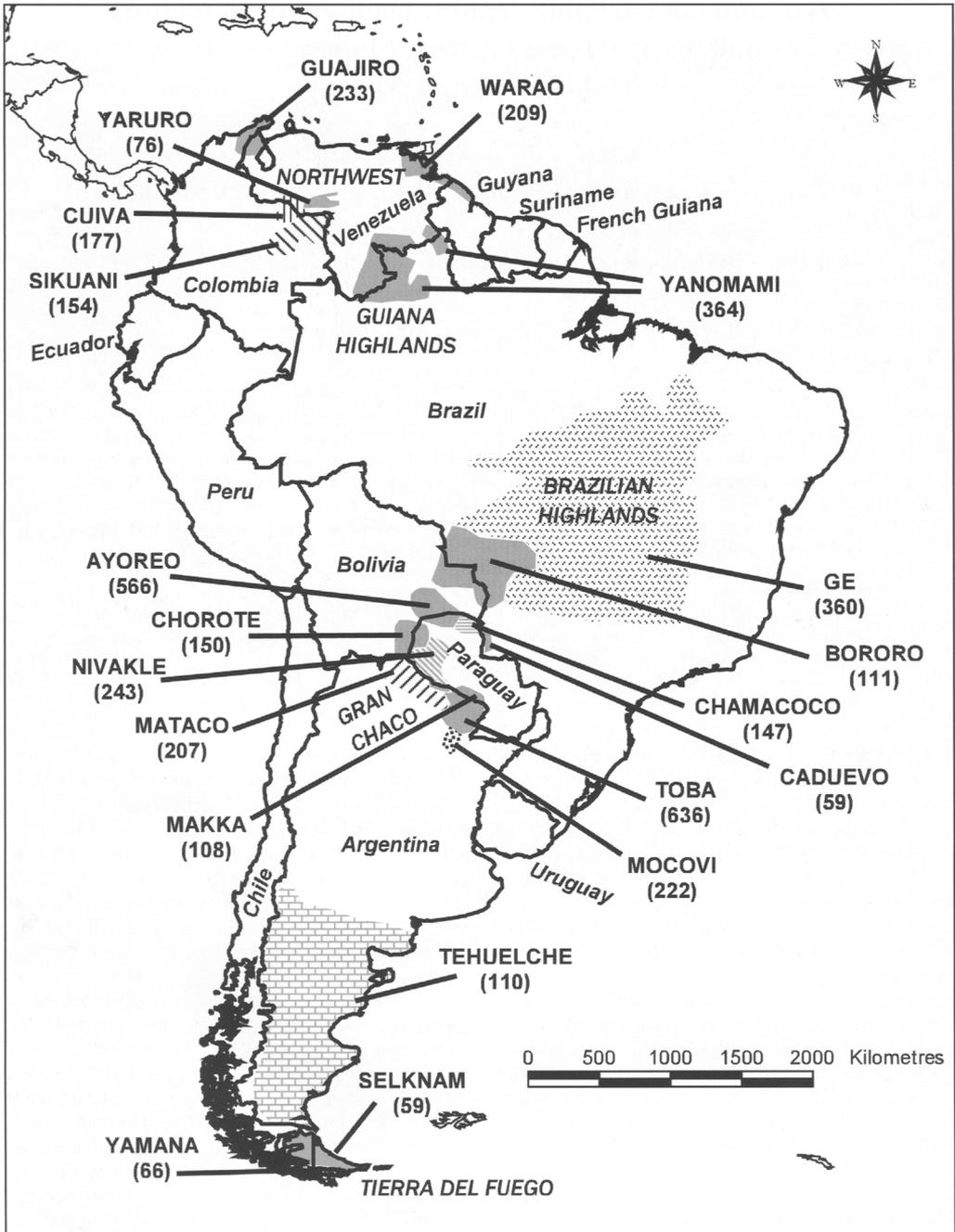
South America is a vast and physically diverse region, occupying some 17 819 000 sq km, approximately 12% of the world's overall land mass. South America was seemingly the last of the inhabited continents to be colonized, a process beginning by at least 12 000 BP. Prior to European contact in the sixteenth century, a wide range of societies developed and flourished throughout South America, ranging from simple migratory hunter-gatherers of Patagonia and Tierra del Fuego to well-known state-level societies of the central Andes and adjacent coastal plains of Peru and Chile. The Inca, the Chimú, and the Moche continue to impress archaeologists and historians with their monumental architecture and their mastery of irrigation and general water management. In between these two extremes were semi-sedentary and sedentary village horticulturalists and various small independent chiefdoms relying heavily on agriculture and maritime resources.

The distinguished anthropologist Julian Steward identified a total of 178 named different tribes for South America (Steward 1946–1959; Steward & Faron 1959). It is readily apparent that thousands of additional 'tribal' names are present in historical documents, and that much confusion exists due to synonymy and language uncertainties. Early

explorers and missionaries had no systematic way to classify the various groups of people they encountered. There are at least 65 known language families in South America with estimates of the numbers of individual languages ranging between 400 to as many as 3000 (Bierhorst 1988, p. 17). This uncertainty is compounded by the fact that many of these languages and the groups who spoke them have become extinct during the past several hundred years.

Despite these conditions, South America has a rich legacy of oral traditions and mythologies. South American mythology has been the source for some of the most creative and comprehensive studies of mythology performed to date (e.g. Lévi-Strauss 1969, 1973, 1978, 1981; Bierhorst 1988). Of particular value for our study is the set of 4259 myths published during the period of 1970–1992 by the University of California at Los Angeles (UCLA) as part of the monumental 24-volume series entitled *Folk Literature of South American Indians* (Wilbert & Simoneau 1992). The distribution of the 'UCLA collection', representing 20 different cultural groups east of the Andes, is depicted in Figure 1.

We hypothesize that 'great' or 'worldwide' catastrophic events appearing in South American Indian



**Fig. 1.** Map of South America depicting countries (e.g. Paraguay), geographic regions (e.g. Gran Chaco) and cultures with their total numbers of myths in the UCLA collection (e.g. Toba with 636 myths).

mythologies are based on actual large-scale natural events identifiable in the geological and archaeological record. These include Plinian volcanic eruptions, cosmic impacts, and mass fires potentially caused by cosmic impacts.

We are not the first researchers to attempt to use myths to elicit historical information about South American catastrophes. A century ago Adolph Bandelier (1905, 1906) attempted to determine the historicity of myths along the western coast of South America relating to earthquakes, volcanic eruptions, and possible impacts by meteorites. Based on Spanish archival accounts and associated Native American oral traditions, Bandelier surmised that a number of South American volcanoes likely had significant eruptive events prior to Spanish colonization. Although several of his named volcanoes cannot be matched with their modern counterparts, Bandelier's list includes the Ecuadorian volcanoes of Capacurcu (?), Cayambe, Chimborazo, Cotocachi (?), Cotopaxi, Gugagua Pichincha, and Tungurahua; the northern Peruvian volcanoes of Guallo (?), Pariacaca (?); the southern Peruvian volcanoes of Coropuna, Huaynaputina ('Omate'), Misti, Quimsachata, and Solimana (?); and the Chilean volcanoes of Planchon-Peteroa and Villarrica. Of the 11 certain identified volcanoes for which Bandelier found oral traditions supportive of significant pre-Spanish volcanic activity, only that of Planchon-Peteroa has yet to provide documented physical evidence of such pre-Spanish Holocene activity (Siebert & Simkin 2005). Bandelier specifically looked for, but failed to find, evidence for either historic or pre-Spanish Holocene volcanic eruptions in the Bolivian Andes.

Native American oral traditions gathered and cursorily evaluated by Bandelier were all from Andean and coastal cultural groups not represented in the UCLA collection. We build on Bandelier's precocious suggestion that myth storylines and the spatial distributions of myth elements and motifs represent a logical and relatively accurate record of catastrophe and its impact on both humans and the environment. A systematic comparative analysis of environmental and geophysical data contained within the UCLA collection reveals patterns that appear to reflect the physical nature of the catastrophe, including the type, location, intensity, and duration.

In order to set the stage for our hypothesis and to identify potential specific catastrophes, we first examine aspects of the Holocene geological and environmental record of South America, including known Plinian volcanic eruptions, data pertaining to climate, regional mass fire events, and the record of known and hypothesized cosmic impacts.

## South American Holocene physical environment

### *The Andes and Holocene volcanism*

The subduction of the Nazca and Antarctic plates along the western continental margin has uplifted and folded the Andes into the longest range of mountains in the world, extending 8900 km from Columbia in the north to Tierra del Fuego (Fig. 2). At least 203 volcanoes with Holocene (c. 11 000 BP to present) activity have been identified, based on radiocarbon and tephrochronological dating and on observed glacial activity on older volcanoes. Holocene volcanism is divided into four main zones controlled by segmentation of the subducted plates along pre-existing zones of weakness. The volcanoes typically range in height from 4000 m to nearly 6000 m in the two northern zones, and are progressively lower in the two southern zones.

Unless otherwise noted, the details listed in the following discussion are obtained from *Volcanoes of the World* (Simkin & Siebert 1994), *Encyclopedia of Volcanoes* (Sigurdsson 2000), and Smithsonian Institution's 'Global Volcanism Program' website (Siebert & Simkin 2005). Reference to the Volcano Explosive Index (VEI) for pertinent eruptions is from the Global Volcanism Program website. Figure 2 illustrates the locations of South American volcanoes highlighted below, presented in order of descending latitude. Thirty-eight Plinian eruptive events have been documented in South America (VEI = 4), along with 14 probable ultraplinian events (VEI ≥ 5). Plinian eruptions are characterized by voluminous eruptions of many cubic kilometres of magma, resulting in eruption columns generally ranging in height between 11 and 40 km. The column is composed of magmatic gases and tephra (fragmental volcanic ejecta), including pumice (frothy low density particles) and ash (glass shards, minerals, and rock fragments less than 2 mm in diameter). Stratospheric winds fan out the tephra column creating an effect commonly referred to as an umbrella cloud. Prevailing winds can distribute pumice tens of kilometres from volcanoes; ash can be distributed hundreds or even thousands of kilometres away. Hot pyroclastic density currents (flows) also are a common feature of Plinian eruptions. Many of the Andean volcanoes are covered in ice and snow, and pyroclastic flows often create destructive mudflows (lahars).

The Northern Volcanic Zone (NVZ), comprising more than 300 volcanic structures, is bounded by the Bahia Solano–Macarina mega shear-zone in central Columbia at the northern edge and extends



**Fig. 2.** Map of South America depicting the distribution of 'sky fall' and 'great darkness' catastrophe myths from the UCLA collection in relation to Nuevo Mundo volcano and known late Pleistocene and Holocene period cosmic impacts.

south 1100 km terminating at the Amotape mega shear-zone in southern Ecuador. Stratocones, clusters of monogenetic cones and several andesitic shield volcanoes dominate the NVZ, many capped by perennial snow or glaciers.

Cerro Bravo is the northernmost active stratovolcano with seven Plinian eruptive phases beginning approximately 6280 BP (Lescinsky 1990). Nearby Nevado del Ruiz stratovolcano has four documented Holocene Plinian eruptions since 2850 BP (Pierson *et al.* 1990; Thouret *et al.* 1990; Voight 1990; Simkin & Siebert 1994). In 1985, a Nevado del Ruiz subplinian eruption (VEI = 3) and associated small pyroclastic flows melted approximately 10% of the summit ice. A series of devastating lahars, including one that travelled 100 km, killed 23 000 people. Complex volcano Galeras has exhibited frequent, modest Holocene subplinian eruptions (Calvache *et al.* 1997; Banks *et al.* 1997). Charcoal evidence of ignited fires has been found 6–8 km from the crater. Cuicocha is a 3 km wide caldera formed during an explosive ultraplinian event in 1150 BC. An estimated 5 km<sup>3</sup> of pyroclastic material was ejected.

Stratovolcano Cotopaxi is the highest active volcano in the world (5911 m) and the site of perhaps the most catastrophic event to have occurred in the Holocene (Barberi *et al.* 1995; Mothes *et al.* 1998). Around 4640 BP a small sector collapse (2 km<sup>2</sup>) of the upper north and NE slope caused an avalanche of ash debris into the valley below. This formed hummocks and a run-out field extending 25 km northward. Pyroclastic flows melted part of the icecap; the meltwater mixed with ash debris and formed an immense lahar. The lahar descended the western flanks of the Andes, entering two parallel river systems. It attained depths of 200 m, finally merging to create an 11 km wide flood front ending 326 km from its origin, emptying into the Pacific ocean. A portion of the lahar descended the SW flanks of Cotopaxi forming a 2–3 km wide path 30–40 m deep, eventually emptying east into the Amazon headwater region.

West of Cotopaxi, Quiltoa volcano generated a major ultraplinian eruption (VEI = 6) around 850 BP, creating a 3 km wide caldera. The eruption produced large pyroclastic flows; lahars reached the Pacific Ocean more than 160 km to the west. It also produced one of the largest airfall-tephra deposits of the northern Andes. Regional human impact is unknown, but is surmised to have been great.

Prehistoric pottery has been found at the base of the Cotopaxi lahar flow, and it is assumed that local cultures would have been greatly affected. A more definitive impact on past Andean cultures was created by the massive caldera-forming Plinian

eruption of nearby Pululagua volcano around 2700–2500 BP. The eruption devastated Formative period archaeological cultures in western Ecuador, and led to major shifts in settlement systems and political alliances (Zeidler & Isaacson 2003).

The seismically active transverse Albancay Deflection shear zone is the northern boundary of the Central Volcanic Zone (CVZ) and is 1600 km south of the NVZ. More than 600 volcanic structures extend southward 1100 km. The southern boundary coincides with a subduction of the Sala y Gomez ridge hotspot track. Andesitic stratovolcanoes predominate.

Huaynaputina stratovolcano produced a small explosive eruption around 5750 BP, and then remained dormant with occasional mild fumarolic activity for the next 5300 years. Early Spanish documents note the Indian population would ascend Huaynaputina to perform appeasing sacrifices. The Huaynaputina eruption that began on 19–20 February 1600 was the most violent ultraplinian event to have occurred during historical times in South America, producing about 30 km<sup>3</sup> of ejecta (de Silva & Francis 1991; Adams *et al.* 2001; Thouret *et al.* 2002). The initial explosive event lasted 13–16 hours; a sustained eruption column ascended to 35 km at around 30 m s<sup>-1</sup>. Strong east winds above the Tropopause formed an umbrella cloud and dispersed pumice fragments 50 km to the west. Thick pumice falls and ash blanked an area of 4900 km<sup>2</sup>. The ultraplinian phase ceased abruptly as pumice debris choked off the vent. A series of vent-clearing explosive events occurred on February 20–22 producing extensive ashfalls. From February 22–24 the volcano was quiescent. Ashfalls began again on February 25 forming 'complete darkness' for around 40 hours. Strong earthquakes on 26 February caused the collapse of a cathedral and many houses. A loud explosion was heard on 27 February; pyroclastic flows and surges covered an area of about 950 km<sup>2</sup> and dammed the Rio Tambo Canyon forming two temporary lakes. The subsequent breach of these dams released large saturated debris flows down the valley into the Pacific Ocean 120 km to the west. Periodic explosions, ashfalls, and pyroclastic surges continued until March 15 when Huaynaputina again became dormant.

The Huaynaputina eruption has been assigned a VEI level of 6, at least equalling the 1883 Krakatau, Indonesia event. Ten villages were buried, more than 1500 people were killed, and the regional economy was devastated for 150 years. The atmospheric acid spike from the Huaynaputina eruption is documented in ice core samples from Greenland as exceeding the spike produced by Krakatau and may have affected world climate for decades.

The stratovolcano Lascar is the most active volcano in northern Chile. The Plinian eruption of 1993 produced pyroclastic flows extending more than 8 km. Tephra fell over large areas in Uruguay, Brazil, Paraguay and Argentina. Buenos Aires, 1500 km distant from Lascar, received light ashfall. (de Silva & Francis 1991; Matthews *et al.* 1997). The 1993 eruption (VEI = 4) demonstrates that moderate Plinian eruptions can distribute tephra over vast regions. Seasonal weather occasionally distributes ashfalls from the Andes into the Gran Chaco, Pampa, and the southern Brazilian Highlands.

The Southern Volcanic Zone (SVZ) is bounded in the north by a fault zone extending from the Galapagos Rise and is a continuous, little studied, volcanic belt extending 1400 km that terminates where the Chile Rise intersects the continent.

Cerro Azul stratovolcano has been historically active from the Quixapu vent on Azul's northern flank. In 1932 the Quixapu vent was the source of one of the most violent ultraplinian eruptions in the twentieth century producing more than 9.5 km<sup>3</sup> of tephra. Llaima stratovolcano has evidence of Holocene ultraplinian events in 8880 BP and 7290 BP. It has remained moderately active since 1640. Sollipulli caldera erupted violently from the SW rim in an ultraplinian event at 2920 BP (Gilbert *et al.* 1996). The stratovolcano Villarica rises from a 2 km wide caldera formed in 3730 BP which itself occupies a 6 km wide Pleistocene caldera. Several ultraplinian events are identified from the late Holocene with pyroclastic flows extending 20 km. Frequent historical Plinian eruptions have melted glacial cover and have damaged several towns on its flanks.

Cerro Hudson stratovolcano (1905 m) is the southernmost volcano in the SVZ. Its base is greater than 300 km<sup>2</sup> and a 10 km ice-filled caldera occupies its summit. It was not recognized as a volcano until its first twentieth century eruption in 1970. An ultraplinian event in August 1991 produced an estimated 4 km<sup>3</sup> of pyroclastic ejecta (Naranjo & Stern 1998). It is now known that a caldera-forming event in 6700 BP deposited more than 10 cm of tephra 900 km south in Tierra del Fuego. A bulk volume of greater than 18 km<sup>3</sup> is estimated for this event. A second massive eruption in 3890 BP approached the magnitude of the 6700 BP event. Both eruptions have been assigned a VEI of at least 6 and are said to have exceeded the 1991 Cerro Hudson event (VEI = 5+) and the 1932 eruption of the Quixapu vent on Cerro Azul (VEI = 5+) in explosive force and tephra bulk volume.

Beginning 290 km south of Cerro Hudson five widely separated stratovolcanoes comprise the Australandean Volcanic Zone (AVZ), defined where a

portion of the Antarctic plate descends beneath the continental plate. Three volcanoes have been observed distantly or by aerial means, including the Volcán Fueguino lava domes, but none has been studied systematically.

Tanguy *et al.* (1998) have attempted to put a human face on volcanic eruptions by creating a worldwide database of the causes of documented death from volcanoes between 1783 and 1997. Of the more than 221 907 victims, the following causes were deduced in decreasing order of significance: Post-eruption famine and disease (30.3%); pyroclastic flows (26.8%); lahars (17.1%); volcano-genic tsunami (16.9%); debris avalanche (4.5%); ashfall (4.1%); and lava flows (0.3%). Most of the volcanic eruptions discussed above for South America are notable for pyroclastic flows, lahars, famine and disease, and to a lesser degree debris avalanches, and ashfalls. However, as one moves east of the Andes, the effects of ashfalls and associated famine take on a heightened role. These proportional relationships can be identified in sky fall and darkness myths.

#### *Climate and fire regimes in the Gran Chaco and Brazilian highlands*

Dominated by oceans, the atmospheric circulation in the southern hemisphere is primarily zonal and is disrupted by the north-south interposition of the South American continent and the continuity of the Andes Mountains. Distinct pressure zones are the intertropical low and subtropical high with air mass movement from east to west. Within the intertropical low the NE and SE trade winds merge forming the Intertropical Convergence Zone (ITCZ) and at convergence the moist air is pushed aloft resulting in a band of heavy precipitation. This band moves seasonally, always being drawn toward the area of most intense solar heating, or warmest surface temperatures. The band of subtropical high pressure forms two distinct cells east and west of the Andes. Temperate low pressure, and polar high pressure air mass movement is west to east. Seasonal fluctuations of these semipermanent pressure systems and their interactions are responsible for the various major climate regimes. Climate is further influenced by seasonal insolation producing local and regional high-pressure zones.

East of the Andes broad natural vegetation zones have developed in direct relationship to the amount and season of rainfall and altitude. Tropical vegetation predominates from 10°N to 10°S. The Amazonian lowlands are occupied by dense rain forest. Extending south and east of the rain forest boundary is the *cerrado* (c. 2 000 000 km<sup>2</sup>) of the

Brazilian highland, characterized by savanna grasslands and low, dense savanna forests of 5–15 m tall evergreens. In the *cerrado* the trees are gnarled and twisted and have a thick, fire-resistant bark—perhaps an adaptation to the many lightning induced natural fires from frequent thunderstorms. The *cerrado* has been termed ‘the natural epicentre of Brazilian fire’ (Pyne *et al.* 1996, p. 685). Temperate vegetation in the Pampa of southern Brazil and Uruguay (327 000 km<sup>2</sup>) changes to a vast tall grass prairie. The rainfall is greater than 1000 mm and is suitable for forests. High evaporation, low water tables, and frequent regional fires inhibit their growth (Clapperton 1993). West of the Rio Paraná and west of the 1000 mm rainfall isohyet is the Gran Chaco (609 600 km<sup>2</sup>), an immense region of dispersed deciduous thorn forests and grassland. Intense evaporation, low rainfall, and very hot summers predominate; lightning induced local and regional wild fires are frequent. South of the Gran Chaco the full effect of the Andean rain shadow, and high steady winds characterize the Patagonian plateau (770 000 km<sup>2</sup>). This semi-arid desert is colonized by short drought-resistant shrubs and grasses in the north and in the far south, forests occupy lower Andean slopes in the west and grassland steppe on the plateau to the east.

A synthesis of palaeoenvironmental data suggests that the early to mid-Holocene was drier than now (Ledru *et al.* 1998; Salgado-Labouriau *et al.* 1998; Behling *et al.* 2001; Marchant *et al.* 2001; Sifeddine *et al.* 2001). Swamps dried up, peat formation was absent, lake levels were lower or dried up, and sedimentation decreased. The ITCZ remained seasonally further to the north. Climate zones moved northward and vegetation became more xerophytic. Savannas in tropical lowlands expanded; temperate forests evolved into *cerrado*. Frequent fires have been identified in lacustrine core samples. The dating of the arid episode varies from site to site and was gradual; no sudden climate changes have been identified. Reported dating of this transition vary widely and range between 7000 and 3800 BP. The return of the ITCZ further southward brought increased precipitation and a climate and vegetation transition to current regimes. At 5000 BP in Columbia, cores disclose degraded vegetation with the presence of *Zea mays* pollen and charcoal, evidence of farming and the use of fire as a forest clearing technique (Marchant *et al.* 2001).

Flammable plant material and an ignition source is all that is necessary to start a wildland fire. If flammable material is contemporaneous with the presence of drought or dry winds, fires can grow to regional proportions. The 1997–1998 El Niño event delayed rainfall to the NW portion of

Brazil, a region already suffering from an extended drought. Once wildfires started, they consumed over 20 000 km<sup>2</sup> of highland savanna in 1997 and 40 000 km<sup>2</sup> in 1998. Drought and fire was worldwide: the popular media defined 1998 as ‘the year the Earth caught fire’.

Ignition may originate from several sources. Lightning is the primary igniter and is pervasive throughout South America starting hundreds of fires annually. It is particularly prevalent in the Pampa and Gran Chaco regions in summer when the southwesterly flow of dry air from Patagonia converges with westward flowing moist air from the SE trade winds forming vast frontal systems accompanied by intense cloud-to-ground lightning (Clapperton 1993). Fire ignition can be volcanogenic. Pyroclastic flows, incendiary bombs, and lava flows can produce local and regional burning (Calvache *et al.* 1997).

Anthropogenic fires can be purposeful or accidental. Amerindian hunters may have used fire regularly as early as 8000 BP to herd or flush prey (Goldammer 1993). In recent times the Toba people in the Gran Chaco commonly set bush and grass fires to procure game, and the burnt ground was searched for injured and dead animals (Métraux 1946, p. 13). There is strong evidence for Mid-Holocene agricultural burning (Marchant *et al.* 2001), although natural causes cannot be ruled out. Frequent charcoal occurrences have been identified between 7000 and 4000 BP (Santos *et al.* 2000). It has been suggested that intensified El Niño events occurred beginning around 5100 BP causing worldwide drought and regional fires comparable to the 1997–1998 event (Haberle & Ledru 2001). Modern examination of controlled burns over single and multiple seasons are helping to document the progression of biotic recovery and can be used to model past events (Bóo *et al.* 1996, 1997).

#### *Late Pleistocene/Holocene cosmic impacts*

The record of cosmic impact is not as well known for South America as that for other parts of the world (University of New Brunswick 2005; Masse 2007). A total of only seven impact structures have been documented to date, two of which are located in Argentina and are of potential significance to our discussion (Fig. 1). One, Campo del Cielo, dates back to the Holocene period. The second, Rio Cuarto, has been dated to the Holocene period, but both its nature and dating is suspect as is discussed below. A third probable impact structure, Iturralde in northern Bolivia, may date back to the end of the Pleistocene. In addition, there are

several glass melt strewn fields dating to the Quaternary period that may relate to either airbursts or to impacts for which the craters have yet to be documented. One apparent airburst in the vicinity of Rio Cuarto has been dated to the middle Holocene and probably produced ground fires.

The 8 km diameter depression referred to as the Iturralde Structure (Araona Crater) was initially identified from 1984 Landsat images. Despite two expeditions by NASA Goddard in 1998 and 2002, its expected meteorite impact origin is not yet confirmed (Wasilewski *et al.* 2003). Both expeditions were hampered by the logistics of site location within the Amazon rainforest. The geological context of the structure indicates a formation date of around 30 000–11 000 BP, possibly too early to have been witnessed by humans unless occurring between about 15 000–11 000 BP.

The Campo del Cielo 'Field of the Sky' crater field in northern Argentina was first mentioned in Spanish colonial reports from 1576 and variously since then. This portion of the Gran Chaco is semi-arid, hot, very flat, and covered equally by savanna, scrub, and dense thorn forests. Reconnaissance of the site in 1961 supported the theory of meteorite origin and the National Science Foundation awarded grants to study the site beginning in 1962. The depressions were confirmed to be impact craters formed from the impacts of multi-ton silicified iron (IAB) meteorites.

The Campo del Cielo crater field contains at least 26 small, elongated impact craters within a north-trending ellipse, 3 km wide and 19.2 km long. The in-fall angle was calculated at 9° from the horizon (Cassidy *et al.* 1965; Cassidy & Renard 1996). The main concentration of craters is at the southern end of the ellipse. A strewn field extends 60 km beyond the craters, and meteorites have been recovered all along the path. Two craters were studied extensively. Three sizeable charcoal specimens were recovered for <sup>14</sup>C dating and the impact event was estimated at around 4000 BP. Impact velocities have been calculated ranging from 1.7–4.3 km s<sup>-1</sup>. An analysis of impact effects yielded a pre-atmospheric entry velocity of 22.8 km s<sup>-1</sup> (Cassidy & Renard 1996), a diameter greater than 3.0 m (Cassidy *et al.* 1965; Liberman *et al.* 2002), and mass minimally at 840 000 kg (926 tons) (Liberman *et al.* 2002). No impact glass melts have been recovered from the Campo del Cielo crater field, indicative of the small size and relatively slow speed of the impactors.

Cassidy & Renard (1996, p. 443) cite and translate traditional information, published by medical doctor and historian Antenor Álvarez in 1926. They suggest this information may relate to the impact and its aftermath as witnessed around 4000 years ago:

The meteorite of the Chaco was known since earliest American antiquity through stories from the Indians who inhabited the provinces of Tucumán. (These Indians) had trails and easily traversed roadways that departed from certain points more than 50 leagues away, converging on the location of the bolide. The indigenous tribes of the district gathered here in useless and vague veneration to the God of the Sun, personifying their god in this mysterious mass of iron, which they believed issued forth from the magnificent star. And there [Campo del Cielo] in their stories of the different tribes of their battles, passions and sacrifices, was born a beautiful, fantastic legend of the transfiguration of the meteorite on a certain day of the year into a marvelous tree, flaming up at the first rays of the sun with brilliant radiant lights and noises like one hundred bells, filling the air, the fields, and the woods with metallic sounds and resonant melodies to which, before the magnificent splendour of the tree, all nature bows in reverence and adoration of the Sun.

Giménez Benítez *et al.* (2000) have conducted a detailed review of the Álvarez information to determine what relationship it may have to the Campo del Cielo event. They question aspects of the findings and suggestions of Álvarez, particularly the notion of a widespread solar cult. However, Giménez Benítez and his colleagues note little archaeological work has been done around Campo del Cielo but that it needs to be done. They also note that there has been little meaningful dialogue between anthropologists and planetary scientists regarding the myths and the physical aspects of the impact site.

Rio Cuarto, in central Argentina, graced the cover of the journal *Nature* (Shultz & Lianza 1992) and was proposed as a Holocene shallow angle meteorite impact zone containing at least 11 elongated craters. The largest is about 1.1 × 4.5 km. Schultz & Lianza (1992) noted that these putative impact structures could be interpreted to be of aeolian origin due to the geological setting; however, they also pointed to the presence of impact glass melts in and around some of the putative craters.

Further laboratory testing and aerial mapping have provided alternate interpretations (Bland *et al.* 2002; Cione *et al.* 2002). Bland *et al.* (2002) suggest that the Rio Cuarto structures are part of a widespread set of several hundred elongated aeolian depressions associated with parabolic sand dunes that formed in the Argentine Pampas during the mid-Holocene. They did support the impact origin of the Rio Cuarto glasses; their interpretation was that the glasses represented the distal ejecta of an impact occurring several hundred kilometres away, that was Pleistocene in age, around 480 ka.

Cione *et al.* (2002) likewise support a non-impact origin for the Rio Cuarto structures, and state that Argentine geologists have long supported the aeolian formation of these structures, pointing out that the alignments match prevailing wind patterns during the period(s) of their formation. Cione *et al.* (2002) argue that the glass melts are unlikely

to be of impact origin, rather they suggest that natural and anthropogenic fires, such as the burning of fields as part of the agricultural cycle, can produce the glass melts described by Schultz *et al.* (2004) and Bland *et al.* (2002). This seems unlikely because of recent detailed studies of the glasses and because of the physics of wildfire.

Schultz *et al.* (2004) have conducted an exhaustive analysis of melt glasses from the Pampas. They identified glass melts from five separate Quaternary period cosmic impacts with four of the impacts dating to the Pleistocene period between  $570 \pm 100$  ka (corresponding to the material identified by Bland and his colleagues) and  $114 \pm 26$  ka. Of significance is the robust documentation of the age of the Holocene impact glasses by three dating techniques: 4–10 ka based on geological context (stratigraphy and preservation state);  $2.3 \pm 1.6$  ka by fission track dating; and  $6 \pm 2$  ka by radiometric  $^{40}\text{Ar}/^{39}\text{Ar}$  dating. The combined suite of dating techniques implies a date for the impact of approximately 3–6 ka, similar to that for Campo del Cielo. No impact craters were defined for any of the five glass melt horizons, but the Holocene Rio Cuarto glass melts are traceable along a corridor extending at least 150 km to the SW, suggesting a sizable impactor. Schultz still favours an impact origin as originally defined for the Rio Cuarto structures; however, he concedes that the Holocene impact glasses could conceivably result from an airburst (Schultz *et al.* 2004; P. Schultz, pers. comm. 2004).

We still have much to learn and understand about airbursts—cosmic impacts by objects that explode and release their energy in the atmosphere above the Earth's surface—such as the well-known 1908 Russian Tunguska event. The frequency and the range of magnitude of large airbursts and all other classes of cosmic impacts are still critical topics of research (Bland & Artemieva 2003; Morrison *et al.* 2003). Most magnitude estimates of Tunguska range between 10–15 megatons (MT), approximately 500 times more energetic than the estimated energy release of the atomic weapons that destroyed Hiroshima and Nagasaki. Recent modelling (Bland & Artemieva 2003; Wasson 2003) suggests that airbursts can be created by objects much larger and therefore much more energetic than that of Tunguska. Objects and resultant airbursts smaller than Tunguska also produce devastating local Earth surface effects. In 1930, an apparent airburst half the magnitude of Tunguska devastated several hundred square kilometres in Brazil's upper Amazonian rainforest, creating widespread wildfires (Bailey *et al.* 1995). Similarly, a poorly documented apparent airburst may have occurred over Guyana in 1935 (Steel 1996).

Petrological and electron microprobe analyses of the Argentine glass melts by Schultz *et al.* (2004) indicated that temperatures in excess of  $1700^\circ\text{C}$  were necessary to completely melt all constituents including quartz grains. The specimens indicated rapid quenching of the melt and is stratigraphically restricted in occurrence. Together with the high temperatures for melt productions, this strongly implies an airburst origin.

Aspects of the physics of wildland fire argue against human burning of fields as the origin of the glass melts suggested by Cione and his colleagues. Pyne *et al.* (1996, pp. 20–23) note that the theoretical maximum temperatures that can be achieved by the burning of combustible gases generated from wildland fuels is around  $1900$ – $2200^\circ\text{C}$ . Most wildland fires, however, are more likely burn at average temperatures of between  $700$ – $980^\circ\text{C}$  with the maximum actually measured for an exceptionally intense fire being not much greater than  $1650^\circ\text{C}$ . The burning of fields in preparation for agriculture, including the presence of smoldering fires, would typically yield temperatures lower than the average wildland fire due to the differences in fuels. These data are also in accord with our first-hand experience with assessing the impacts of wildfire on soils and archaeological sites in the North American Southwest (e.g. Nisengard *et al.* 2002).

## Mythology

Our view of the nature and meaning of mythology, along with the structure and utility of oral tradition, is discussed earlier in this volume (Masse *et al.* 2007a) and other publications (e.g. Masse 1995, 1998, 2007; Masse & Espenak 2007; Masse *et al.* 2007b). This differs considerably from the manner in which myth is portrayed by most contemporary anthropologists and mythographers. We recognize that myths do have important psychological and structural aspects, in addition to the basic fundamental values given to myths within their traditional cultural settings; however, we chose to emphasize that myth can represent a coherent form of historical narrative.

## The UCLA collection

Our environmental analysis of South American mythology is indebted to the efforts of Wilbert and Simoneau in putting together and publishing *Folk Literature of South American Indians* (Wilbert & Simoneau 1992). A total of 4259 myths from 31 South American Indian societies representing 20 major cultural groups were assembled and reproduced along with a detailed

classification of the complex motifs contained in each story. These myths are the contribution of 111 authors, translated into English as necessary, and published over the course of 20 years as a set of 23 separate volumes. The cultural groups themselves are widely dispersed: five from the 'North-west' region of Columbia and Venezuela at the northern tip of the continent, one from the Guiana Highlands along the border of Venezuela and Brazil, two from the Brazilian Highlands of central and eastern Brazil, nine from the Gran Chaco of northern Argentina, Paraguay and eastern Bolivia, one (now extinct) from Patagonia in southern Argentina, and two (also extinct) from Tierra del Fuego at the southern tip of the continent (Fig. 1).

Although there are many societies and myths not included in the UCLA collection, the coverage is sufficiently widespread and diverse to permit our preliminary attempt to draw inferences from the distributions and regional patterns of myth motifs. The sample is particularly robust for the Gran Chaco region. The 4259 myths do not represent all recorded stories for each cultural group and cannot be used to achieve absolute quantification of motifs for each culture and between cultures. The editors deliberately attempted to include as many substantive story variants as possible to provide a qualitative sense of story and motif prevalence.

A single person, Simoneau, is responsible for the motif classification and indexing of 22 of the 23 volumes. This gives the whole body of work a uniformity of approach and consistency unparalleled by any other large regional body of myths. A total of 54 637 motifs were identified, divided into 23 motif groups and 135 subgroups. The motif groups include the following categories: mythological motifs, animals, tabu, magic, the dead, marvels, ogres, tests, the wise and the foolish, deceptions, reversal of fortune, ordaining the future, chance and fate, society, rewards and punishments, captives and fugitives, unnatural cruelty, sex, the natural life, religion, traits of character, and humour. The mythological motif category contains a total of 11 958 motifs or approximately 22% of all motifs. Within the mythological motifs are the following subgroups: creator, gods, demigods and culture heroes, cosmogony and cosmology, topographical features of the earth, world calamities, establishment of the natural order, creation and order of human life, creation of animal life, animal characteristics, origin of trees and plants, origin of plant characteristics, and miscellaneous explanations.

Any given myth can of course contain dozens of motifs, and any specific motif subgroup, for example 'world calamities,' can occur as a minor

theme within the context of other subgroups and groups. Our focus in this paper is on the motif of 'world calamities'.

### South American catastrophe myths

A small but persistent motif within the mythologies of the 20 studied cultural groups is 'world cataclysm', in which most people of a particular tribe and their neighbouring tribes, or typically all people worldwide, are said to have died. Wilbert & Simoneau (1992, p. 27) provide insights regarding the possible aetiology of such catastrophe myths:

Accounts of universal or local catastrophes are told by all our sample societies except the Caduveo, whose failure to do so may be attributable merely to the limited size of the collection. Many tribes describe a number of disasters, some ordered by a supernatural being as punishment for perceived offenses, others simply regarded as spontaneous events which the myths attempt to rationalize. Whatever their source, such cataclysms play a major role in shaping the world as we know it today. The Flood motif and the Great Fire are the most common, but the Long Drought, the Wave of Cold, the Fall of a Meteor, the Great Darkness, and the Collapse of the Sky also appear. Doubtless many such tales reflect the environmental hazards faced by the Indians, as long-gone natural disasters, dimly preserved in tribal memory, tie in with creation or other myths to explain the present natural order.

Wilbert & Simoneau (1992, p. 54, 353–357) identified a total of 685 individual motifs within the world calamity subgroup. Some of these variables are what we suggest to be environmental observations contained within the myth storylines.

We have chosen five categories of world calamity for our environmental and geological analysis of South American mythology (Table 1). These are the 'great flood,' the 'great cold,' the 'world fire,' the 'sky falling down' (sky fall) and the 'great darkness'. These are the most prevalent cataclysms, being mentioned in 284 of the 4259 myths. There is some indication, particularly from the Gran Chaco, that cultural groups placed these stories into relative order: the flood and cold occurred first, the world fire in the middle, and sky fall and darkness occurred most recently, but still prior to European colonization in the early 1500s.

Regrettably, the relative order of disaster myths has not been a specific topic for investigation by most ethnologists and collectors of mythologies, nor was this apparently the case for the editors of the UCLA collection, thus much potentially valuable relative chronological information has been compromised or lost in the recording of these myths. In those few cases in the Gran Chaco where relative information is provided, the flood is consistently singled out as the earliest of the worldwide disasters. It is notable that the flood is

**Table 1.** Number of individual UCLA Folk Literature Collection myths containing specified 'world calamity' motifs for each cultural group in the collection.

Culture & location	Great flood [earliest in myth cycle]	Great cold [after flood myth]	World fire [middle of myth cycle]	Sky fall darkness [latest in myth cycle]	Great darkness [latest in myth cycle]	Total
Northwest						
Cuiva	13	–	–	4	–	17
Guajiro	9	–	–	–	1	10
Sikuani	10	–	–	–	–	10
Warao	3	–	–	–	–	3
Yaruro	10	–	–	–	–	10
Guiana Highlands						
Yanomani	17	–	–	11	2	30
Brazilian Highlands						
Bororo	4	–	1	–	–	5
Ge	11	–	6	–	1	18
Gran Chaco						
Ayoreo	17	–	2	–	1	20
Caduevo	–	–	–	–	–	0
Chamacoco	10	–	1	1	–	12
Chorote	10	–	7	1	–	18
Makka	2	–	–	–	1	3
Mataco	12	–	5	–	1	18
Mocovi	7	–	3	–	–	10
Nikvale	6	1	6	9	–	22
Toba	24	5	27	–	12	68
Patagonia						
Tehuelche	2	–	–	–	–	2
Tierra Del Fuego						
Selknam	1	–	–	–	–	1
Yamana	3	1	2	–	1	7
Total	171	7	60	26	20	284

by far the most prevalent of the disaster myths. In this regard, the prevalence of the myth of the great flood in South America matches that for virtually all other regions of the world and as such represents the one truly universal human myth not traceable to a common source (Frazer 1919; Dundes 1988; Dang Ngheim Van 1993; Masse 2007). The flood myth lies beyond the scope of this paper, but is subjected to similar environmental analysis elsewhere (Masse 1998, 2007).

#### 'Sky fall', 'great darkness' myths and Plinian volcanic eruptions

Motifs about the 'sky falling down' (sky fall) are common in mythology worldwide, and logically could allude to several different natural phenomena. Intense rain, large hailstones, smoke from mass fires, volcanic ashfall, and debris from tornadoes and waterspouts could provoke images of the sky falling, as could airbursts and meteorite falls such as have been documented at various places

throughout the world in virtually every decade throughout the twentieth century (Lewis 2000, pp. 14–25, table 1.1). A period of intense darkness during daytime hours could logically result from several phenomena, including solar eclipses, dust storms, smoke from mass fires, volcanic ash plumes, or the stratospheric dust loading from the coma of a dusty large near-Earth comet as has been hypothesized for an extended period of worldwide diminished sunlight beginning in AD 536 (Baillie 1999; Gunn 2000).

Figure 2 illustrates the distribution of 'sky fall' and 'great darkness' myths in our sample of 20 cultural groups. 'Sky fall' and 'great darkness' myths are most prevalent in the Gran Chaco region, and also occur in substantial numbers for several cultures in the northwest and the Guiana Highlands. The myths themselves provide a number of substantive clues as to the nature of the observed natural disaster(s).

*Gran Chaco 'sky fall' and 'great darkness' myths.* In the Gran Chaco (Fig. 2), there are nine

'sky fall' myths for the Nivaklé, with single stories found also for the neighbouring Chorote and Chamacoco tribes. Pertinent environmental details contained in the 11 Gran Chaco 'sky fall' myths are presented in Table 2. It is evident that all eleven stories refer to the same event—ashfall from a Plinian eruption. The following Nivaklé story is representative (Chase-Sardi, in Wilbert & Simoneau 1987a, pp. 101–102, story no. 35):

Now I am going to tell you about the time, long ago, when the sky fell. A heavy rainfall began, until finally the sky began to descend. The people were very frightened and asked the shamans to order the rain to stop. But not even those who sang to the rain could do anything. The next day they saw the clouds falling. 'Now the terrible moment has come,' said the people. Among them was one man who now warned everybody to take refuge under a *molle* [Brazilian Peppertree, *Schinus mole*] tree, for the sky would fell all the other trees. Only the *molle*, could not be either crushed or felled. All the people who stood under the other trees would be smashed: only the *molle* could support the weight of the sky. The men ran toward the forest where they found some *molle* trees to take refuge under. They had with them their wives and children, and a few sheep which they had been able to round up quickly.

The sky crushed the huts, killing all those who were sheltering inside. It was very heavy. Intense darkness covered everything, and the people could no longer see one another. Disoriented, they did not know what to do. They tried to cut through the sky with their knives and axes, but in vain: it was very hard, seemingly impenetrable. They did not know what to do, and were terrified. It was not like daytime; they could not see, for it was darker than during the night. 'Are you still alive?' some would ask. 'Yes, I am alive,' others would answer. In the meantime it dawned. One of the men remembered some tuco-tuco teeth [incisors of the burrowing rodent *Ctenomys*] which he had kept for many years inside a rolled-up piece of string. This saved them. Quickly he started cutting the sky with the tuco-tuco teeth. Suddenly it opened above him. He ran to the other people and distributed his tuco-tuco teeth among them, and everyone worked to cut through the sky that covered them. Soon it opened, and once more they could see the day. They were happy. For many years we heard the old people saying that the sky was going to fall, and that is how it happened. All those people died who had taken refuge under the white quebracho, the red quebracho, and the other trees, which were all smashed by the sky. Only the *molle* trees survived, and with them those people who were sheltering beneath them. It was the owner of the tuco-tuco teeth who saved the members of his clan. He had had those teeth for a long time. Every time he caught a tuco-tuco he kept its teeth, for he used to hear the old people saying: 'Be sure to save the teeth of the tuco-tuco, and keep them ready for when the sky falls.' When the sky was cut it suddenly turned into smoke and rose upward. For they say it was fairly thick when it fell. The only place where it did not fall was over a stream. The people from all the villages died, except the ones near the man who had the tuco-tuco teeth. All those years he had kept them. Those people were the only ones who were saved. Some time after this had happened the men went to look at the other villages, or the places where they used to be. They found nothing. Nothing remained of them, not even the bones of the people who had died. There was only grass, covering everything. Since that time the people always save the teeth of the tuco-tuco and keep them handy. But since then the sky has never fallen again.

In addition to the 'sky fall' myths there are a number of 'great darkness' myths that, while not alluding to actual ashfall, generally appear to articulate with the 'sky fall' myths. A dozen such myths are associated with the Toba, along with single examples each by the Ayoreo, the Makka, and the Mataco. The following two Toba 'great darkness' myths are typical:

Darkness came over the sky. At noon the sun was covered and the people beat trees and yelled, making all the noise they could. Those who had gone to pick up *mistol* were lost; others who were fishing could not see to return home. In the evening the darkness moved toward the north. Twenty men were missing. They had been eaten by jaguars (Métraux, in Wilbert & Simoneau 1982a, pp. 94–95, story no. 39).

People had many different kinds of power then. When they all got together, there was a clash of power, and that is why the world was plunged in darkness. All the shamans knew it was coming, and they stockpiled food. There was one person who was always warning: 'Store away food, and see to it that your children don't wander too far away.' Suddenly it came. One could see a cloud descending which got darker and darker. People put their things away and stayed in their houses. Whenever they did come out they only spoke to one another in very low voices because they were afraid. If they spoke loudly, dangerous animals might come, like jaguars that were out hunting. The jaguars came out of the ground and down from the sky. People were singing and praying, and were very careful not to go out of their houses. If anyone went out, he would surely be eaten by the jaguars. People stayed inside very quietly, and, if someone wanted to eat, he would touch another person and ask him to feed him. It went on like that for several days. Sometimes it was dark for a little while, and there was danger outside because animals came out of the ground and ate people. Everyone prayed and sang a great deal, and as they did so, the darkness began to dissipate, little by little. As time went by people were separated. Some women and children were eaten by jaguars. It was very sad.... Finally the darkness vanished and people began to sing and to jump and to make [collective ritual magic]. The darkness had lasted fifteen days. When things like that happen, all the shamans come together and sing and talk. They help each other, their sons and grandsons. Those things are terrible, but the darkness finally came to an end (Téran, in Wilbert & Simoneau 1989, pp. 98–99).

Based on the characteristics of studied historic Plinian eruptions (e.g. Blong 1982; Baxter 2000; Cioni *et al.* 2000; Schmincke 2004, pp. 163–176), the picture that emerges from the Gran Chaco 'sky fall' and 'great darkness' myths is of a major Plinian ashfall event, with the eruption column and associated ashfall being sustained and persisting for approximately two days. (The 15 days noted in the second Toba myth quoted above is considered an outlier, as noted in our discussion of Blong's work in Papua New Guinea). The myths lack details indicative of lahars, pyroclastic flows, lava flows, or aerial bombardment by large stones. This suggests that the observers were probably a considerable distance from the volcano at the time of the eruption.

Assuming that the modern distribution of Gran Chaco cultures (Fig. 1) reflects their approximate

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**Table 2.** *Environmental details contained in Gran Chaco sky fall myths from the Chorote (Wilbert & Simoneau 1985), Nikvalé (Wilbert & Simoneau 1987a), and Chamacoco (Wilbert & Simoneau 1987b).*

	Chamacoco (Story 38)	Chorote (Story 18)	Nikvalé (Story 10)	Nikvalé (Story 22)	Nikvalé (Story 33)	Nikvalé (Story 34)	Nikvalé (Story 35)	Nikvalé (Story 37)	Nikvalé (Story 38)	Nikvalé (Story 39)	Nikvalé (Story 164)
Earthquakes before or during sky fall event	X										
Loud earth or sky sounds heard before or during sky fall event	X	X	X	X	X	X	X	X	X	X	X
Sky—clouds fall, celestial vault collapses	X	X	X	X	X	X	X	X	X	X	X
Rainfall associated sky fall		X					X		X		
Duration of Darkness		?	2 days		8 days	2–3 days	?		2 days		
Survivors protected under hard tree		X			X	X	X		X		
Houses crushed					X	X	X		X		
Vegetation—landscape crushed, covered, or otherwise altered and destroyed											
Starvation during or after sky fall event					X	X					
Numbers of human survivors		1 family			5 people	1 village	1 village	1 village	9 people	None	

distribution at the time of the Plinian eruption, the resultant distribution of myth motifs (Figs 2, 3) reveals a strongly patterned situation that mirrors the characteristics of historic Plinian eruptions. There is a central corridor of 'sky fall' (ashfall) and associated 'great darkness' myths stretching from the west to the east surrounded by stories of 'great darkness' without an explicit 'sky fall' motif. The presumed west–east nature of the ash cloud and tephra fallout plume, due to sustained winds moving toward the east, would effectively block out sunlight for cultures living on either side of the central ashfall corridor; the ash cloud generally followed the ecliptic path of the Sun. The Nivaklé are situated much closer to the Andes, therefore it is consistent with our Plinian eruption model that they would have received greater densities of ashfall and thus have more associated 'sky fall' stories than would the Toba living to the east. Similarly, of the two cultures with stories of the distant sounds of explosive volcanism caused by atmospheric sound waves, one, the Chorote, is the closest of the Gran Chaco cultures to the Andes and is best positioned to feel and hear such sensory volcanic phenomena. The Chamacoco story of an earthquake and volcanic sounds does not fit this pattern given their location to the NE of the Nivaklé.

The Gran Chaco 'sky fall' and 'great darkness' stories largely mirror the 'time of darkness' myths collected by the geologist Russell Blong (1982) in his exquisite study of the seventeenth century pre-European eruption of the Long Island volcano off the coast of Papua New Guinea. Blong found that the length of the period of volcanic darkness was occasionally exaggerated in the Papua New Guinea myths, similar to the Gran Chaco myths, due to the combination of the disorienting nature of extended darkness and the fear that such an event would produce. Despite the potential for exaggeration, the typical stated duration of the Gran Chaco 'sky fall' and 'great darkness' event is a very realistic 'two days' (see Table 2), interpreted here as roughly 36–48 hours. This duration and the level of associated destruction suggest an eruptive event similar to that of the Long Island eruption with a VEI of approximately 6, equalling or exceeding that of the 1991 eruption of Mount Pinatubo in the Philippines. The Gran Chaco myths are not as richly detailed as the Papua New Guinea myths. This may reflect the greater antiquity of the Gran Chaco myths. Based on the archaic style of the myths and the general lack of identifiable references to the Spanish and other historic peoples, the observations were made long before the arrival of the Spanish in the early sixteenth century.

The Nuevo Mundo lava dome complex (de Silva & Francis 1991, pp. 144–147) is an obvious

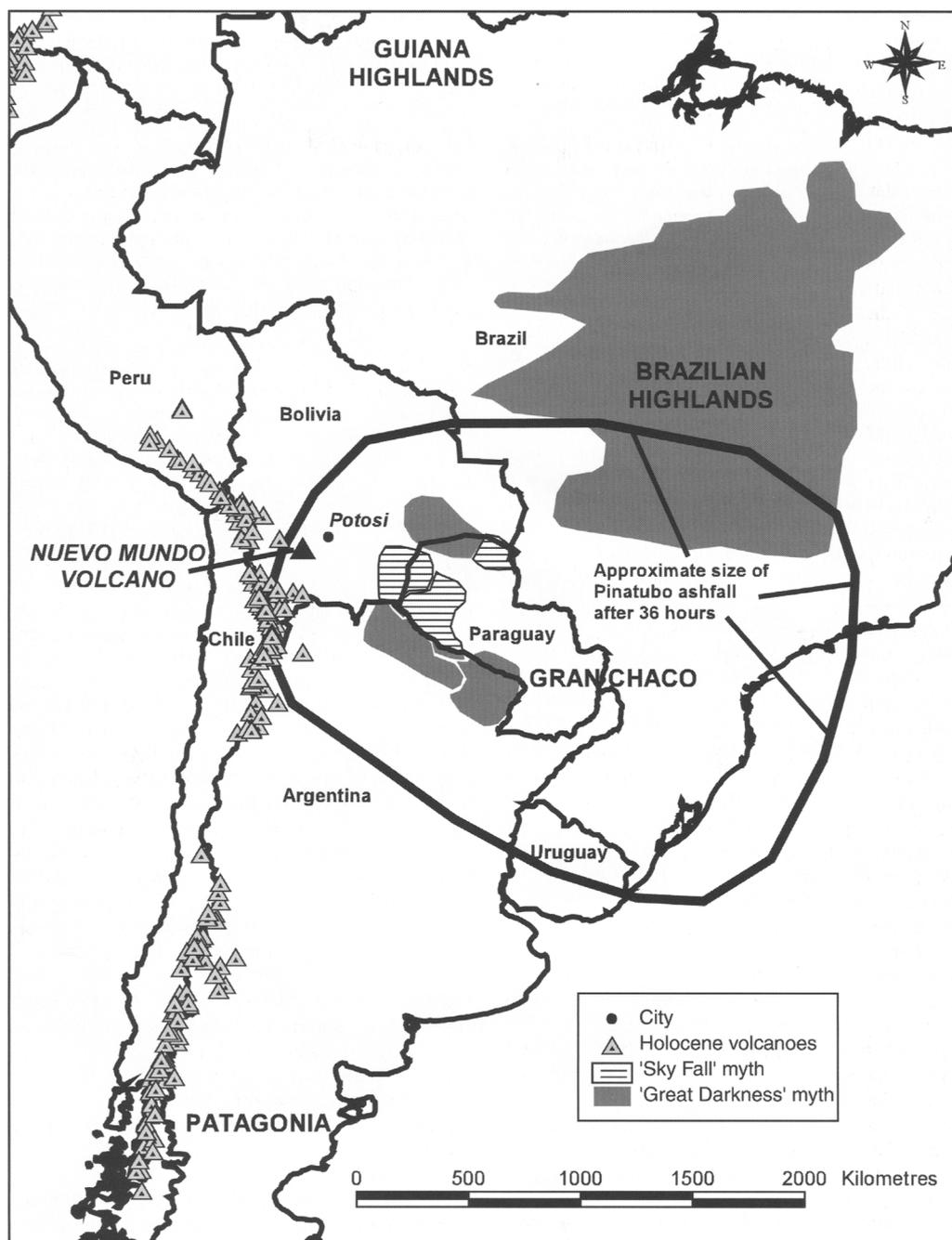
candidate as the source for the Gran Chaco 'sky fall' and 'great darkness' stories. Nuevo Mundo (5438 m) is the single extra-Andean volcanic centre with Holocene activity, and derives its magma from the descending Nazca Plate. As such, it represents the closest known Holocene volcano to the general Gran Chaco region, approximately 500 km to the west (Fig. 2). Viscous dacitic lava flows emerged along a north–south fault forming coulées that overlay moraines in the NE and developed minor ash and block flows to the east. Sometime after the coulée emplacement small cinder and ash cones developed.

A recent Plinian eruption deposited fresh tephra and ash, blanketing the area between Nuevo Mundo and the town of Potosí about 200 km to the NE (Fig. 3). There is no historical record of the event, so it must be older than regional Spanish settlement. Field inspection of Nuevo Mundo indicated that the Plinian event was '... younger than a few thousand years old on the basis of preservation' (de Silva & Francis 1991, p. 186). These observations suggest a late Holocene date perhaps in the range of 2000 to 1000 BP. The geographic propinquity and eastward orientation of the Nuevo Mundo ashfall are strongly suggestive. This relationship is evident in Figure 3, which for comparison overlays the area covered by the distribution of ash from Mount Pinatubo after a period of 36 hours. The distance of the Gran Chaco cultures from Nuevo Mundo (500+ km) is not a significant problem if we consider that, originally, they may have lived somewhat further to the west. It is also possible that the ashfall behaved similarly to the 1980 Mount St Helens eruption. The thickness of the Mount St Helens ashfall decreased to less than 5 cm abruptly between 100 and 250 km from the eruptive column, beyond which it increased to a thickness of up to 12 cm (Schmincke 2004, p. 173, fig. 10.26).

Most of the volcanoes in the CVZ are remote from population centres and have not received adequate study, and volcanic eruptions other than the late Holocene Nuevo Mundo Plinian eruption cannot be excluded from consideration as the source for the Gran Chaco 'sky fall' and 'great darkness' myths.

*Northwest and Guiana Highlands 'sky fall' and 'great darkness' myths.* A large number of 'sky fall' and 'great darkness' myths are found with the Yanomami of the Guinea Highlands (Fig. 2):

This happened in the direction of the Waika region but well beyond it, on the savanna, where the tapirs go to rub themselves against the *tokori* trees. It happened beyond the region inhabited by the Yanomami. They occupied a vast area of this land, but this happened in a place where one does not meet them, in an uninhabited region, where the celestial disk is as fragile as an old tree.



**Fig. 3.** Map of the Gran Chaco geographic region depicting the distribution of 'sky fall' and 'great darkness' catastrophe myths from the UCLA collection in relation to Nuevo Mundo volcano. These are compared with the size and shape of the 1991 Pinatubo (Philippines) Plinian ashfall distribution after 36 hours.

This land, which is as ancient as an old man, and its celestial disk as ancient as the land, this area is haunted by supernatural beings. Those were the beings that fell on the people of long ago. Those were the ones! They are spirits! Then the people were carried far away by an irresistible force: the sky broke above their heads. In vain the shaman pronounced propitiatory formulas, in vain they invoked their protective spirits: the sky broke in spite of everything. Our ancestors truly witnessed extraordinary events. But how did it occur to them to seek refuge under the canopy of the great cacao tree? Nevertheless that was where they ran when the celestial disk broke. The cacao tree bent under the weight but managed to support it. The sky, which was very close to their heads, emitted unbearable heat, and the people were complaining. But they knew what to do, and using their axes they opened a passage through the sky. Thus our ancestors found refuge under the cacao tree. Afterward they became underworld creatures, *amahiri* (Lizot, in Wilbert & Simoneau 1991, p. 44).

These myths are similar to but uniformly less detailed than those from the Gran Chaco, and suggest a longer period of oral transmission. It is clear from the storyline that the ancestors of the Yanomami were living NW of their present location at the time of the hypothesized Plinian ashfall event. The storyline suggests that the eruption may have been a deciding factor for migration away from the area; the area of original occupation was considered haunted and cursed.

Presumably the ancestors of the Yanomami originally lived close to the flanks of the Andes, perhaps near Cerro Bravo and Nevada del Ruiz (Fig. 2). The shift southward of the ITCZ permits eastern movement of air masses into Columbia and NW Venezuela and ashfalls originating in the Columbian Andes can blanket this region. There also is a remote possibility that the NE trades will carry ash from eruptions in the West Indies into central and southern Venezuela. We cannot dismiss the possibility that the original homeland of the Yanomami was instead relatively close to the very active arc of Caribbean volcanoes to the north.

The Cuiva along the Venezuelan and Colombian border have a remarkable set of 'sky fall' and 'great darkness' stories that are distinct from those of the Yanomami:

At the beginning there was only daytime, for the sun did not move but remained stationary at the center of the sky. At that time men wore clay medallions around their necks. The women, laughing at this style, told the men the medallions were awful and should be thrown away. The men, refusing, said women knew nothing about the medallions, which belonged to the grasshopper . . . and to the black ant . . . . Women kept on laughing and telling men to throw them away. But the men always refused. Then one day the women took the medallions from the men and broke them into pieces either with their fingers or by throwing them to the ground. At that very moment the sky fell on their heads, and with the pieces of sky falling everywhere and injuring people, down came gigantic grasshoppers and black ants. They were enormous; they had large teeth, and they began to eat people. It was dark everywhere, as the ground was buried under a huge pile of

sky. The grasshoppers and the ants were eating people, especially women's vaginas. The dead bodies that were all around created quite a stench. Many of the women who had been so foolish as to break the medallions were now lying dead, their tongues sticking out. This situation continued until the pygmy kingfisher . . . and the dragonfly . . . reassembled the sky by carrying back into place all the fallen pieces of sky. They needed to make many trips to the sky. They also took back the grasshoppers and the black ants which, even today, live up there. 'We told you so,' said the men to the women, who were no longer laughing. There were bodies all over the ground, ribs without skin or flesh. It is since then that we sleep at night. Since then the sun no longer remains still in the center of the sky, and there is a day and a night (Arcand, in Wilbert & Simoneau 1991, p. 29).

Formerly there was no night. People could not sleep because it was always daylight, and the daylight never ended. Then a woman went crazy, perhaps because she had eaten too much. Perhaps her gluttony caused her to go mad. She broke the sky. Her husband was a shaman, and he had a dream. He had warned her: 'Don't you go and break the sky; it belongs to the locusts.' The woman paid no attention and threw a stone at the sky. She broke it because it was made of clay. Immediately darkness fell and many locusts came flying. They were enormous, as big as iguanas. The locusts pecked out the eyes of all the people, of the women and children. There was only one person whose eyes they did not peck out: the shaman's. Then the swallows repaired the sky. They are very hard workers and can carry heavy loads. They took earth and repaired the sky. That is why the days are short now (Ortiz, in Wilbert & Simoneau 1991, p. 31–32).

The fantastic images of giant grasshoppers/locusts and ants are much further removed from the more realistic images of eruptive ashfall represented by the Gran Chaco and Yanomami stories. There is enough descriptive detail, such as the sky being made of clay and the darkness associated with the sky fall event, to associate the Cuiva myths with a Plinian tephra/ashfall event, presumably from the vicinity of Cerro Bravo and Nevada del Ruiz. The description of giant grasshoppers descending from the sky is not so fantastic if the Cuiva were close enough to the source volcano to experience the fall of pumice lapilli (pyroclastic particles between 2–64 mm in diameter).

### South American meteor and meteorite myths

Meteorite falls rank with Plinian volcanic eruptions as being among the most spectacular natural events that can be witnessed by people (Masse 2007; D'Orazio 2006). Meteor storms have been known to evoke strong reactions, such as was the case across North America during the great Leonid storm event of 1833 (Littmann 1998; Masse & Espenak 2006).

Meteors and meteorite falls play a prominent role in South American myth and culture. For example,

two related Gé myths from the Brazilian Highlands tell of the lethal fall of a single small meteorite:

At a water-hole two Indian women who were collecting *piacaba* palm nuts in the steppe found a callow young bird the size of a chick. They took it home and raised it, letting it bathe in a gourd bowl. Then they saw that the water in it was boiling as it came out. As it grew larger, they filled a mortar with water, which also began to boil as soon as the bird had bathed in it. At last it grew as large as a domestic fowl. The feathers, however, were pink like those of the spoonbill. One day the Indians put on paint and went out to catch fish with *timbó*. After a while the women said: 'Let us also go there and see whether they have already caught many fish!' They went, taking the bird along. But when they got near the fishing-grounds and the bird saw the water glittering through the trees, it flew up and straight into the water. There was a loud clap of thunder, and all of the Indians who happened to be in the water at the time at once fell dead. Then the bird rose to the sky and the people recognized it as a meteor (Nimuendajú, in Wilbert & Simoneau 1984, p. 45).

Meteors (*akrá*), which luminously descend at night, are evil demons who assume human or animal shape on the earth.

The youths of a village were once bathing in a deep rivulet. Then they noticed two boys at the bottom of the water. 'Look, there are two boys!' they cried, 'let us get them out!' Several dived in, but as soon as they touched the two there was a stroke of lightning that killed the divers, for the two boys were *akrá* (Nimuendajú, in Wilbert 1978, p. 125).

There are no meteor or meteorite stories for the Bororo of the southern Brazilian Highlands in the UCLA collection; however, ethnologists have recorded a remarkable set of ritual behaviours (*aroe butu*) pertaining to loud atmospheric bolide impacts and the witnessed impacts on the Earth of small meteorites (Crocker 1985, pp. 216–220). This is the only circumstance that brings together the shamans from all related villages for collective ritual appeasement. Such an event causes great alarm and commotion among the general populace, as it is believed such impactors steal possessions and souls (Crocker 1985, pp. 217–220):

Everyone, women and children down to young toddlers, sets off a chaotic uproar. People scream urgently, fire off guns, beat on pots, pans, and logs, crash rolled-up mats against the ground . . . . In the single *aroe butu* I witnessed the din was impressive, and nearly everyone was acutely anxious, on the verge of panic. Even the *emijera*, the titled subclan chiefs, always self-possessed and calmly dignified, were obviously very worried and led the noise-making, which struck me as having the quality of a cathartic outbreak. The women rushed to gather in a few houses within each moiety, while the children screamed with fear . . . . There can be no question that the Bororo feel their society acutely threatened by the noise of a 'falling star'.

This culturally ingrained dramatic response to meteorites suggests that the Bororo witnessed one or more devastating cosmic impacts at some point within their culture history. It is noted that neighbouring cultures in the Gran Chaco to the south and their Gé neighbours to the north both apparently experienced major consequences from meteoritic airbursts.

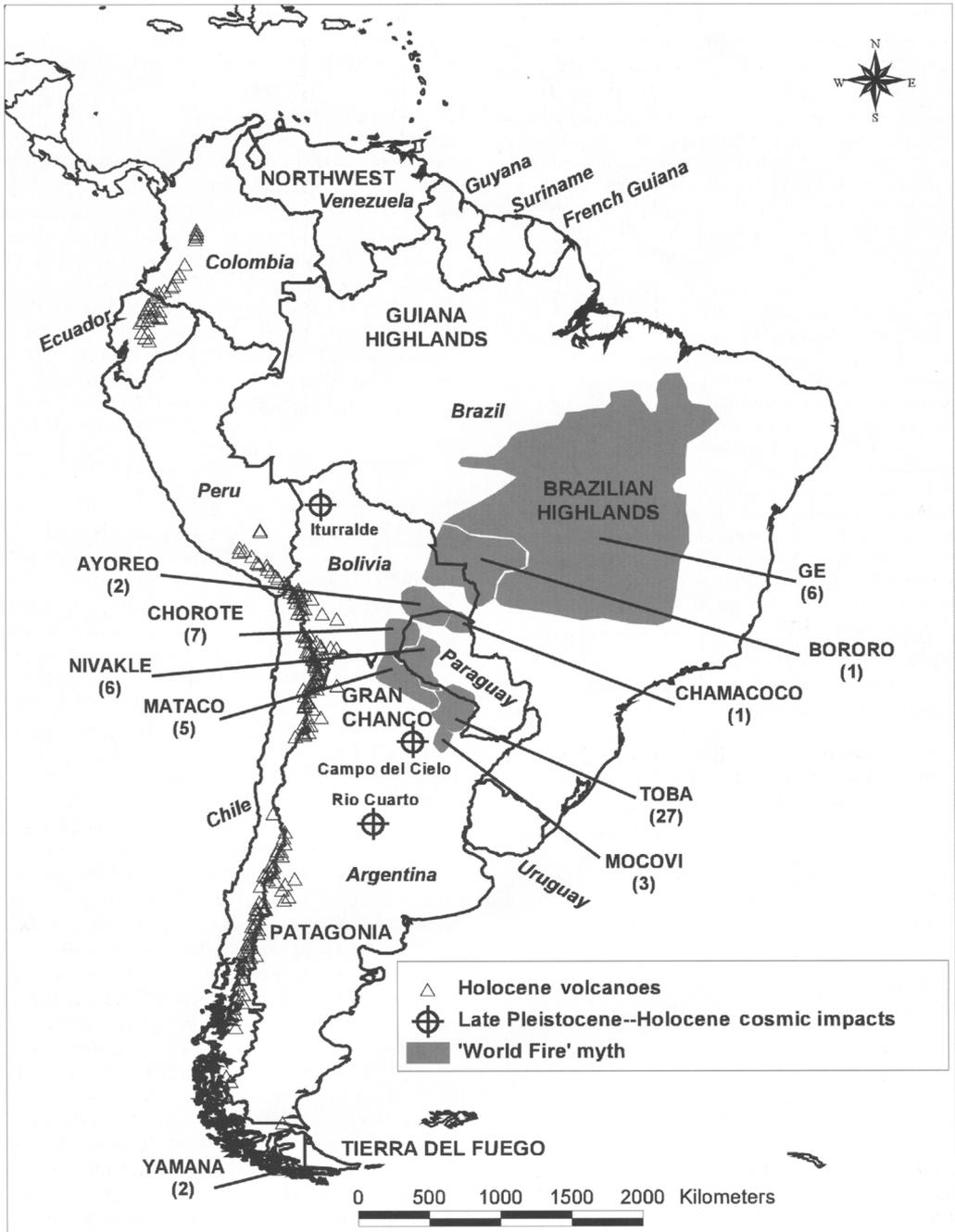
There are also possible meteorite impact myths from Ecuador and Peru as noted by Bandelier (1905, 1906). In the sixteenth century, Spanish historian, Juan de Bentanzos collected many detailed stories relating to the rulers and their gods, including one about the deity *Con Ticci Viracocha* who caused fire to fall from heaven burning a mountain range near Cuzco (de Bentanzos 1996, p. 10). Bandelier (1906) suggests that the myth relates to a pre-Spanish eruption of isolated Quimsachata volcano. Although Bandelier does not suggest a cosmic impact explanation for the *Con Ticci Viracocha* story, he does suggest such an explanation for a seemingly similar worded myth about the destruction of a race of giants, alleged to have taken place near the city of Puertoviejo in Ecuador (Bandelier 1906, p. 52).

#### 'World fire' myths and cosmic impacts

*Distribution of 'world fire' myths.* The UCLA collection identifies three separate regions containing a total of 60 myths about a great fire that destroyed humankind. These include the fire-prone Gran Chaco, the Brazilian Highlands, and Tierra del Fuego (Fig. 4).

It is not unexpected that myths about devastating mass fires are identified. What is surprising, however, is the stated cause of the mass fire for each region. In the nine myths actually specifying a cause for the fire (four each from the Gran Chaco and Brazilian Highlands, and one from Tierra del Fuego), all point explicitly to a cosmic rather than an earthly cause. This link with the sky is even implicit in several of the remaining 51 myths: 'The fire, when it burned everything here on the earth, was made by Fitzököjíc [a creator demiurge present at the great flood, the great fire, and the sky fall events]; he did the burning. He alone did it. The entire earth was burned, even the water in the lagoons. Even the sky burned' (Wilbert & Simoneau 1987a, p. 84). Fitzököjíc is thought by the Nivaklé to live in the sky (Wilbert & Simoneau 1987a, p. 85).

*Gran Chaco 'world fire' myth details and their potential relationship to the Campo del Cielo and Rio Cuarto cosmic impacts.* Alvarez was the first to claim a connection between the Campo del Cielo impact and the generation of a mass fire event (in Giménez Benítez *et al.* 2000, p. 337): '[T]his tribe (toba) . . . also tell the tradition . . . 'that, one day the Sun had fallen from the sky, setting on fire the forests and that the tribes survived becoming caimans [alligators]; legend that was born, without a doubt, because the fall of the superb meteorite'. Giménez Benítez *et al.* (2000) have raised reasonable doubts about the connection between the 'world fire'



**Fig. 4.** Map of the Gran Chaco geographic region depicting the distribution of 'world fire' catastrophe myths from the UCLA collection in relation to known cosmic impact locations (e.g. Campo del Cielo).

myths and the Campo del Cielo impact; however, it is possible to build an equally reasonable case for supporting Álvarez's hypothesis based on a thorough analysis of the myths.

The UCLA collection contains a total of 51 Gran Chaco myths about a single catastrophic 'world fire,' representing seven of the nine cultures in the region (Table 1, Fig. 4). The two cultures lacking such myths, the Caduevo and the Makka, are also the two cultures with the smallest numbers of total myths in the collection (Fig. 1). The rapidity of the spread of the fire and the extent of its destruction is captured in the following Mataco myth (Fock, in Wilbert & Simoneau 1982*b*, p. 126):

Once, a very long time ago, the life-style of the Mataco developed into near anarchy. Wives left their husbands and lived with other men for a year or so, and then they lived with still others. The people spent all their time drinking beer, dancing, and shouting. All was chaos. Then one day a big black cloud gathered in the south, and lightning and thunder began. When the cloud had covered the entire sky it began to rain a bit here and there, but the drops that fell were not like rain but like fire. The people tried to jump into the river to save themselves, but the water was boiling. Tokhuah was among them, but he saved himself because he could go wherever he wished, and he decided to go underground. All died but a very few, and they did not know why they had survived. Bits of fire continued to fall from the sky and everything, including the entire forest, burned: nothing remained except a few people here and a few there. They did not understand why they were still alive and what they were to do next.

Volcanoes have the capacity to start wildfires; however, the great distance of the Gran Chaco cultures from Holocene volcanoes and the absence of other volcano motif indicators in the 'world fire' myths, suggests a likely meteoritic origin for the 'rain of fire,' such as a Tunguska-like airburst or perhaps the rain of small meteorites associated with the Campo del Cielo impact event. The distribution of a number of South American meteorite myths is depicted in Figure 5.

The likely meteoritic origin for the 'world fire' myths is more clearly spelled out in several Moco*v*í and Toba Pilagá myths, including the following:

When the sun once fell from the sky a Moco*v*í was so moved to pity that he devised a way to raise it: he tied it so that it would not fall again. The same accident happened to the sky, but the clever strong Moco*v*í lifted it with sticks and put it back in its proper place. The sun fell a second time, either because the knots were not tight enough or because they had been weakened in the course of time. Waves of fire spread everywhere, the flames consuming trees, plants, animals and men (Guevara, in Wilbert & Simoneau 1988, p. 100).

The people [Toba Pilagá] were all sound asleep. It was midnight when an Indian noticed that the moon was taking on a reddish hue. He awoke the others: 'The moon is about to be eaten by an animal.' The animals preying on the moon were jaguars, but these jaguars were spirits of the dead. The people shouted and yelled. They beat their wooden mortars like drums, they thrashed their dogs, and some shot at random with their guns. They were

making as much noise as they could to scare the jaguars and force them to let go their prey. Fragments of the moon fell down upon the earth and started a big fire. From these fragments the entire earth caught on fire. The fire was so large that the people could not escape. Men and women ran to the lagoons covered with bulrushes. Those who were late were overtaken by the fire. The water was boiling, but not where the bulrushes grew. Those who were in place not covered with bulrushes died and there most of the people were burned alive. After everything had been destroyed the fire stopped. Decayed corpses of children floated upon the water (Métraux, in Wilbert and Simoneau 1982*a*, p. 68.)

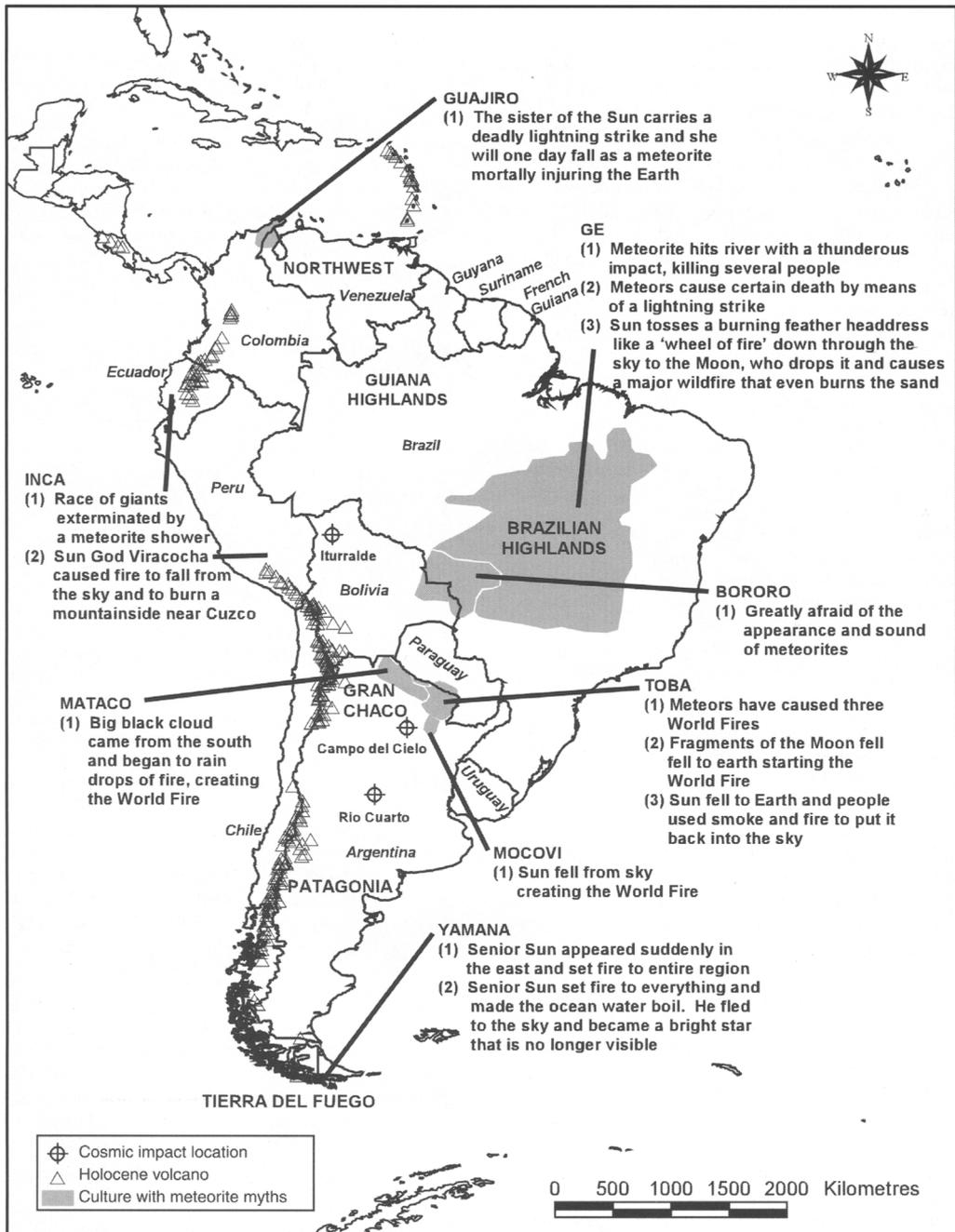
The occasional intrusion of minor details about post-European material objects and animals into ancient myths, such as the presence of guns (noted above), horses, and cattle, is not uncommon in oral transmission (Barber & Barber 2005), and should not be construed as obviating the reality of the basic myth storyline. Such practice simply reflects the considerable importance that such initially alien objects and animals have come to assume in the storyteller's culture.

The meteoritic cause of the 'world fire' is most explicitly stated in Toba cosmology (Métraux 1946, p. 19):

Moon . . . is a pot-bellied man whose bluish intestines can be seen through his skin. His enemy is a spirit of death, the celestial Jaguar. Now and then the Jaguar springs up to devour him. Moon defends himself with a spear tipped with a head carved of the soft wood of the bottletree . . . which breaks apart at the first impact. He also has a club made of the same wood which is too light to cause any harm. The Jaguar tears at his body, pieces of which fall on the earth. These are the meteors, which three times have caused a world fire.

It is possible that these stories simply reflect the coincidental observation of a spectacular individual meteor or meteor shower at approximately the same time as a mass fire generated by lightning or anthropogenic means; however, the details of the stories argue against such coincidence. The Mataco story cited above and a number of Toba great fire stories about people saving themselves in 'holes in the ground' stated to be several metres deep is suggestive of the Campo del Cielo impact event given that the meteorite strewn field lies immediately to the south of the present geographic distribution of the Mataco, and that the associated crater field is composed of both large explosive craters and a number of craters in which the meteorite fragment burrowed into the ground, leaving holes and tunnels that would have been visible to people for a number of years following the impact (Cassidy & Renard 1996).

There has been considerable debate as to the capacity of meteorite impacts to trigger ignition fires (e.g. Jones & Lim 2000; Jones 2002; Svetsov 2002; Durda & Kring 2004). So far, the discussion has been geared to large impactors. However, in contrast to the conclusions of Jones and Lim, it



**Fig. 5.** Map of South America depicting cultures with myths about explicitly stated or inferred meteorite impacts, or the potential effects of meteorite impact upon humanity.

would appear that eye-witness accounts of falls, the limited archaeological record of impact sites, and the myths discussed here indicate that wildfires are indeed associated with at least some smaller impacts (Masse 2007). A key, of course, is the availability of fuel and suitable weather/climatic conditions, which in places such as the Gran Chaco and the Brazilian highlands should not be an issue.

An impact scenario can be developed for Campo del Cielo, which would fit most of the myth and scientific details. A bolide greater than 3 m in diameter entered the atmosphere about 1000 km SW of the crater zone. As bright or brighter than the Sun it blazed brilliantly from ionized gases, a long swath of ablation smoke trailing the 'fireball'. If weather permitted it could have been viewed from the Andes in the west to the Atlantic shore, and northward past the Gran Chaco. Descending slowly, it would have had an atmospheric time greater than 2 minutes. Early in its descent, compressed air against the meteoroid face facilitated fragmentation along existing cracks or across silica inclusions. It would suddenly have become brighter; the surface area available for ablation increased by the break-up. A sparkling trail would have formed adjacent to and behind the 'fireball' when air drag differentially slowed the smaller to tiny fragments. Late into the flight the meteoroid would have slowed sufficiently to end ionization and the brilliant light would have faded out. Unless immediately adjacent, the impact itself would have been anti-climatic—a series of loud thuds, small explosions of loess ejecta carried a few tens of metres and ignition of small fires. The sonic booming and rushing sound of the meteoroid flight would finally have caught up. Within the strewn field, small meteorite fragments would rain down. Local fuel loads and weather conditions may have permitted the fires to grow into regional conflagrations.

The Gran Chaco 'world fire' myths may also encode an airburst event other than that of Campo del Cielo. The Holocene Rio Cuarto airburst probably occurred too far south of the Gran Chaco to be the model for the Gran Chaco myths. The event defined by Schultz *et al.* (2004) would have resulted in a mass fire greater than that associated with the Tunguska event. Another still to be discovered airburst may be responsible for the myths, or a combination of these possibilities may have occurred. It is sobering to note that recent archaeological and palaeoenvironmental research has identified a likely major population replacement that took place in the SE Pampas of Argentina at some point between about 1500 and 4000 BC (Barrientos & Perez 2005). The possibility that Holocene cosmic impacts played a significant role in such replacement should be considered in future studies of regional culture history.

It is unfortunate that Métraux did not further pursue the meaning and context of the Toba statement that meteors had on three separate occasions been responsible for a world fire event. Of course, the best way in which to determine if a mass fire was associated with the Campo del Cielo impact event is to conduct additional microstratigraphic investigations where feasible in and around the crater and strewn fields (Masse 2007). Similar studies should be attempted for the Rio Cuarto airburst defined by Schultz *et al.* (2004). At the very least, this should provide more definitive dates for the impacts.

*Brazilian Highland 'world fire' myth details regarding a potential airburst.* There are seven stories of a 'world fire' in the Brazilian highlands, six associated with the Ge and one with the Bororo. These include a series of elaborate myths regarding Sun and Moon in which Moon is jealous of the feather ornament that Sun has obtained from the red head feathers of Woodpecker. The ornament subsequently falls to Earth and causes a world fire. Wilbert (1978 p. 15), in analysing these myths, likens the ornament to a 'wheel of fire'. One of these stories, from the Craho band of the Ge, is presented here in detail (Schultz, in Wilbert 1978, pp. 40–41):

Pud [Sun] then said to Pudleré [Moon]: 'Friend, you stay here. I'm going over there.' They were at the foot of the sky, seemingly walking close to it. Pudleré went home and waited at his house for Pud. Pud went to the foot of the sky and plucked a hat from the head of a woodpecker, the bird with a red head (the informant made a gesture, passing his hand over his head)—'no, not a hat, an adornment.'

When Pud came back with it, Pudleré saw the plumes and said: 'Friend, give me that headdress so that I can wear it.' But Pud said: 'No, I won't give away my headdress! I found it and I'm going to wear it. I'm going to sing while wearing it.' Pudleré said: 'Let's go back there: I want one too.' Pud went with him to the foot of the sky and arranged the woodpecker's feathers on his head. He then seized the adornment and spoke from above to Pudleré below: 'Well, here it is. Catch the plumes and don't let go of them!' And he added: 'Look now, if you let go of them you are going to see something!' Pudleré said: 'No, I'll catch them.' Pud replied: 'Look here, friend, when I throw the plumes to you, don't move, but grab them. Don't let them fall to the ground. If you do you're going to see something.' Then he threw the feathers to Pudleré, and with them came a lot of hot coals. He hadn't mentioned the coals before, when he was getting ready to throw the plumes, but had just said: 'Look here, catch them and don't drop them. If you drop them you're going to see something!' As he threw them, with the coals inside, he was saying: 'Come on, grab it, grab it!'

But when the headdress came near Pudleré he could not catch it. He pulled his hand away and the feathers fell to the ground. The sand caught fire and everything was burning. All the sand in the world, or almost all of it, was burning.

Burning sand is an unusual myth motif, and is absent from Gran Chaco world fire myths. The

statement that 'almost all of the sand in the world was burning' may reflect the creation of a large region of impact glass melt in the Brazilian Highlands by a sizeable airburst at some point during the Holocene. This interpretation is consistent with the findings by Schultz *et al.* (2004) regarding the glass melts in the Argentine Pampas loess, and with our discussion above regarding the general inability of most wildfires to create and sustain temperatures hot enough for the formation of soil silica melts.

*Tierra del Fuego 'world fire' myth details regarding a potential oceanic impact.* Two Yamana myths from Tierra del Fuego describe a 'junior' and 'senior' Sun in which the senior Sun creates a world fire by appearing suddenly in the east and making the ocean boil and burning down the forests. He then changes into a bright star that eventually disappears (Gusinde, in Wilbert 1977, pp. 17–18):

In those days there lived a man here among the first families who was of evil nature. He was not only unfriendly toward all, but quite openly hostile, always intent on hurting everybody else. Everyone despised him, which angered him the more, and made him try even harder to do everybody harm. He was extremely powerful and wielded great authority. Once, in a rage, he set fire to everything within reach, for he made the water of the ocean boil by bringing forth intense heat. Also all the forests burned down, and from that time to this very day the mountaintops have remained bald and bare. All this happened because at the height of his fury he produced tremendous heat.

This may be a somewhat confused rendering of a hypothesized oceanic comet impact described elsewhere (Masse 1998, 2007). Alternatively, it may represent an impact witnessed by the Yamana in the waters near Tierra del Fuego. Volcán Fuego is yet another possible source of Yamana myth. A group of andesitic, columnar-jointed lava domes and pyroclastic cones up to 150 m high on Isla Cook mark the southernmost Holocene volcanoes of the Andes (Fig. 2). The closest Holocene volcano occurs 420 km NW, at Monte Burney. The volcanoes, known as Volcán Cook or Volcán Fuego, occupy a broad peninsula forming the SE end of Isla Cook. The lava domes and pyroclastic cones are possibly emplaced along north–south trending faults. Passing navigators observed possible eruptive activity in the direction of Cook in 1712 and the eruption of incandescent ejecta in 1820. Unfortunately, since the Yamana are now extinct, there will be no future chance to clarify the details of their myths.

## Conclusions

Past cultural groups in South America typically led rich and full lives, as did their counterparts

elsewhere in the world. Catastrophic drought, floods, famine, volcanic eruption, and even rare cosmic impacts also played a significant role in their cultures, either as witnessed events or as cautionary stories of such events passed down through the generations.

These cultures were no less gifted observers of their natural world than we are today. They differed from modern western society primarily in the lack of our technology and through the their use of a holistic approach by which to deal with the world around them. It was a dangerous beautiful world populated by animistic creatures and supernatural powers, filled with competing beneficent and malevolent forces.

It was not a random and unstructured world. The creation of myths served past societies as a tool to categorize and explain natural phenomena and spectacular and catastrophic events unfolding around them, and facilitated the transmission of events and lessons to be taught to subsequent generations. This structure permits us as geologists, archaeologists, anthropologists, historians and even astrophysicists to examine and analyse catastrophe myths systematically, and to discern the very real natural events that are their foundation. The selected UCLA collection catastrophe myths presented here are only a fraction of the overall myths of South America that can be studied systematically from a geological and historical perspective.

Myth by itself can rarely be used to prove the existence of a specific catastrophic natural event. However, myths do allow us to model plausible or hypothetical events such as the Plinian eruptions, cosmic impacts, and mass fires outlined and hypothesized above. It is only when we bring to bear the full force of our scientific knowledge of the regional setting, the geology, the climate, the palaeoenvironment, and the archaeological and cultural context, and use these disciplines and their analytical techniques to explicitly test these models of myth, that we can transform myth back into the catastrophic reality that our ancestors so earnestly sought to pass onto future generations.

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