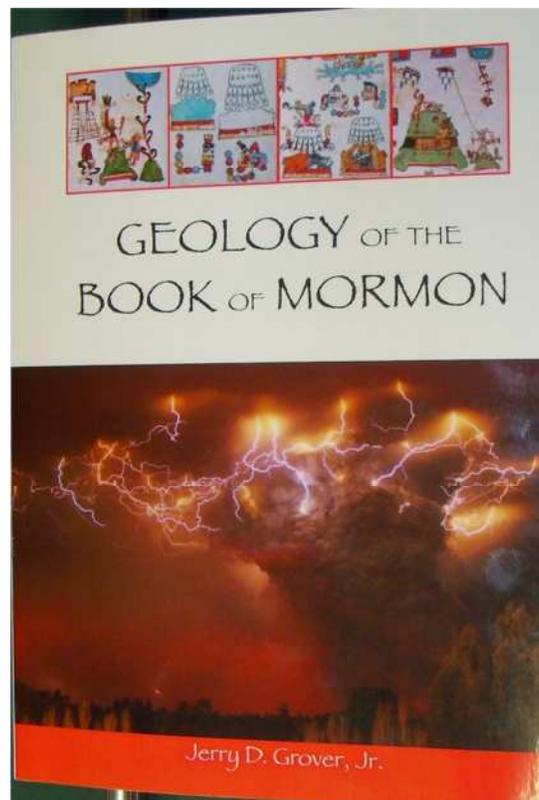


Geology of the Book of Mormon

Tyler Livingston, recently named President of Book of Mormon Archaeological Forum, introduced me to a new book a few days ago. I immediately purchased a copy, read it, and wrote a favorable review on Amazon. The book is entitled *Geology of the Book of Mormon* by Jerry D. Grover, Jr., PE, PG.



Important New Book

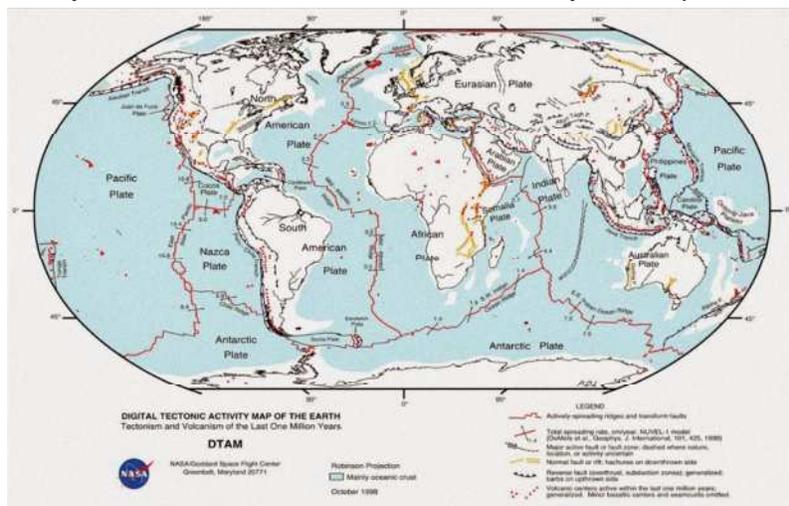
Grover is both a geologist and an engineer. 222 pages of lavishly illustrated text are followed by 122 bibliographic references, one of which is this blog, and a 3 page index. The real glory of the book are the 91 striking visuals, many from online sources. The cover features images of Popocatepetl, the most active volcano in Mexico, from the Mixtec Codex Vindobonensis C, aka Mexicanus I, and from the Toltec-Chicimec Codex Rios, aka Vaticanus A. The impressive cover photo is of a Chilean volcano that erupted in 2011. John L. Sorenson's son, Curtis, prepared the splendid maps in *Mormon's Codex: An Ancient American Book* (Salt Lake City: Deseret Book and Neal A. Maxwell Institute for Religious Scholarship, 2013). Grover worked with Curtis to enhance some of John's maps and figures 1 - 5, 82, 85, and 87 in *Geology* are either direct copies or adaptations of maps from *Mormon's Codex*.

Seasoned professionals reading the Book of Mormon in light of their expertise often find exciting insights. See the blog article BMAF 2014 for discoveries Wade Miller made when he engaged the text based on his experience as a geologist and paleontologist. Miller's *Science and the Book of Mormon* (Laguna Niguel: KCT & Associates, 2010) explores fauna in pre-columbian Mesoamerica. See the blog article "The Legal Cases in the Book of Mormon" for another book I highly recommend. It contains insights Jack Welch gleaned through decades of experience in Biblical Law. The Book of Mormon has material enough for specialists in dozens of disciplines to study it in depth.

Ben L. Olsen worked in Mexico, Guatemala and Belize as a petroleum geologist for Shell Oil Co. After taking a Book of Mormon tour with Joe Allen, Olsen wrote a small piece entitled "Some Thoughts Regarding Geology and the Book of Mormon." Russell H. Ball published "An Hypothesis Concerning the Three Days of Darkness among the Nephites" in *Journal of Book of Mormon Studies* 2:1, 1993. Bart J. Kowallis wrote an article entitled "In the Thirty and Fourth Year: A Geologist's View of the Great Destruction in 3 Nephi" that appeared in *BYU Studies* 37:3, 1997. In 55 pages he summarizes evidence from Papua, New Guinean oral traditions, an Egyptian stela ca. 1,500 B.C., and modern earth sciences to explain 3 Nephi 8-10 as an explosive volcanic eruption similar to Tambora (1815 Volcanic Explosivity Index - 7) or Krakatoa (1883 VEI - 6). That prompted Benjamin R. Jordan to write the short article "Many Great and Notable Cities were Sunk: Liquefaction in the Book of Mormon" that appeared in *BYU Studies* 38:3, 1999 where he describes a natural phenomenon with supersaturated soils that can sink coastal cities even without a tsunami.

None of these previous geological overviews approaches the depth or scope of Grover's work. *Geology of the Book of Mormon* attempts not only to explain the natural disasters the Nephites described but also to help identify Book of Mormon cities based on the location of Mesoamerican tectonic plates, volcanoes, fault lines and hurricane tracks.

This image from NASA's Goddard Space Flight Center shows the major tectonic plate boundaries that heavily influence volcanic and seismic activity on the planet.



Global Plate Tectonic Boundaries

The Book of Mormon area in Mesoamerica has a triple junction of the North American, Caribbean and Cocos Plates. This makes the geology of the area diverse and complex.



North American, Caribbean and Cocos Plates Junction

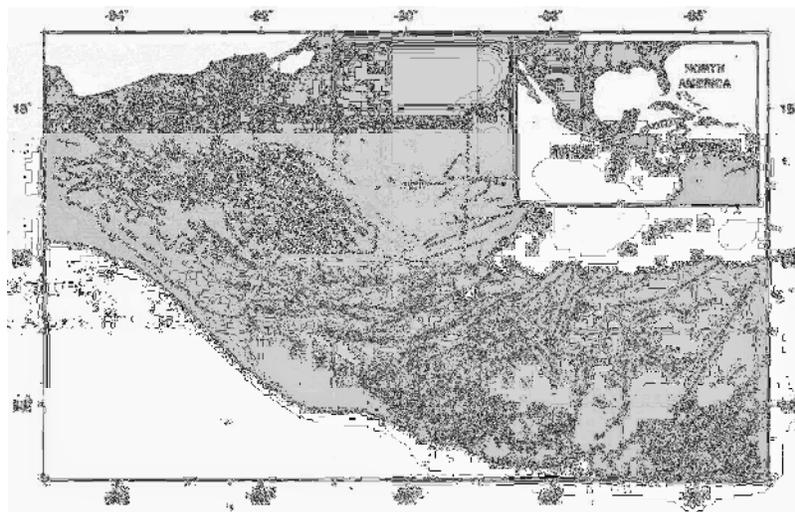
In Mexico and Guatemala the North American and Caribbean Plate boundary is known as the Cuilco- Chixoy-Polochic Fault, part of the Polochic Motagua Fault System. Uplift along this fault has created an east-west line of steep mountains we correlate with the narrow strip of wilderness in Alma 22:27. See the blog article "The Narrow Strip of Wilderness."

Geologic maps of the Isthmus of Tehuantepec area utilize many abbreviations and some specialized vocabulary:

- AC Altos Cuchumatanes Fault
- BVF Baja Verapaz Fault
- CAFS Central American Forearc Sliver
- CAVA Central American Volcanic Arc
- CFTB Chiapas Fold and Thrust Belt
- CH Chicomuselo Fault
- CM Chiapas Massif
- CR Colima Rift
- ECV El Chichon Volcano
- GCA Grabens of Central America
- Graben Depressed block of land bordered by parallel faults
- JAL BL Jalisco Block
- JChFZ Jocotan - Chamelecon Fault Zone
- Lahar Flow of pyrochastic material in slurry with debris and water
- LCF La Ceiba Fault
- LTVF Los Tuxtlas Volcanic Field
- Maar Broad, low volcanic crater often filled with water
- MAT Middle America Trench
- MCVA Modern Chiapanecan Volcanic Arc (contains El Chichon Volcano)

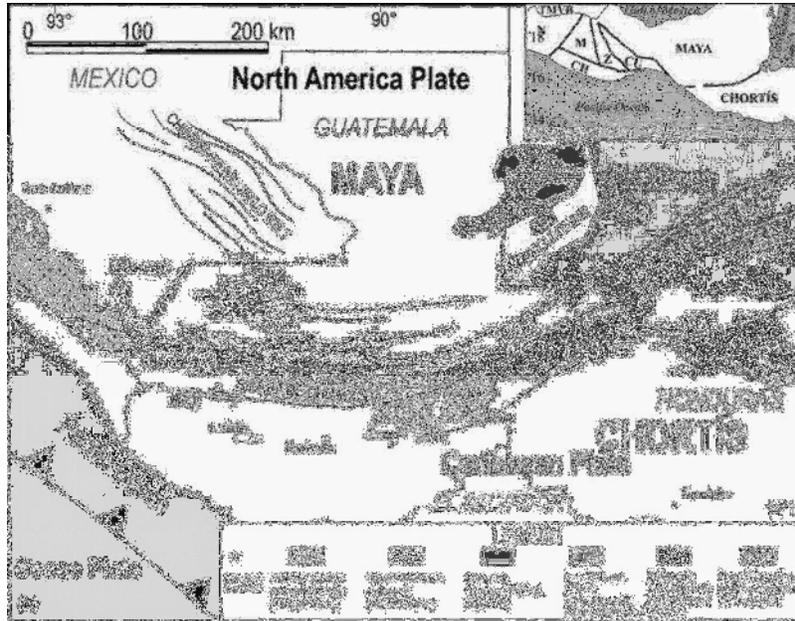
- MFZ Motagua Fault Zone
- PFZ Polochic Fault Zone
- PMFS Polochic Motagua Fault System
- R Reverse Faults
- RFP Reverse Fault Province
- SMB Southern Mexico Block
- SS Strike Slip Faults
- SSFP Strike Slip Fault Province
- TCFS Tula-Chapala Fault System
- TMVB Trans Mexican Volcanic Belt
- TR Tepic Rift
- VB Veracruz Basin
- VF Veracruz Fault
- VF in Guatemala Volcanic Front (contains Agua, Pacaya, Tecuamburro, Muyuta Volcanoes)

This map shows fault lines in Guatemala and Mexico south of the Isthmus of Tehuantepec.



Fault Lines in Southern Mesoamerica

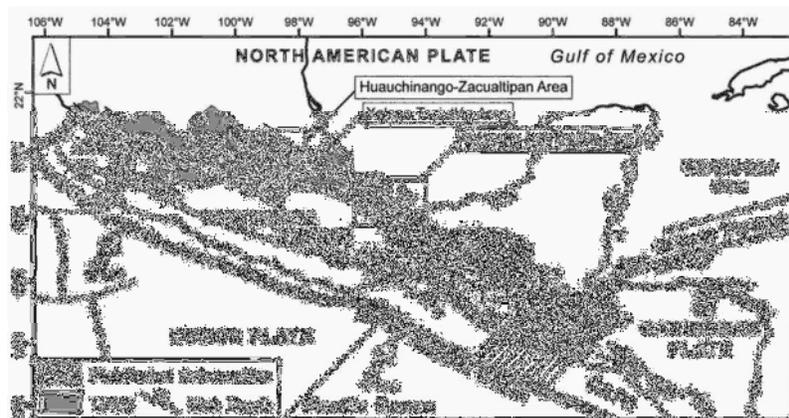
Another view of major fault lines in Guatemala as extensions of the deep water Cayman Trough.



Fault Lines along the North American & Caribbean Plate Boundary

Maya and Chortis are blocks within the North American and Caribbean plates respectively.

This illustration of major fault zones north and south of the Isthmus of Tehuantepec is from a 2008 article by Louis Andreani and 6 other authors entitled "The Neogene Veracruz fault: evidences for left-lateral slip along the southern Mexico block."



Major Mesoamerican Faults

Grover includes this map as Figure 9 in *Geology of the Book of Mormon*. Note that The Yucatan Peninsula is much more geologically stable than the rest of Mesoamerica.

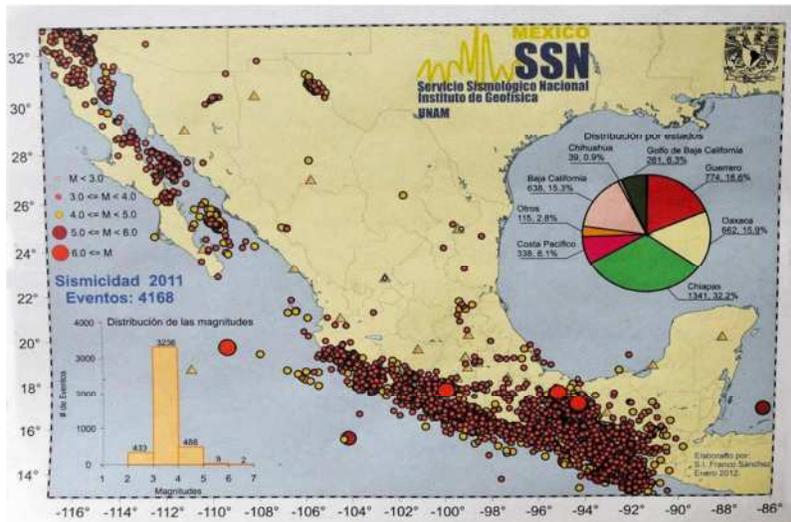
Volcanic arcs or fields and fault systems are generally found together, This map of volcanoes is from the Smithsonian Institution's Global Volcanism Project. For its modest size (108,890 square kilometers) Guatemala has one of the densest concentrations of volcanoes (24) on the planet.



Mesoamerican Volcanoes as Red Triangles

These volcanoes are all known to have erupted during the Holocene (last 10,000 years). The Smithsonian currently lists 1,565 Holocene volcanoes in its database.

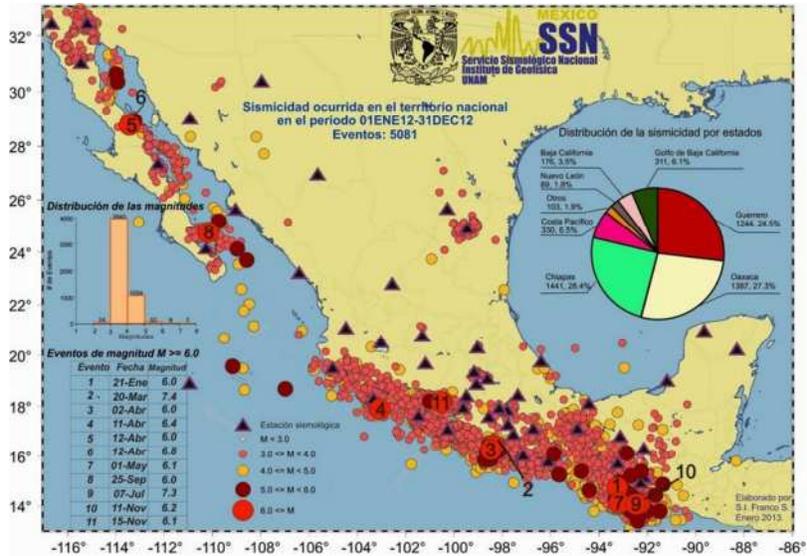
Earthquakes obviously follow fault systems. This is a map of earthquakes detected by Mexico's SSN Servicio Sismológico Nacional during the year 2011.



2011 Earthquakes Documented by Mexico's SSN

SSN measured 4,168 seismic events in 2011, most of them very small tremors. In that year, 96% of the earthquakes occurred in only 5 regions of the country: Baja California and its gulf aka the Sea of Cortez, the Pacific coast, Guerrero, Oaxaca and Chiapas.

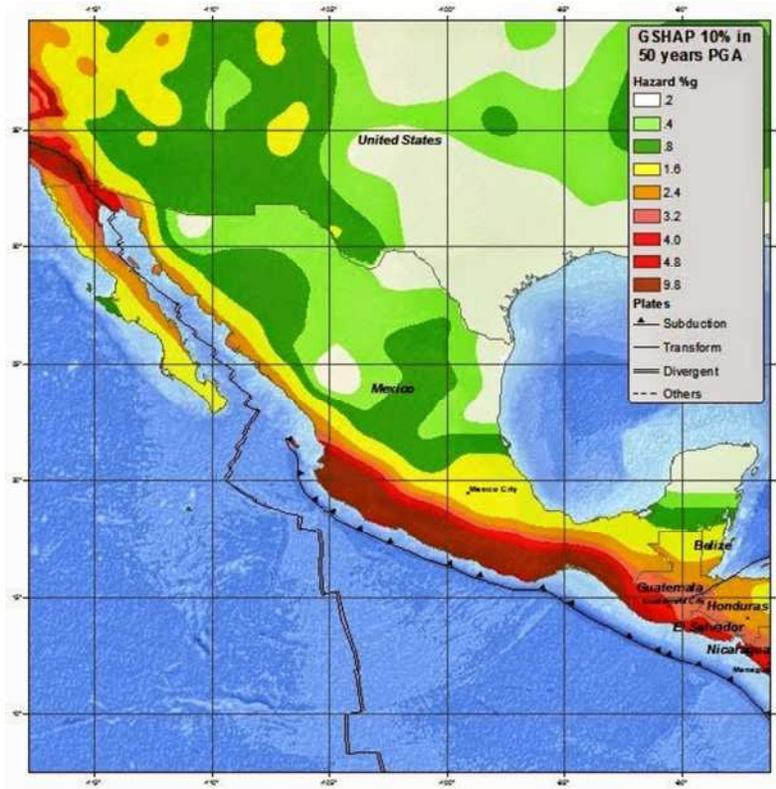
This is a similar map for 2012. Again in that year, 96% of the earthquakes were in Baja, the Pacific, Guerrero, Oaxaca and Chiapas.



2012 Earthquakes Documented by Mexico's SSN

In the maps above triangles represent seismograph locations. Clearly, earthquakes are common in certain parts of the country, rare in others.

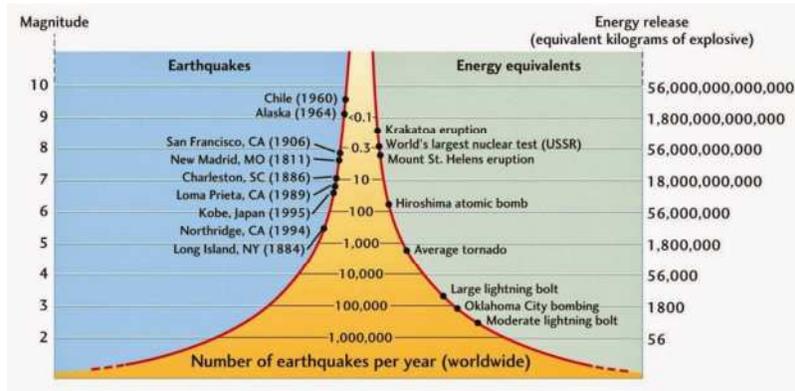
This is a USGS Hazard Map of Mesoamerica. Areas in white experience virtually no seismicity. In brown areas earthquakes are routine.



Probability of Seismic Events

As this map makes explicit, earthquake frequency decreases with distance from a tectonic plate boundary.

This chart puts seismic and volcanic events in some perspective.



Earthquake Moment Magnitudes & Energy Release

The upper range of energy released from known terrestrial geologic events in historic times is on the order of 10 - 50 trillion kilograms (10 - 50 thousand megatons) of TNT equivalent. The largest terrestrial geologic event known was the Oligocene eruption of La Garita Caldera in SW Colorado. Its estimated energy release was on the order of 250 thousand megatons of TNT equivalent. These earthbound events pale in comparison with the estimated energy released by celestial impacts, widely believed to have caused mass planetary extinctions. The Cretaceous-Paleogene impact that formed Chicxulub Crater in northern Yucatan, for example, probably released energy on the order of 100 million megatons (100 teratons) of TNT equivalent. In other words, La Garita was 5X larger than anything mankind has experienced in historic times. Chicxulub was 400X larger than La Garita. It would be interesting to estimate the size of the energy release implied by the events described in the 3 Nephi destruction text.

Jerry Grover uses John L. Sorenson's geographic model of the Book of Mormon throughout his book since Sorenson enjoys broad academic acknowledgement. Terryl Givens, for example, in his foreword to *Mormon's Codex: An Ancient American Book*, says "So influential has Sorenson's work on Book of Mormon geography been that there is widespread consensus among believing scholars in support of what is now called the 'Sorenson model,' which identifies the scripture's setting with a Mesoamerican locale." Givens is correct in his assessment of Sorenson's Mesoamerican correlation. Every discipline has a mainstream and mainstream scholars who take Book of Mormon studies seriously are nearly unanimous in support of Mesoamerica as the Book of Mormon homeland. When it comes to specifics within Mesoamerica there is far less consensus. The Sorenson model, first synthesized in 1953-55, has been widely available in print since 1985. Larry Poulsen's work branches from Sorenson. The Hauck model was published in 1988. Joe Andersen follows Hauck and Bob Roycastle branches from him. The Allen model was published in 1989 and revised in 2008. BMAF began holding annual Book of Mormon Lands Conferences in 2003. Aric Turner's excellent work based on RLDS (now Community of Christ and Restoration Branch) scholarship first appeared in 2004. The Norman model, first synthesized in 1965-66, has been widely available in print since 2006. The model in this blog began to take shape in 2011. It is an amalgam of Sorenson, Norman, Hauck and Allen with a handful of original correlations from myself (Kirk Magleby). Turner corroborates much of it. The lack of consensus among Book of Mormon Mesoamericanists provides the fertile intellectual vacuum in which the Heartland movement thrives. Grover views himself as providing another realm of inquiry that can inform the Mesoamerican discussion and

for that he deserves a great deal of credit.

One note about consensus. On October 18, 2014 I gave a presentation at BMAF 2014 entitled "Book of Mormon Trifecta." It was in response to Jack Welch's request that I come up with a methodology that could successfully evaluate any proposed Book of Mormon geographic correlation. On the evening of October 18th, Joe Andersen proposed to the assembled BMAF board that a working group convene a seminar with the express intent of achieving consensus among believing Mesoamericanists. Joe's proposal was accepted. The meeting Neal Rappleye and I had with Jack Welch in his office on December 19, 2014 (see the blog articles "The Legal Cases in the Book of Mormon" and "Sermon at the Temple") was part of the process. The tests I have been elaborating since October, 2013 (see the blog article "Test #11 The Big Picture") are part of the process. At least three more tests should soon be added to the list. At a BMAF board meeting held on January 31, 2014 I reported on progress toward realization of Andersen's proposal. At that meeting Tyler Livingston was named President of the organization succeeding Doug Christensen who succeeded the late Steve Carr. I was named VP - Special Projects. There is only one special project on my agenda - building Andersen's proposed consensus. Stay tuned.

Grover begins in chapter 1 with a recitation of scriptural passages that either prophesy about or describe the destruction in 3 Nephi 8-10. He is careful to use Royal Skousen's Yale edition (see the blog article "Scribal Error"). His chapter 2 depicts the Sorenson model with maps provided by John's son, Curtis. Chapter 3 is an excellent introduction to the geology of the Isthmus of Tehuantepec region with special emphasis on the Veracruz Fault, San Martin Volcano in the Tuxtlas and El Chichon Volcano in Chiapas. Eruptions of San Martin (1793) and El Chichon (1982) in historic times are well-documented. Discussions of the Volcanic Explosivity Index VEI metric and eruptions of certain volcanoes within confirmed date ranges begin to set the stage for serious comparisons with events described in the Nephite annals. Chapter 4 describes many ways volcanoes, earthquakes and hurricanes destroy life and property. Discussion of the Mercalli intensity scale focused on the effects of a seismic event adds another empirical tool scholars can use to evaluate the Nephite text in light of modern earth sciences. One of Grover's most valuable contributions is his summary of the Nephite destruction texts organized by geologic hazard. In chapter 5 Grover presents a preliminary timeline for the 3 Nephi destruction drawing on the work of Book of Mormon chronologists Randall Spackman and Jeffrey Chadwick. In chapter 6 Grover assesses the viability of Kowallis' 1997 proposal that a single large volcanic explosion with its associated earthquakes and ocean wave action could account for the destruction in 3 Nephi. Grover calls this the "volcano-only scenario." Marshalling data from dozens of USGS shakemaps, detailing differences between volcanic and non-volcanic earthquakes, and examining textual and lexical references, the author discounts this scenario. His lexical resources are Websters 1828 and Websters 2013.

Grover's chapter 7 about storms and tempests is inconclusive. His single page chapter 8 highlights the tenuous nature of the data in our area of interest. Could a unitary explosive volcanic event such as San Martin 1793 blanket "most or all of the land northward and land southward" with enough ashfall to account for the 3 Nephi three days of darkness? Figure 29 on page 39 suggests not. Since "it is difficult to pinpoint historical eruptions into a given century, let alone a 3-hour period on a particular day" correlations with the Book of Mormon text will necessarily be tentative. Single page chapter 9 strengthens Grover's thesis that 3 Nephi describes a concurrent seismic + volcanic event. In chapter 10 the author makes his case for a simultaneous earthquake along the Veracruz fault and explosive eruption of San Martin Volcano. Chapter 11 fine tunes the Sorenson model with some of the author's own geographic insights. For example, since Sorenson's Jerusalem in the south of Lake Atitlan doesn't fit the

Veracruz Fault/San Martin Volcano scenario very well, Grover posits a possible second city named Jerusalem in the land northward. Some linguistic derivations suggested by Brian Stubbs are fascinating. Stubbs, who has spent his career becoming one of the world's leading scholars of Uto-Aztecan, has a great deal to offer the Book of Mormon community. I hope we hear much more from him in coming years. Chapter 12 brings the geological data and Sorenson's model together and - no surprises here - they fit like a hand in a glove. Chapter 13 shows Grover at his creative best, interpreting half a dozen Nephite and Jaredite events in a geological & biological light. In chapter 14 the author spends some time with V. Garth Norman's map and concludes it does not fit his preferred geological scenarios as well as the Sorenson model. He also casts doubt on the Ammonihah/El Hormiguero II correlation I propose in the blog article "Ammonihah." See below for reasons I believe Grover's objections are unfounded. Chapter 15 summarizes what the author thinks he has accomplished in his useful and in some ways groundbreaking new book. He has made a solid contribution to Book of Mormon studies and earned my respect. I appreciate any work that helps me better understand Nephite scripture. *Geology of the Book of Mormon* by Jerry D. Grover opened my eyes to a number of exciting things in the text I had not previously considered. I recommend this book to serious students.

Where Grover interprets the text correctly, I find his analyses enlightening. But, the old adage "when you have a hammer, everything looks like a nail" applies in this case. I believe he has forced some readings in support of his thesis that result in illogical conclusions. Specifically,

- The "plains" referenced in 1 Nephi 12:4 are probably not referring uniquely to the Tabascan coastal plain bordering the Bay of Campeche.
- The verb "shewing" in 3 Nephi 11:1 (the Yale edition replaces "show" with "shew") refers to verbal communication, not visual observation.
- Alma₂'s and Amulek's escape from prison in Ammonihah Alma 14:26-29 resulted from a localized event, not a major strike-slip fault boom-generating earthquake measuring at least VIII on the Mercalli intensity scale.

Plains. Both Nephi in his small plates and Mormon in his abridgement are meticulous to document prophesy fulfilled. As he discusses the scribal task of engraving on plates, Nephi bears witness that God's words will all be fulfilled 1 Nephi 9:6. Lehi's prophecy in 1 Nephi 1:13 was explicitly fulfilled and Nephite record keepers half a world away made sure we understand God kept His promise 2 Nephi 1:4, Jacob 2:32, Helaman 8:20-21. This emphasis on prophesy-become-history leads to many parallel texts throughout the Book of Mormon such as 2 Nephi 25:24 fulfilled by 3 Nephi 9:17 and the spectacular example of 3 Nephi 18:37 where a dutiful son made good on his late father's promise post holocaust Moroni 2:3. This prophecy/fulfillment duality is evident in 1 Nephi 12:4 fulfilled by 3 Nephi 8:12-14. This means "the plains of the earth" that were broken up in Nephi's vision and the "many smooth places" that became rough in the 3 Nephi destruction text are paired elements. There were multiple plains and they were clearly associated with the land northward.

There is even a larger prophetic narrative at work. The level and smooth becoming broken and rough is associated with the first advent of the Savior Moses 7:56, Matthew 27:51, 1 Nephi 19:12. At the second coming, the reverse happens and rough places will become smooth Isaiah 40:4. The New International Version of the Bible NIV renders this verse "the rough ground shall become level, and the rugged places a plain." Luke 3:5 repeats Isaiah. In his inspired translation of the Bible, the Prophet Joseph made it clear this passage refers to the second coming JST Luke 3:4-11. D&C 49:23 and D&C 109:74 continue the theme. Nephi shows that ca. 600 B.C. he was aware of the geologic events associated with both advents 1 Nephi 17:46.

The Book of Mormon mentions several discrete plains.

- An area between the cities of Bountiful and Mulek (less than 1 day's march distant according to the battle narrative in Alma 52) along the east coast of the land southward Alma 52:20
- An area adjacent to the city of Nephihah which was between Aaron and Moroni in the Nephite SE Alma 62:18-19
- Plains of Heshlon near the Valley of Gilgal in the land northward Ether 13:29-29
- Plains of Agosh in the land northward Ether 14:15-16

It is very unlikely 1 Nephi 12:4 is referring exclusively to the Tabascan coastal plain when it uses the term "plains of the earth."

Shewing. We now know the language that fell from the lips of the Prophet Joseph at the moment of translation was Early Modern English. See the blog article "Early Modern English." This makes our indispensable lexical resource the incomparable Oxford English Dictionary OED. The Yale edition of the text uses some form of the verb "show" 8 times. It has 156 instances of the older "shew." The OED has 2 very different senses of meaning for shew:

- look at, gaze upon, behold or view
- point out, explain or expound through verbal or written statements or arguments

The Book of Mormon uses "shew" with both senses of meaning. Spiritual communications from a divine source predominate. Mere mortals are rarely the agents doing the shewing and even when they are, except in one case, an element of divinity is present. Most of the instances of the word are the Lord shewing visions, truths, His power or Himself in the case of the Brother of Jared and the Nephites assembled at the Temple in land Bountiful. And even the Lord often speaks words in His powerful spiritual communications 1 Nephi 20:3, Prophets shew signs to unbelievers via verbal expression Helaman 9:25-26. Sometimes the object being shewn is the Book of Mormon itself or selections of its words Title Page, 2 Nephi 27:15, Alma 37:14. In the Book of Mormon, the Lord 1 Nephi 1:15 and the Holy Ghost 1 Nephi 11:9 show visions. The Lord shows truths via words spoken by angels 2 Nephi 6:9. "Shew" in the text is usually part of a revelatory process. Prophets in their role as authors make editorial promises to shew truths in future writings 1 Nephi 1:20, Mosiah 23:23, Alma 57:8. The 3 Nephites invested with divine power can shew themselves 3 Nephi 2:30. The only secular instance in the text of a mortal shewing other mortals something visually is Alma, helping the Lamanites and Amulonites find their way back to Nephi Mosiah 23:36-37. Other times mortals shew repentance or good works as part of their spiritual progression Alma 7:15.

In the passage at issue, 3 Nephi 11:1, almost one full year had passed since the great destruction described in 3 Nephi 8. Approximately 2,500 people 3 Nephi 17:25 gathered at the temple were marveling, wondering and shewing things of interest among themselves. And what was their medium of communication? Human speech as 3 Nephi 17:2-3 makes explicit. What was the great and marvelous change that was their topic of conversation? Localized topographies, demographics and the nature of their society. The wicked had perished leaving only the righteous 3 Nephi 10:12 who were now free to explain and expound recent history in light of their prophetic texts 2 Nephi 10:14-17 without persecution. One of the primary matters they were discussing one to another was the Savior and his imminent visit 3 Nephi 11:2.

Ammonihah Sesimic Event. I have personally experienced several earthquakes including the 1974 Lima earthquake that killed 79 people. It registered 8.1 on the Moment Magnitude Scale with maximum Mercalli Intensity of IX. I have spoken with many people who have been in large earthquakes. This is the common pattern of animal and human behavior we have seen:

- Dogs whine in a peculiar way, acting as an early warning system. Many people are already out in the streets before the ground begins to move because they recognize the sound dogs make just before a sizable earthquake.
- When the ground and structures begin to shake, people run for the doors yelling and screaming. In Spanish style homes with large enclosed courtyards, they often gather in the garden. Most people run out into the streets. Catholics often engage in panic rituals.
- When the quaking stops, people linger for awhile expecting aftershocks.
- After they are convinced the earthquake has passed, almost everyone goes back inside to check for damage. This can take several minutes. Families try to account for all their members. There are lots of phone calls or quick visits across town to check on relatives and friends.
- After they are satisfied they know the extent of the damage to their loved ones and property, people then begin to visit their neighbors to check on them and swap stories. Intense interaction with neighbors on all sides ensues. People listen for radio or TV reports.
- If there has been damage, the slow process of healing and rebuilding begins almost immediately.

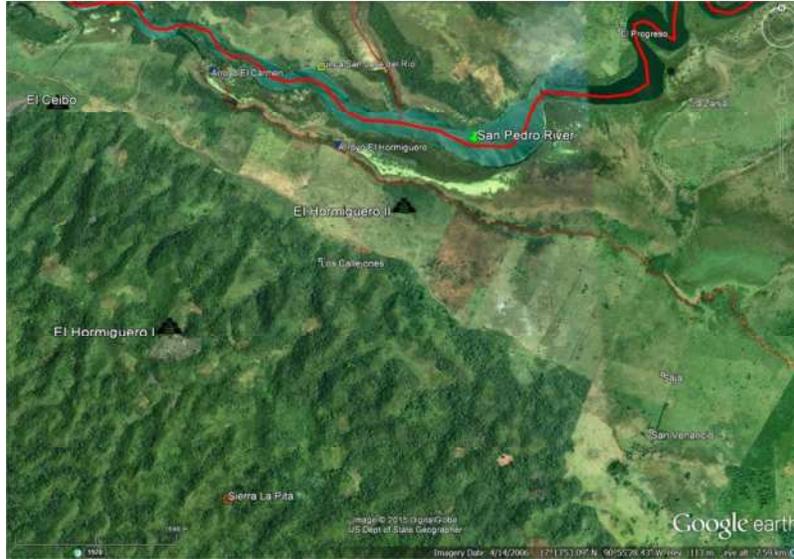
I have not personally heard an earthquake boom, but I have spoken with people who have. They describe it as a sound like thunder or artillery. Since it is associated with ground shaking, people recognize the sound and know what causes it.

Contrast known large earthquake behavior with the description of the unusual event in Alma 14:25-29.

- The power of God came upon Alma and Amulek.
- The two bound captives rose to their feet.
- Alma prayed for strength.
- Alma and Amulek broke their bonds, scaring those around them.
- The others in the prison began to run away from the two prophets.
- Overcome with fear, the others in the prison fell to the ground, still inside the structure.
- The ground shook.
- The prison walls collapsed.
- The falling structure killed all the malefactors lying on the floor.
- Sole survivors Alma and Amulek walked out of the destroyed prison unharmed.
- Alma and Amulek began walking toward the city.
- Many people heard the prison collapse.
- Townspeople came running to see what had caused the noise.
- Seeing the former prisoners walking out of the ruined structure scared them.
- They began to run away in fear from Alma and Amulek.

Property damage and mortality in Ammonihah were apparently limited to the prison, allowing residents to explain the event away with scurrilous tales Alma 15:15. Widespread destruction in Ammonihah came a few months later via military invasion Alma 16:2.

It is clear the prison was some distance outside of town because Alma and Amulek were walking "into" the city when they met the multitudes running the other direction Alma 14:28. If our correlation for Ammonihah is correct, the prison may have been near the San Pedro river in which case liquefaction could have been a factor in the structure's collapse.



Proposed Ammonihah - El Hormiguero II on the San Pedro

The river in this location is at an elevation of 40 meters. The site sits on a bench above the river at 50 meters elevation, less than 1 kilometer from the south bank. We identify Sierra La Pita as the wilderness side of Ammonihah Alma 16:2. The highest mountainous point in the view above has an elevation of 470 meters. Marshy wetlands lie between Arroyo El Hormiguero and the San Pedro.