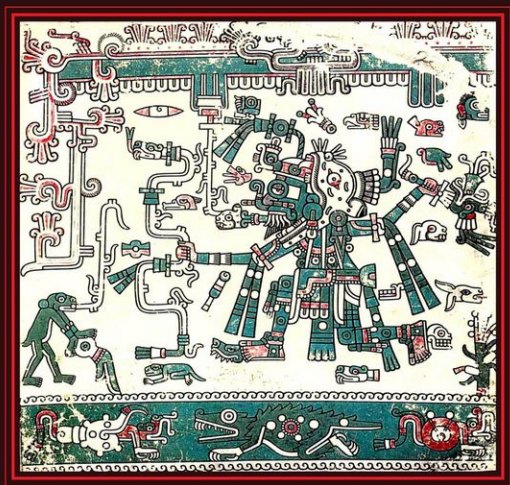


LIGHTNING IN THE ANDES AND MESOAMERICA

PRE-COLUMBIAN, COLONIAL, AND
CONTEMPORARY PERSPECTIVES



JOHN E. STALLER & BRIAN STROSS

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PREFACE

In the pre-Columbian Andes and Mesoamerica the three most powerful and venerated celestial deities were lightning, the sun, and the moon. In the Inca seat of royal power, Cuzco, a faceless golden idol of lightning was kept with idols of the sun and of the moon, in the Coricancha or Golden Enclosure, the most sacred temple in the imperial capital. That peoples and cultures in these regions, separated by more than two thousand miles of ocean and mountainous terrain, should focus their veneration on lightning, the sun, and the moon is perhaps not so surprising. These were agricultural civilizations that needed to keep track of solar and lunar cycles, along with the coming rains and dry seasons, in order to survive. As a result, the pre-Columbian cultures of these culture areas created highly sophisticated and detailed calendars that kept track of solar and lunar cycles as well as the cycles of Venus. Some scholars speculate that hieroglyphic writing in Mesoamerica and *quipus* (knotted cords) in the Andes were created in these culture areas in order to provide a means of keeping track of annual cycles, resources, and managing their polities. The sun, with its steady progress along the plane of the ecliptic from sunup to sundown, creates a daily timetable, periodic warmth, and light to see by, in addition to providing the energy for the photosynthetic redistribution process that underlies most life on earth. The moon and its lunar cycles are tied to the night sky and thus represent the celestial complement to the sun, its symbolic associations more directly tied to the Other World or *mundo interior* (inside world), and to the reproductive cycles of a number of species of plants and animals. The moon controls the ocean tides and has associations to the female menstrual cycle and thus to blood. Through such associations the moon is commonly linked to female gender and perceived by many indigenous cultures to control important aspects of agriculture and human fertility. Lightning is perhaps the most awe-inspiring of the trinity: certainly the most feared, in effect the most capricious, and often understood to be the most immediately powerful. Lightning can strike out of the blue, kill in an instant, and create raging fire, and the associated rain and hail can create floods and destroy agricultural crops. Yet, like the sun and the moon, lightning is often perceived as a bringer of fertility. Its common occurrence with the coming rains, so necessary for crops, and its production of nitrogen that can be utilized by vegetation, explain at least in part its importance to the fertility and fecundity of the earth. We were both more interested in lightning and its place in the cultures and imaginations of people than in the sun and the moon. The reasons for our

interest should become clear in this book, and we hope to have provided some data and some stimuli for further studies of lightning. Despite a wealth of scholarly and scientific information regarding the sun and moon and their associated cycles to the world's civilizations, and despite lightning's iconic importance to ancient civilizations throughout the world, lightning is the least understood and researched—particularly with regard to its significance and importance to ancient religious ideologies, folklore, and legend.

Our coauthored book came out of a series of collaborations beginning in 2004, when Brian Stross contributed chapters to several books that were edited or coedited by John Staller. During the course of our communications we came to realize that we both had independently wondered about lightning with regard to the worldviews and cosmologies of indigenous peoples in these culture areas. Staller has long had an interest in lightning in the Andean region, going back to his dissertation research. He has published on the possible existence of archaic forms of lightning veneration that may have created ethnogenesis or cultural horizons, and has long had an interest in how such horizons and the spread of politico/religious ideologies are associated with language. Stross, a linguistic anthropologist by training, had been intrigued by the apparent lightning connections of Classic Maya predecessors of both God B (called the rain god) and God K (called by some the god of dynasty, but recognized also as a lightning god) of the Maya codices, and fascinated by the fact that while animal co-essences or “familiar” are attributed to both humans and the lightning deity in Mesoamerica, some people in contemporary cultures also have lightning as a co-essence. On discovering our mutual interest in lightning, Staller suggested that we coauthor an article on the symbolic associations of lightning in the Andes and Mesoamerica, and thus what came to be a book project on lightning was initiated.

Stross initially produced a list of sixteen cultural and symbolic associations that could be found for lightning in much of Mesoamerica past and present, beginning with ethnographic and language-related information, realizing in the process that these associations not only tell something about how lightning is perceived and imagined, but also that, even without pursuing these associations any further, they present a fascinating picture (if only a specialized and partial one) of religious thought and practice in these ethnically and culturally distinct regions of the New World. Staller found a number of similar associations with lightning in the Andes and with his scholarly interest in archaeology and Colonial accounts of the indigenous population, focused on these aspects of lightning perceptions for the Andes. Our earlier drafts produced rather different presentations of the separate regions, reflecting not only the different regions themselves and the different histories that they have endured, but also differences in our training, biases, and presentation styles, in addition to differences in what we considered meaningful and relevant to the pre-Columbian, Colonial, and contemporary populations in these culture areas. We value

these differences because they provide some information about the filters through which the data have been drawn in each case, as well as the different perspectives that we brought to bear on the original question of what the cultural perceptions and lightning associations were in these two ecologically, culturally, and geographically distinct regions of the New World.

Stross went through the Andean and Mesoamerican sections, initiating a discussion and compiling the similarities and differences to which Staller added a great deal of relevant information. The conclusion was similarly generated, and as we sent the manuscript back and forth, we realized that the article we initially planned had become a book. Although each author has had primary responsibility for the various lines of evidence concerning his own culture area, as a whole it has been truly a collaborative effort. We have reason to thank each other for engaging in this collaboration with a minimum of the kind of stresses that sometimes present themselves in a joint undertaking of this sort.

The book was sent out for publisher review, and the reviewers provided some useful suggestions for various ways of improving it. We were sincerely grateful for the constructive comments of several anonymous reviewers. We also extend our sincere thanks to Dr. Paul Heggarty (Max Planck Institute for Evolutionary Anthropology, Leipzig) and Dr. David Beresford-Jones (McDonald Institute for Archaeological Research, University of Cambridge, UK) for kindly passing along their generous comments and many insights regarding the processes underlying language spread in the Andes. In their careful readings of earlier drafts of this manuscript, they provided both encouragement and valuable information on how we had to proceed with this comparative study. We are greatly indebted to both. Thanks also to Dr. Tristan Platt (University of St. Andrews, Scotland, UK) for kindly passing along some of his published research and that of his colleagues and their research around Potosi, Bolivia. We are additionally indebted to Xmal Ton, Alonso Mendez, Santiago Tzapat, and Slus Bot of Chiapas, Mexico, for multiple ethnographic insights, and to linguists Rosemary Beam de Azcona and Mark Sicoli for generously providing unpublished data gleaned from their linguistic and ethnographic fieldwork in Oaxaca. All interpretations and statements of fact are solely our responsibility.

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Lightning in the Andes and Mesoamerica

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Introduction

Lightning has evoked a numinous response as well as powerful timeless references and symbols among ancient religions throughout the world. The thunderbolt is a conspicuous image among the ancient civilizations, and thunder and lightning also have very powerful associations with some of the primary deities of the ancient world (**Figure 1**). The thunderbolt image is present in ancient Mesopotamia, associated with Sumer, Babylonia, Akkad, and Assyria, and later inherited by the Greco-Roman tradition¹ through Zeus and Jupiter respectively (**Figure 2**). Zeus is frequently depicted in one of two poses: seated in majesty or standing, striding forward, with a thunderbolt leveled in his raised left hand (Bulfinch 1976:4). Jupiter or Jove essentially represents the Roman counterpart of Zeus, with similar symbolic referents, and he is likewise the primary deity in the pantheon (Bulfinch 1976:40). In ancient Rome, places where lightning struck were “considered holy and became the sites of oracles and temples” (Friedman 2008:30). These oracles and temples were consecrated to Jupiter, deity of the sky, and of thunder and lightning. Lightning divination was practiced some three hundred years before and after the current era and had definite political implications. The Romans believed that a lightning bolt passing from left to right was a favorable omen, while a bolt passing from right to left was a sign that Jupiter disapproved of current political events (Friedman 2008:31). Thor is the god of thunder and lightning in Norse myth and cosmology (**Figure 3**). Thor wielded a hammer and is mentioned prominently throughout the recorded history of the Germanic peoples. The name Thor is from Old Norse *Þórr*. Linguists indicate that the Old English *Þunor* and High German *Donar* are cognates within Germanic languages descending from a Common Germanic word, **þonaroz* or **þunraz*, which means “thunder.” The

¹ Zeus (“living one,” from the Sanskrit *dyaus*, “heaven”) is the primary deity of Greek mythology and is associated with the sky and thunder.



FIGURE 1 The Mesopotamian sun god Marduk, patron of Babylon, holding the thunderbolt (*vajra*) in both hands pursuing the Chaos Monster, Anzu. The *vajra* was a symbol of the thunderbolt among the various Indo-European civilizations. This carved stone panel is from the ancient Assyrian site of Nineveh, located along the Tigris River in what is today northern Iraq, with occupations dated to c. 1800 BCE (from Layard 1853: Plate 19/83).

Celtic god of thunder, Taranis, and the Irish god Tuireann are also symbolically related. Norse mythology, largely derived from Scandinavia, has numerous legends and tales associated with this deity (Bulfinch 1976:331–332, 355).

In the Hindu and Buddhist² tradition, Indra is the storm-god, and as the bringer of rain he is commonly invoked throughout the Indian countryside (Ions 1967:15). Indra is often depicted holding the thunderbolt Vajra in his right hand. In Hindu mythology, Indra is the king of the gods or *devas*,³ Lord of Heaven, god of storms, rainfall, and war. Indra hurls thunderbolts using a rainbow as a bow (Ions 1967:73). Post-Vedic texts, the Upanishads, speak of a great monster, Vritra, that enclosed all of the waters of the world, bringing on a terrible drought (Ions 1967:15). Indra seized a thunderbolt and dropped it on

² The Aryans entered the Indus Valley at around 1700 BCE, and narratives of their gods stem from the Vedas, a collection of hymns completed around 800 BCE (Ions 1967:14). The mythology and legends associated with the Vedas have come to be seen as *apauruseya* (of divine origin), revealed indirectly by what is *sruti*, or “heard,” and *smṛti*, “remembered” (Apt 1965:109).

³ Indra is the Sanskrit term (इन्द्र in Devangari, the *abugida* alphabet of India and Nepal), and *deva* is the Sanskrit word for deity and can be loosely interpreted as any supernatural being (Apt 1965).

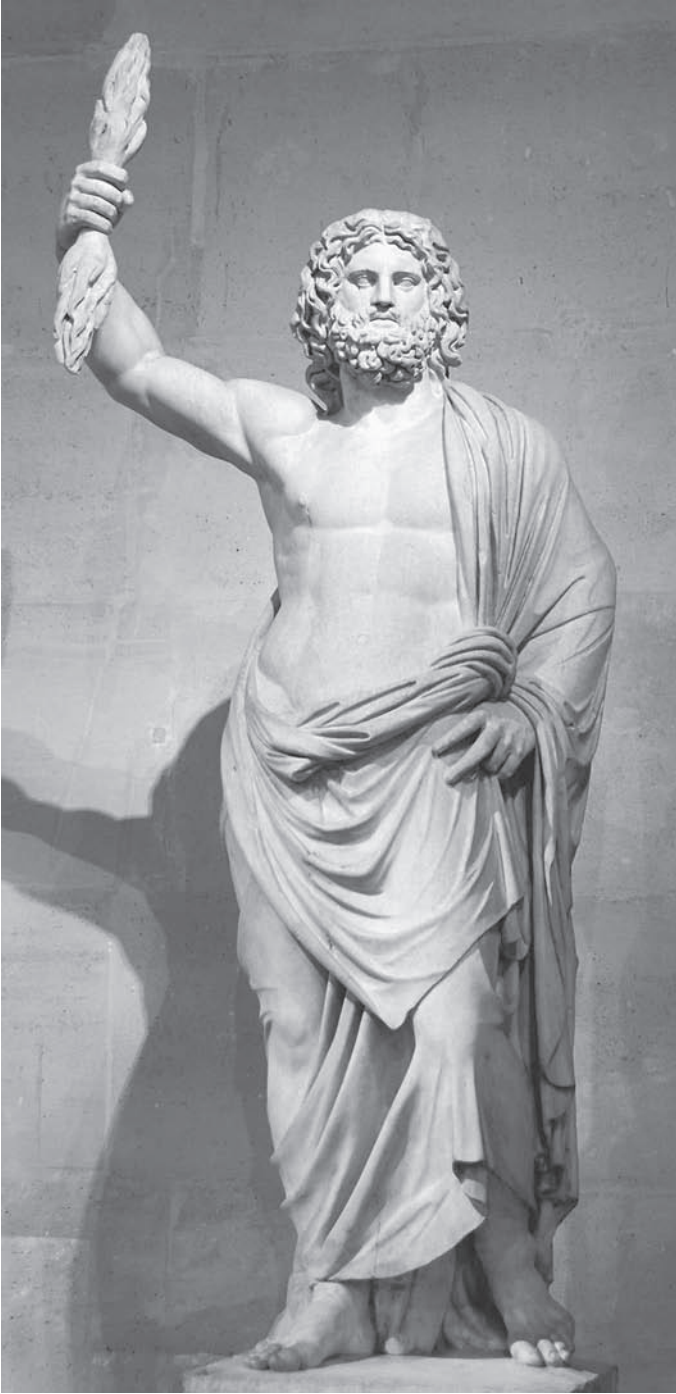


FIGURE 2 Zeus of the sky and thunder, the primary deity of Greek mythology. In this pose, Zeus is standing with a thunderbolt leveled in his raised right hand. Zeus represents the counterpart of Jupiter or Jove in the Roman pantheon. This statue is known as *Zeus of Smyrna*. Found in 1670 in İzmir, Turkey, it was restored by Pierre Granier, c. 1686. The arm raising the thunderbolt was added in restoration. Marble, middle second century, the Louvre, Paris.



FIGURE 3 Thor wielding his hammer. A primary deity in Norse mythology, Thor was the god of thunder and lightning and was associated with the power of nature and death. (*Thor's Battle with the Ettins*, by Mårten Eskil Winge, oil on canvas, 1872.

the monster, blowing him up and thus releasing the waters (Ions 1967:15–16). Indra then climbed Mt. Meru, the cosmic mountain, and had a magnificent palace built in his own honor (Ions 1967:73; Campbell 1974).

Indra is believed to regulate the heavens as well as the annual seasonal cycle (Ions 1967:16). Indra is the chief *dharmapala*, or wrathful deity, of Hindu mythology. He is defender and protector of the Buddha, Dharma, and Sangha (Ions 1967:73, 76; Campbell 1974:169).⁴ The thunderbolt or *vajra* is one of the most powerful symbols of Buddhist iconography, representing indestructible enlightenment (Campbell 1949:87–88). The Adi Buddha represents the Tibetan Vajra-Dhara (Tibetan: Dorje-Chang) or holder of the brilliant lightning bolt (Campbell 1949:88; 1974). Throughout the ancient world, thunder and lightning had primary importance and associations among the various pantheons, religious ideology, and origin mythologies with common symbolic references to death, rainbows, the coming rains, caves, mountain summits, and war. Similarly, lightning veneration played an important role in the ancient civilizations of the Andes and Mesoamerica. Lightning veneration and the religious cults and their associated rituals represent, to varying degrees, a worship of nature and the forces that shape the natural world.

The interrelatedness of the cultural and natural environment stems from what may be called a widespread cultural perception of the natural world as sacred—a kind of mythic landscape (Moore 1984; Lane 2002; Bauer 1998; Moore 2005; Staller 2008a). Comparative analysis of the Andes and Mesoamerica has been a recurring theme ever since Kirchhoff (1968) attempted to delineate culture areas in the Americas and to define them in terms of various culture traits (see also Armillas 1957, 1968). It has been a recurring theme in part because two of the areas of “high civilization” in the Americas have much in common despite substantial ecological differences, and in part because there is some evidence, of varying quality, that some people have migrated from one area to the other. There is other evidence that some items, particularly food crops, have found their way from one region to the other, leading to the important questions: How many and which of the apparent commonalities found between the two culture areas is due to independent innovation and convergence, and how much to pre-Columbian migration and/or diffusion? Was there trade between the regions, and if so, when did it occur? Was it through indirect contact, direct contact, or both, and was Central America from Honduras to Colombia involved in any such interactions? Which commonalities might be ascribed to colonial influence?

⁴ Sometimes Indra is called Śakra and embodies the power of all primordial Dhyani Buddhas among the Buddhists. Indra also has symbolic reference to the ancient Zoroastrian tradition and to traditional religions in Burma, Thailand, China, and Japan. In Malay he is called Indera, and in Tamil, Intiran (Apt 1965; Ions 1967).

Our comparison, while bringing to the foreground some of the commonalities that have not been identified before and thus allowing for an analysis of whether or not they might have independent roots, cannot be expected to resolve these basic questions about the nature of the relationship between the Andean region and Mesoamerica in past times, since it involves only lightning and directly associated concepts, but it does sort through some of the more important commonalities and differences with respect to lightning veneration. We are particularly focused upon native perceptions of how lightning fits into individual and regional cultural traditions, allowing at least for an assessment of whether or not similarities of these sorts could have arisen independently or, alternatively, might have required some explanation in terms of diffusion or stimulus diffusion. Our goals regarding comparative analysis are thus not only to separately present the cultural webs of relationships binding the perceptions of lightning to other related phenomena and cultural traditions through time in both Mesoamerica and the Andes, but also to evaluate how various associations held in common might have come to be shared. Beyond that we seek also to understand the specific forms and contexts of lightning associations that are not held in common by inhabitants of the two regions.

Enough is already known about each region and of possible connections between the Andes and Mesoamerica to allow for some interesting comparisons and conclusions. We maintain the additional goal of more fully understanding how natural phenomena associated with lightning functioned in indigenous religions in these two culture areas in order to refine our knowledge of how deities were and are conceptualized and of indigenous worldview in general. This process should allow for the revision of simple analogies with the pantheon of classical deities, whose natures are also probably obscured by use of this label.

Our interdisciplinary research extends from pre-Columbian cultures to colonial clerics, as well as to current folklore and legends among indigenous populations that have reference to lightning. Our data provide evidence of acculturation and document the varying degrees to which native societies have maintained their earlier meanings or have otherwise interacted with colonial entities to produce syncretic cultures, influenced in particular by Western religious orthodoxy. Lightning veneration was of particular concern to early colonial Spanish clerics in these regions because the patron saint, Santiago or St. James, was associated with the thunderbolt and believed by them to have had a major role in the conquest of the New World (Madariaga 1947). Chroniclers indicate that Spanish clerics emphasized symbols, and associated religious beliefs regarding traditional lightning veneration to the cult of Santiago or St. James, the patron saint of New Spain (Krappe 1932; Madariaga 1947; Cardinale 1983). Ethnographic accounts and ethnohistoric documents provide insights through firsthand accounts that broaden our understanding of levels of syncretism since the European contact. Indigenous cultures in the Andes and

Mesoamerica transferred their veneration from the pre-Columbian deities to Catholic saints through conversion or the fusing of indigenous perceptions to Catholic orthodoxy, and, with respect to lightning, particularly to the cult of Santiago (Cardinale 1983; Topic et al. 2002). Among contemporary Andeans, syncretism of lightning involves fusing the ancient concepts with the Catholic saints Santiago or St. James and to a lesser extent Santa Barbara, patron saint of miners (Gade 1983).⁵ In Mesoamerica, San Juan is more frequently linked to the lightning deity than is St. James (Santiago). The folklore, legend, and cultural beliefs surrounding lightning are to varying degrees an indirect reflection of how later Western religions were absorbed and integrated into indigenous and Latino ethnic and cultural identities (Staller 2010b).

This volume explores the symbolic elements surrounding lightning, as they existed in the associated pre-Columbian religious ideologies and iconography. Our research extends to contemporary cultures to reveal how cultural perceptions of the sacred, their symbolic representations, ritual practices, and architectural representations in the landscape were conjoined in the ancient past. It provides a basis for tracing back pre-Columbian manifestations of lightning and its associated religious beliefs and mythological, symbolic, and iconographic representations to earlier civilizations. The interrelatedness of the cultural and natural environment is a primary characteristic of pre-Columbian religions and cosmology (Moore 1984; Sullivan 1985, 1988; Lane 2002; Foster 2005; Staller 2008a, 2008b). Pre-Columbian lightning veneration and its associated cults and rituals represent a worship of nature and the forces that shape the natural world (Frazer 1926; Zuidema 1980, 2011; Taube 1996b; Sullivan 1985, 1987, 1988, 2002; Conrad and Demarest 1984, 1992; Markman and Markman 1989). Our analytical approach was undertaken in part to determine whether similarities and differences in the patterns and associations brought out by our comparative framework would address larger questions regarding distinctions and similarities in pre-Columbian religious thought, and how legend and folklore have been transformed to varying degrees by religious conversion and acculturation in the post-Conquest and modern world (Brinton 1894; Krappe 1936; Foster 1945; Toor 1947; Costas Arquedas 1967; Gade 1983).

The striking linguistic diversity of Mesoamerica and the relative linguistic homogeneity of the Andes made direct comparative analysis of pre-Columbian religious beliefs, cosmology, and indigenous worldviews problematic from a contextual standpoint. There are three or four major families in Mesoamerica and over seventy indigenous languages. On the other hand, in the Andes Quechua and Aymara are the most widely spoken language families, and they share similarities revealing long periods of interaction. There are many fewer

⁵ The evidence presented in this study indicates that lightning has strong symbolic and metaphorical associations to metallurgy and the metallurgical arts in the Andes.

languages overall in the Andean region. This disparity was revealed in part when we considered the relative linguistic homogeneity of the Andes compared to the heterogeneity of Mesoamerica and the extent to which nearly ubiquitous similarities in lightning veneration in the Andes and its associated rites are related to such linguistic differences.

In Mesoamerica, the contextual variability of the meanings and associations is considerably greater in the particulars, with multiple languages represented in multiple language families, thus existing in many more separate and for the most part closed corporate communities. In stark contrast to Mesoamerica, in the central and southern Andes little remains to us of the languages other than Quechua dialects and Aymara that must have once existed there. Such linguistic homogeneity is reflected in the similarities of language, rites, and rituals surrounding lightning over a vast geographic area of the South American continent. The linguistic diversity in Mesoamerica and continuous widespread language convergence of Aymara and Quechua in the Andes is also related to some extent to cultural and economic as well as geographic and environmental factors that facilitate the integration or the isolation of language groups. Linguistic and cultural differences make direct comparisons of the significance of lightning to pre-Columbian cultures in the Andes and Mesoamerica challenging, but most important is the fact that describing cultural traditions is best done within relevant cultural contexts prior to comparing culture elements shorn of some of their context, relying on the language of comparison (here English) to supply a kind of “etic” context.⁶

This study documents analytical and symbolic relationships through an emphasis on how and why cultural beliefs concerning lightning have particular symbolic and metaphorical associations to pre-Columbian mythology and cosmology. It became apparent early on that direct comparative analysis would pose contextualization problems related in part to the linguistic differences that characterize the two culture areas. Thus, we have deliberately organized the volume as separate presentations of lightning in these culture areas before making comparisons. Our goal was to provide contextualized descriptions of lightning ideology and veneration that would not be reduced to listings of present or absent traits from each region to be directly compared. Identifying and separating “traits” from their respective cultural contexts could potentially misrepresent their cultural and religious meanings. Furthermore, our respective descriptions are colored by our individual understandings of meaning, relevance, and coherence of the available evidence. Direct comparison could potentially obscure information derived from our individual understandings.

⁶ Etic description is from the point of view of an outside observer of a culture, with a view toward comparisons with other cultures, attempting to be as neutral and objective as possible. On the other hand, an ‘emic’ description, is one that is given in terms of a culture’s language, is meaningful to members of the society itself, and shares values and evaluations made in that society.

Therefore, we felt it necessary to clarify the meanings related to our individual interpretations from our respective analyses of each culture area by presenting them separately and in context. Within a framework of separate accounts of these two culture areas we have then considered elements taken from each account, which can be contrasted and compared, having already been presented in their respective contexts. The various similarities and differences as well as the broader implications of the data generated by this comparative analysis are addressed at the end of each section and synthesized in the discussion and conclusions. Our presentation of these data and the organization of the book are consistent with traditional anthropological processual approaches to comparative analysis (Binford 1962, 1964, 1965; Coe 1994; Cook 1998; Conrad and Demarest 1992).

Our study of lightning in the Andes and Mesoamerica includes sections that explore places in the natural world, such as caves, mountains, and bodies of water, as well as locations that were modified by indigenous populations, who in the Andes perceived such places to be endowed with a spiritual life force or the animating essence associated with lightning. Landscapes provide meanings through a connection with creation and origin myths, folklore, legends, and rituals performed to venerate and animate the specialized spiritual forces or powers such as lightning, keeping their symbolic and metaphorical associations alive, and at the same time transforming them through syncretism as cultural histories and identities changed. Caves and water sources, so strongly connected to lightning and the rain deities in Mesoamerica, also have significance to lightning in the Andes, primarily as a metaphorical reference to emergence into a world or creation cycle or to accessing the tripartite cosmos, particularly through feline and reptilian animal familiars. Lightning is also commonly associated with meteorological phenomena such as life-giving rain, rainbows, and bodies of water, as well as destructive elements such as hail, fire, and resultant crop failure and destruction of the natural environment. Lightning and its various symbolic and anthropomorphic manifestations were of central importance to agriculturally based civilizations such as those under consideration herein, primarily because agriculture depends on rain and lightning is a harbinger of rain, but, perhaps more importantly, lightning's power to create as well as to destroy, to aid a community or to damage it.

We found that lightning was associated with pre-Columbian rulership in both regions and, at least in recent times, with shamanism. Lightning bolts in both regions, as well as in several other parts of the world quite independently, are seen as a source of stone tools, including obsidian, flint, and other silica-based stones and transparent or translucent quartz crystals. In Mesoamerica lightning is commonly associated with riches and good fortune. In Quechua regions of the Andes, riches and good fortune are linguistically related to the root for the current term for lightning; precious metals and sites associated with the metallurgical arts are associated with lightning in certain regions of

the Andes. Child sacrifice was practiced in connection with lightning in both regions. Contemporary shamans in both culture areas are frequently “recruited” by surviving direct lightning strikes. Lightning is closely linked in contemporary cultures in these regions to the ideology of consumption associated with ecstasy and ecstatic trance, which can be induced by lightning.

This introduction only begins to approximate the scope and content of the volume. It was one of our goals to demonstrate the importance of lightning and the coherence of associated concepts in parts of the Western hemisphere in order to provide a basis for further discussions of the place of lightning as embedded in other cultural traditions. We also wanted to illustrate an approach to regional comparison that stresses separate presentations of material from each region with a view to presenting information in context as well as providing acknowledgment of author predispositions along with transparency of analytical presuppositions.

The Nature of Lightning

Lightning as we understand it today is a discharge of static electricity, not so different in character from the electricity that shocks your fingers when after walking on a carpet you reach for the doorknob and feel it, hear it, and maybe even see the spark. But the difference in magnitude and the power of the shock produced by lightning is obviously enormous. The giant discharge of static electricity that we know as lightning is produced within clouds and also occurs between clouds and other clouds, and more spectacularly between clouds and the earth. Possibly related to the differences in electrical potential created by friction of tiny ice crystals within clouds, lightning and the thunder that follows it usually attend rainstorms, or thunderstorms.

Thunderstorms are a result of either the displacement of warmer air by an invading cold front, or, more commonly in the tropics, strong convection currents intensified by intense solar radiation. While lightning itself is not fully understood, the word as used here assumes the following: lightning is an electrical phenomenon of great power and heat energy, a discharge of static electricity usually associated with clouds and with rain. In the tropics, thunderstorms frequently generate anvil-shaped cumulonimbus clouds, unleashing powerful updrafts and fearsome strokes of thunder and lightning. The convection currents caused by the displacement of warm air by a cold front creates a friction, generating electrical charges or electrons. Rain or hail carry charged electrons to the lower portions of clouds, where the negative charge builds, while positive charges build on the tops, and lightning bounces back and forth within the clouds, a phenomenon generally referred to as cloud-to-cloud lightning. When the flash of such lightning is hidden in the clouds, the broadly visible illumination is often called sheet lightning. Most of the electrical

energy in a thunderstorm is dissipated in this manner within and among the rain clouds. When the negative charges in the lower portion of the clouds are great enough, they become attracted to positive charges emanating from the surface of the earth, and the effect is a lightning bolt.⁷ Bolts are first and foremost attracted to hilltops or mountain summits, and, in the case of tropical rain forests, the tallest trees or architecture—that is, the highest points on the surface of a particular landmass.

The visual expression of lightning is generally accompanied or shortly followed by sound waves, generally assumed to be from the rapid expansion of the air that has been immediately displaced by the lightning. This heated expansion of air around lightning and lightning bolts is superheated to about 54,000°F (29,982°C), expanding faster than the speed of sound,⁸ and the result of the sudden heating and expansion is heard as thunder, the audible pressure (compression) wave causing the sonic expression.⁹ When a discharge of lightning or lightning strike hits the earth, and even sometimes when it remains in the clouds, it is often described as a lightning bolt (emphasizing the visual expression) or as a thunderbolt (emphasizing the sonic expression) (**Figure 4**).

Almost all lightning is generated by thunderstorms. However, lightning, both cloud-to-cloud and bolts hitting the earth, have been observed during snowstorms and in smoke from forest fires, as well as in and around clouds of volcanic ash created by volcanic eruptions. Lightning also results in ionization in the atmosphere, leading to the formation of nitric oxide (NO) or nitrogen monoxide, and ultimately to nitrogen dioxide (NO₂) when exposed to oxygen (O₂). Another chemical pathway of NO is to the formation of nitric acid (HNO₃), which is beneficial to plant life in the form of nitrates in fertilizer (Zumdahl 2009; Bond et al. 2002). Ultimately all life depends on the availability to plants of nitrogen in “fixed” form. Since the nitrogen molecule is quite inert, large amounts of energy input are needed to break it apart so that its atoms can combine with atoms of other elements, notably oxygen and hydrogen. Lightning can supply the energy to thus “fix” nitrogen, making it useful for plants, and paradoxically can also create pollutants (Bond et al. 2001, 2002).

The increased intensity and association of lightning storms with forest fires has been found to be related to reactive nitrogen oxides (NO_x) emitted

⁷ Although all lightning bolt discharges effectively transport cloud charge to the ground, 90 percent of them are of a single type, known as downward negative lightning. Upward lightning strokes are believed to occur only when delivered from very tall objects, i.e., three hundred or more feet high (Rakov and Uman 2007:4–5).

⁸ This is five times hotter than the sun, and the light thus produced travels 186,291 miles per second (299,806 km/sec); sound travels only 1,088 feet per second (332 m/sec), thus the perception of lightning usually precedes thunder (Bond et al. 2002).

⁹ The differences in speed is why thunder is sometimes heard to rumble, in that each shock wave takes a different amount of time to reach the listener.



FIGURE 4 Cloud-to-cloud lightning is the most common and referred to by native Andeans by the Spanish term *relámpago*.

into the atmosphere from natural and anthropogenic sources (Seinfeld and Pandis 1998; Bond et al. 2002). Biomass burning related to slash-and-burn agriculture is a common source of reactive nitrogen oxide outside major population centers (Bond et al. 2002). Reactive nitrogen oxides are also released by industrial pollutants, discharges of lightning bolts, and cloud-to-cloud lightning, as well as released through evapotranspiration by the soil.

Research results indicate the possibility that convection in thunderstorms can transport NO_x -rich air as a result of anthropogenic, biomass burning, or soil emissions from the planetary boundary layer into the middle and upper troposphere. This leads to an enhancement of NO_x in the free troposphere that appears to have a profound impact on ozone (Bond et al. 2002:1516; Tie et al. 2001; see also Dickerson et al. 1987). This impact is related to an overall thinning of the upper ozone layer. However, the magnitude of those enhancements is dependent on the amount of pollutants in the planetary boundary layer and the dilution rate in transporting of NO_x to the middle and upper troposphere, which is difficult to quantify (Bond et al. 2002:1516). Biomass burning emits the greatest annual amount of NO_x and lightning discharges rank third in magnitude among the four variables considered in various studies. However, lightning occurs throughout the annual cycle and is the most significant source of NO_x over the world's oceans (Bond et al. 2002:1517).

Recent technologies have provided increasingly detailed information regarding the occurrence and intensity of lightning storms in different parts of the world. In past centuries, sailors had reported seeing the most intense and

frequent occurrence of lightning in the tropical latitudes (Orville 1990). Recent quantitative data generated from satellites, Optical Transient Detectors, and Lightning Imaging Sensors have reported significant detailed information on a global scale along these lines (Pinto 2009a, 2009b; Pinto et al. 2006). Lightning satellite observations have indicated about forty-five ground and cloud flashes occur throughout the world every second, more than a billion flashes per year, and about 70 percent of these are in the tropical latitudes. The more technologically sophisticated sensors validate sailors' observations, indicating that 76–85 percent of lightning worldwide occurs in the tropics (Christian and Latham 1998; Christian et al. 1999). Thus, NO_x production by lightning occurs predominantly in the tropics. For example, in the Western hemisphere, lightning produces at least 40 percent of the NO_x over much of Central and South America (Bond et al. 2002:1513). Observations for the various landmasses along the tropics indicate that the largest total lightning activity in the Americas occurs in Colombia and Venezuela, that is, the northern Andes (Pinto et al. 2006, 2009a, 2009b). It has also been found that lightning activity in Brazil is of a longer duration than in either Colombia or Venezuela (Pinto 2009b:173–174). Scientific research on reactive nitrogen oxides NO_x suggests that this may be related in part to the deforestation of the tropical forests in Amazon region of lowland South America. Production of NO_x by tropical lightning is significant throughout the year. Although lightning strikes are far more frequent over land than at sea, lightning accounts for almost all of the NO_x emitted over the oceans and 50–90 percent emitted over continental landmass areas on a seasonal basis (Bond et al. 2002). Annually the contribution of lightning to total NO_x production is 23 percent in the tropics, and overall NO_x production by lightning occurs predominantly in the tropics.

There is good reason for humans to fear lightning and to worry about being struck and perhaps killed by it, especially if one is outdoors and the tallest thing around during a lightning storm. Lightning can potentially affect all the organs, particularly in the cardiovascular system. The primary cause of death following a lightning strike is cardiopulmonary arrest. Changes in the heart rhythm and even heart stoppage may temporarily occur, but usually normal rhythm will quickly be resumed. Paralysis of the respiratory system appears to be more common and longer-lasting than heart stoppage. If artificial respiration is not initiated immediately, a person will usually die of hypoxia or lack of oxygen (Charleton 1995: 265–266). Another common effect is first- and second-degree burns on the skin or scalp. Bleeding within the brain is another possible result of a lightning strike (Rakov and Oman 2003). Approximately 50 percent of all surviving lightning victims have some kind of damage to their eyes, usually on the cornea. The most common serious eye injuries are cataracts, which may last for only a few days but can last as long as several years after the lightning strike (Browne and Gaasch 1992; Graber et al. 1996; Rakov and Oman 2003).

Worldwide, there are some 16 million lightning storms annually. More deaths are caused by lightning strikes than by any other natural phenomenon, including tornadoes, hurricanes, and floods (Rakov and Oman 2003:642–649). Approximately one thousand to fifteen hundred people are seriously injured by lightning strikes annually in the United States, and of those, between one hundred to six hundred people perish (Browne and Gaasch 1992; Rakov and Oman 2003). Thus mortality rates range between 25 to 32 percent. Approximately 75 percent of survivors of a direct or indirect strike sustain permanent injuries (Browne and Gaasch 1992:225; Rakov and Oman 2003:449; Taussig 1968).

Men are said to be about four times more likely to be struck by lightning than women (Friedman 2008:6), but then men are also more likely to spend time outdoors. Rakov and Oman (2003:2) report that 103 church bell ringers were killed in Germany by lightning bolts that struck 386 church towers during a thirty-three-year period in the late eighteenth century (cf. Friedman 2008:43). Such statistics make one wonder not only what incentives could attract one to that profession, but also why church bells would be rung during thunderstorms. In answer to why they would be rung, for many hundreds of years Europeans believed that ringing church bells could ward off lightning, and this effect could be augmented by prayers of the faithful on hearing the bells (Friedman 2008:42).¹⁰

Although in some contexts it is perfectly understandable for one to fear lightning, there are situations in which it is not such a rational fear, such as when riding in a subway. An irrational fear of thunder and lightning is referred to as *astraphobia*, and it has been known to affect both humans and their domesticated animals, particularly dogs and cats. Between the rational and irrational fear of lightning, it is clear that lightning is always an object of potential terror, for animals as well as humans. In addition to killing people directly, lightning can also start fires with the same effect. Humans, finding it useful for cooking food, preparing land for planting, and keeping wild animals at bay, have a healthy respect for fire but generally aren't alarmed unless it gets out of control. Lightning, on the other hand, is always out of human control.

Flint striking iron produces bright flashing sparks that can start fires, and lightning has the visual appearance of giant bright traveling sparks such as might be struck from iron or steel by a gargantuan piece of flint. It is not surprising, then, that lightning is likened by some to giant sparks and thought to be a similar power contained within the flint itself. The analogy is inaccurate

¹⁰ In many and diverse parts of the world there are peoples who practice loud noisemaking to ward off various perceived dangers, such as eclipses, lightning strikes, wild animals, evil spirits, etc. In China, Borneo, and parts of Mesoamerica, for example, loud noises, including beating of pots and pans together, are made as an eclipse commences, for it is believed that a monster is eating the moon. Until very recently, Bantu priests made loud noises, shouting and playing flutes, to try to scare off the thunderbirds responsible for lightning.

according to current science, however, in that lightning is primarily electrical in nature, whereas sparks struck from iron, a material that spontaneously ignites below room temperature, are seen as due to rapid oxidation of minute iron particles, a process facilitated by the small size and therefore large surface area of the particles. Banging pieces of flint or quartz together will also produce sparks, but not hot enough or long-lasting enough to start a fire. Sparks, both hot and long-lasting, are produced in metal smelting processes, and since metallurgy was practiced on a relatively large scale in the Andes, it is unsurprising to find that metallurgy is, and was in the past, connected to lightning.

Lightning and thunder are almost invariably accompanied by rain, though rain may well occur without accompanying lightning. When there is lightning, the weather phenomenon is often termed a thunderstorm, a lightning storm, or a rainstorm. Nevertheless, electrical discharges or lightning strikes rarely occur in a clear blue sky. Statistics indicate that the majority of people struck by lightning bolts are struck just before or after a thunderstorm, not during the heaviest rain. Many languages make distinctions among “lightning,” “thunder,” “lightning bolt,” “thunderbolt,” “rain,” and “rainstorm” that are similar to our own, though not necessarily the same, while also recognizing, as we do, some ambiguity in application of the words.