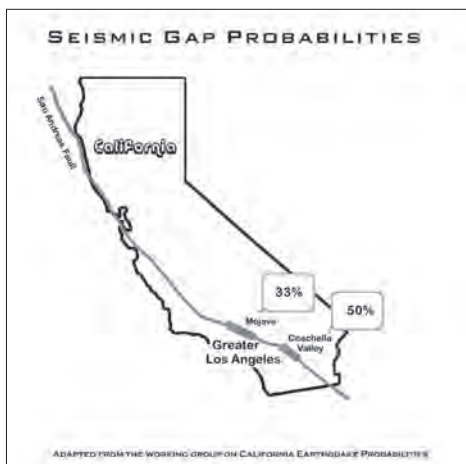


A Pattern of Seismicity in Southern California: The Possibility of Earthquakes Triggered by Lunar and Solar Gravitational Tides

David Nabhan

Helen Keller wrote that the heresy of one age is the orthodoxy of the next, giving ample proof that although sightless, she possessed extraordinary vision. Moreover, it has been said that every new fact must pass through a crucible by which first it is ignored or ridiculed, then vigorously attacked, and finally



Seismic Gap Probabilities. Author's collection.

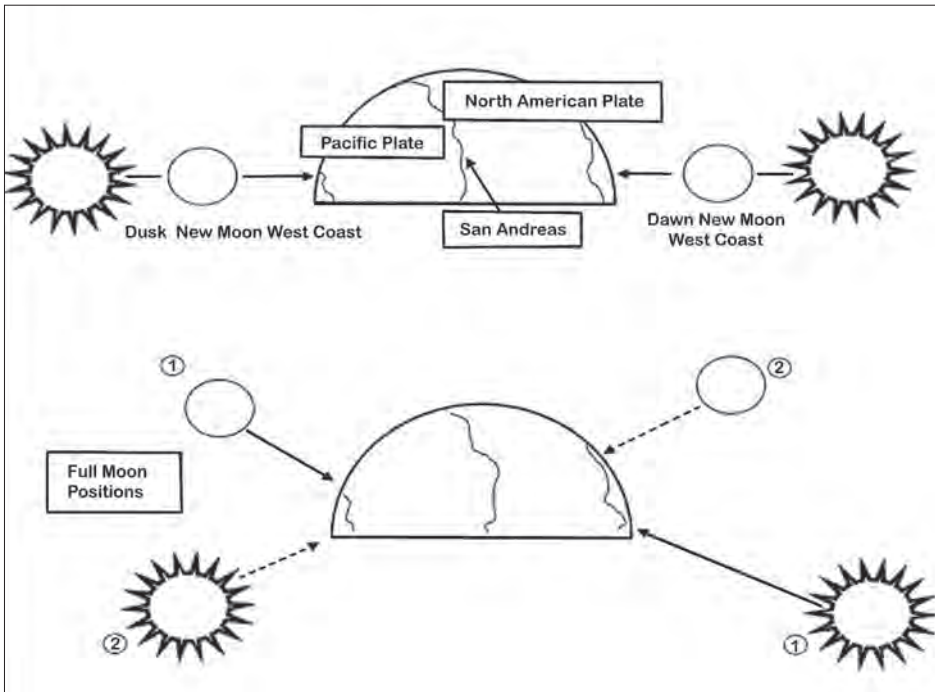
accepted as though the truth had been apparent from the beginning. Earthquake prediction is no exception but for the anomaly that the first two stages have endured far longer than what the immense populations on the U.S. West Coast might hope to expect regarding a matter so important to their safety and welfare. Residents of Southern California have been left with a bewildering set of claims and counter-claims regarding this issue for many decades. While scientific data can be presented any number of ways to say any number of things, there is

another arbiter that, weighed alongside the conflicting findings, may allow fair-minded observers to come to their own cogent conclusions: history. There exists a long and verifiable record of events on the Pacific Coast and elsewhere

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that at minimum implies that the tepid verdict rendered regarding seismic forecasting might not be the final and correct judgment at end.

Empirical historical evidence is a powerful tool in eliciting the closely guarded secrets of nature. Many assume that thoughts about earthquakes in the distant past have always resided in the realm of folklore and mythology. Thousands of years ago, however, Lucretius, Seneca, Aelian and others were positing theories about earth tremors that had nothing at all to do with Poseidon, some of it gleaned from events at Pompeii and Helike. When the horrific 1755 Lisbon earthquake struck, a seminal event in European history, it radiated shock waves from Portugal that caused the great thinkers of the Age of Reason such as Rousseau and Voltaire to exchange opinions as to the cause of this monumental calamity. Immanuel Kant offered his thoughts also, making what may be one of the first recorded seismic “predictions” in history. He noted that Lisbon and Iceland suffered an earthquake on the same day and hypothesized that those two locales must be connected by some “hollow” beneath the crust of the Earth. Two centuries later it was discovered while surveying the floor of the Atlantic Ocean that such a nexus does indeed exist between Lisbon and Iceland: the awesome Mid-Atlantic rift. Alfred Wegener, the discoverer of plate tectonics, seismology’s equivalent of biology’s Charles Darwin, came to his discoveries



New-Full Moon Positions at Dawn-Dusk. Author's collection.

from the most prosaic beginnings: staring at a map and realizing that South America and Africa fit together as if parts of a puzzle.

In our own modern age and concerning the Pacific Rim, the International Date Line has been put in place to separate Monday from Tuesday. The laws of physics, nonetheless, operate with equal validity on either side of that imaginary limit. Many governmental authorities in Asia have established bureaus dedicated to earthquake prediction that have been operating for many years. China's State Seismological Bureau's (SSB) Center for Prediction and Analysis is one example; Japan's Tokai Warning System is another. The record in Asia contradicts the prevailing thought in California, since it confirms official government action—evacuating thousands—before massive earthquakes striking, right where they were advanced to occur, exactly when they were expected to evidence themselves. One of the best documented examples involved Carnegie Institution seismologist Paul G. Silver and Tokyo University Professor Hiroshi Wakita who convinced the governments of Burma and China to evacuate a border district between those two countries scant hours before a magnitude 7.3 tremor struck on July 11, 1995, "averting substantial loss of life," according to the *Los Angeles Times*. This event was witnessed and verified by news sources across the globe. Silver and Wakita used geohydrochemical precursors in issuing their advisory, just one of many fields of study currently underway in the attempt to identify seismic precursors. Regarding Southern California, however, there is another dynamic that should garner the attention of San Diegans: conjoined lunar and solar gravitational tidal effects.

As far back as 350 BCE, eclipses and earthquakes had come to be spoken in the same breath by classical scholars two millennia before Isaac Newton gave an explanation of the tidal effects of Sun and Moon. The list includes Aristotle, Thucydides, Phlegon and a number of Babylonian astronomers. Abbasid intellectuals of the Islamic Golden Age such as Ibn al-Batriq and Hunayn ibn Ishaq were repeating the same speculation a thousand years later. Excluding unsupported rumination from an era in history which is replete with errors of every sort, from the dawn of our own rigorously scientific epoch until the present, there exist literally hundreds of peer-reviewed abstracts lending plausible credence to the idea that tidal forces may indeed have a hand in pushing forward seismic events on a time-table in concert with celestial mechanical influences. The studies below are but some examples published in the most prestigious scientific journals in existence between 1845 and 2010. Indeed, typing "tidal triggering of earthquakes" into the search field at the NASA/Harvard Astrophysics Data System will elicit hundreds of others that should capture the attention of any interested investigator. (<http://adswww.harvard.edu/>).

Table 1: Peer-Reviewed Gravitational Tidal Studies (1845-2010)

Scientist	Title of Study	Journal	Date
Richard Edmonds	On the Remarkable Lunar Periodicities in Earthquakes	Edinburg New Philosophical Journal	1845
Alexis Perrey	Frequency of Earthquakes Relative to the Phase of the Moon	American Journal of Science	1876
Arthur Schuster	On Lunar and Solar Periodicities of Earthquakes	Proceedings of the Royal Society-London	1897
R.D. Oldham	Periodicities of the Tidal Forces and Earthquakes	Journal of the Asiatic Society of Bengal	1903
H.V. Gill	Some Recent Earthquake Theories	Nineteenth Century	1908
Myron Fuller	The New Madrid Earthquake	USGS Bulletin #494	1912
Charles Davison	Diurnal Periodicities of Earthquakes	Journal of Geology	1934
H.T. Stetson	Correlation of Deep-Focus Earthquakes with Lunar Hour Angle	Science	1935
Maxwell Allen	Lunar Triggering Effect on Earthquakes in Southern California	Seismological Society of America	1936
Michael Shimshoni	Evidence for Higher Seismic Activity	Geophysical Journal	1971
Dror Sadeh	Periodic Earthquakes in Alaska and Central America	Journal of Geophysical Research	1978
Leon Knopoff	Lunar-Solar Periodicities of Large Earthquakes in Southern California	Nature	1983
Elizabeth Cochran	Earth Tides Can Trigger Shallow Thrust Fault Earthquakes	Science	2002
Laurent Metivier	Evidence for Earthquake Triggering by Solid Earth Tides	Earth and Planetary Science Letters	2009
V.I. Kolvankar	Lunar Periodicities and Earthquakes	New Concepts in Global Tectonics Newsletter	2010

In very recent years some plain-spoken statements have been issued by impeccably credentialed seismologists regarding the tremendous effects the tides can exert on the surface of the Earth. In 2006 a team of Italian and American seismologists, led by Carlo Doglioni at Rome's La Sapienza University, declared in the January/February 2006 issue of the *Geological Society of America Bulletin* that the tidal force of the Moon was literally pulling the Earth's lithosphere westward. If the entire North American continent itself can be "dragged west," as the *National Geographic News* paraphrased in the title of their article referencing the study, it should be seen as no great leap of imagination to conceive that these very same powers might be considered as at least ancillary factors in triggering seismic events. The truth is that gravitational tides are primal and ubiquitous forces that are responsible for some of the most iconic and awe-inspiring features of the Solar System.

The geysers of Enceladus are powered by the Saturnian tides and make anything on Earth seem quite mundane. Steamboat Geyser in Yellowstone has set the record for the highest ejection ever recorded: 300 feet. NASA's Cassini spacecraft took photos in July 2005 of explosions on Enceladus that blasted liquids and ices over eight kilometers high. There are no terrestrial examples, however, to stand next to the moon's volcanoes. Suffice it to say that Jupiter's inner-most moon, having to contend with the titanic forces brought to bear by the Jovian tides, is bursting with the tallest, most ferocious volcanoes imaginable. These raging goliaths send furious jets of ejecta as high as 500 kilometers above the



Southern California. Author's collection.

hadean surface. Earth, too, is the stage for daily demonstrations of a colossal example of gravitational tides at work, with countless trillions of tons of water in her oceans being sloshed around the planet as if it were nothing more than bathwater in a baby's bassinette.

The thesis that conjoined lunar and solar gravitational tidal forces have played a part in triggering large seismic events in Southern California (specifically at dawn and/or dusk, on new and/or full moon phase dates) would have at least a modicum of plausibility if the facts and studies above are considered. If so, there should be then documentation of the same—and there is. It is a record that suggests no matter the world-wide average science has compiled that deems tidal triggering as a real but fairly insignificant factor in seismicity, this may have nothing at all to do with what is transpiring on the U.S. West Coast. The historical facts might be sufficient to cause any open-minded observer to entertain the idea that the extremely anomalous data listed below can hardly be dismissed as coincidence or happenstance.

- Between 1933 (the year of the Long Beach disaster) and 1994 (Northridge), six temblors large enough to have caused fatalities have struck in Greater Los Angeles (within a 70-mile radius of downtown Los Angeles). Each of those earthquakes (between magnitude 5.8 and 7.3) occurred either at



Long Beach, 1933, United States Geologic Survey, Long Beach, 1933. USGS Photo Library.

dawn or at dusk. That is to say that every individual who perished in an earthquake during those 61 years in Greater Los Angeles died between the hours of 4:00-7:45 a.m. or p.m., or more accurately correcting for daylight savings time, within symmetrical three hour dawn/dusk windows that correspond to 11:45-14:45 UT (dawn, Pacific Time) or 23:45-2:45 UT (dusk, Pacific Time). The probabilities of this happening randomly are in the realm of 1 in 5,000.

- Regarding those same earthquakes, not only did they all strike either at dawn or dusk insofar as the hours of the day are concerned (indicating solar influence), but two-thirds of them also evidenced themselves within 36 hours of the new or full moon phase (pointing to the lunar tides). Such a remarkable occurrence due to simple chance is highly unlikely: 1 out of 10,000 ‡. (See table below.)

Table 2: History of Earthquakes in Greater Los Angeles (1933-1994)

Earthquake	Mag.	Solar Tides Time of Day	Lunar Tides Time of Month**	Death Toll †
Long Beach 3-10-33	6.4	Dusk-5:54 PM/1:54 UT	Full-24.88 hours	115
Gorman 7-21-52	7.3	Dawn-4:51 AM*/11:51 UT	New-11.65 hours	12
Sylmar 2-9-71	6.6	Dawn-6:00 AM/14:00 UT	Full-17.35 hours	65
Whittier 10-1-87	5.9	Dawn-7:42 AM*/14:42 UT		8
Sierra Madre 6-28-91	5.8	Dawn-7:43 AM*/14:43 UT	Full-35.73 hours	2
Northridge 1-17-94	6.7	Dawn-4:30 AM/12:30 UT		60

*Daylight Savings Time **Duration between new/full moon phase and corresponding earthquake.

† 3 additional fatalities were suffered in two aftershocks of two of the quakes listed in this table: two after Gorman and one subsequent to Whittier.

‡ n=total earthquakes (6) r=dawn/dusk/near-syzygy quakes (4) P=probability (.0513) Q= 1-P (1-.0513= .9487).

nCr= Combination of n things taken r at a time.

- Casting a wider net north of Los Angeles similar earmarks are to be noted. The two greatest seismic disasters in the history of San Francisco took place 83 years apart as we reckon the years between 1906 and 1989, and yet almost exactly twelve hours apart as we count the hours: 5:18 a.m. and 5:04 p.m. (PDT) respectively.



San Francisco Earthquake-USGS12. San Francisco, 1906. USGS Photo Library.

- In the Pacific Northwest, Seattle's second greatest earthquake since 1965 (May 2, 1996, magnitude 5.4) shook the Puget Sound just 7 hours 46 minutes away from the full moon and only 79 minutes outside the solar parameters above. Vancouver experienced only very recently an explosive indication that lunar and solar tides in concert may indeed be a force with which to reckon on the U.S./Canadian littoral. On October 27, 2012, the greatest seismic occurrence in Canada in six decades took place north of Vancouver Island, 123 miles south-southwest of Prince Rupert. This magnitude 7.7 eruption took place 19 minutes outside the solar window and 4 hours 47 minutes before the full moon dusk parameter. And, although aftershocks are not being considered in this article since their production after large quakes is to be expected, it is worth noting that the Canadian rupture was followed by a 6.1 telluric outburst that fell exactly within the same bounds—if 4 minutes can be forgiven—as those listed in the table above.

- The greatest earthquake in the recorded history of North America (magnitude 9.2) devastated Anchorage, Alaska, at dusk, 5:36 p.m., exactly 47 minutes from the precise instant that the Moon entered the exact moment of its fullest extent, on March 27, 1964.

Considering what could account for such a series of occurrences on the North American western coast from Southern California to British Columbia requires vision that takes the focus far afield. An anomaly of geography places the San Andreas and Cascadia fault lines (the boundary between the Pacific and North American plates) almost equidistant from the far edges of those same plate boundaries on the other side of the Earth. The author has posited that at dawn and/or dusk West Coast time during new and/or full moon phases, while tidal forces would be at their maximum at those distant locales, the effect could be translated to produce small changes in the frictional equilibrium under Southern California. Not just earth tides themselves, but the resultant shifting of trillions of tons of ocean water could be a real leveraging device to provoke seismic results in fault lines that might be under stress and about to fail in any event. Even minute adjustments on the San Andreas and Cascadia could have repercussions on a fault zone that runs north and south for the most part and would receive those forces laterally.

California's large population centers range along the San Andreas Fault Zone, with a varied calculus of seismic risks posed to each by their respective locations. San Diego, by virtue either of fortuitous happenstance or perhaps due to some as yet undiscovered dynamics, has a relatively quiescent seismic record in contrast to other California cities such as Los Angeles and San Francisco. This long history of comparative calm has engendered an understandable attitude among that city's residents that puts earthquake worries a bit further down the list on the catalog of concerns. There are, however, certain segments of the San Andreas that should nonetheless garner the attention of the citizens of San Diego, Los Angeles, and indeed, all residents of Southern California.

In the late 1970s, Dr. Kerry Sieh and his colleagues dug trenches across Pallet Creek in California and took samples from ruptures in the layers of peat. The seismologists were able to prove that the disturbances in the peat were the vestiges of ancient



San Andreas Fault. Author's collection.

earthquakes transpiring on the San Andreas Fault. That the deeper breaks corresponded to the older earthquakes was apparent. Thanks to radio carbon-14 dating, however, a much better appreciation of the age of each offset in the peat layers (and hence the date of the earthquake that caused it) was established.

Geologists Tom Fumal, Silvio Pezzopane, Ray Weldon, and David Schwartz dug similar trenches across a creek near Wrightwood, California, more recently. They were able to determine, using the same methods as Dr. Sieh that twelve “Big Ones” occurred on the southern sections of the San Andreas Fault in the last 1,300 years. The results were published in *Science* (1993), with the authors concluding in the final paragraph that “the data shows that for the last five earthquakes on the southern San Andreas Fault northeast of Los Angeles the recurrence interval has averaged around 100 years, significantly shorter than the 132 years reported by Sieh, et al., and the elapsed time of 135 years since 1857.”

Proximate estimates of periodicities on the San Andreas Fault have at least then been sketched and published in peer-reviewed scientific journals, giving an inexact answer as to when great ruptures might take place. Determining the locations more prone for such occurrences might also be regarded as a task not that far removed from the realm of plausibility, as seismologists have been pointing for a long time at the exact stretches of the fault line where a great quake might more likely be seen to occur. Unfortunately for the population of Southern California, the most worrisome lengths of the San Andreas are the very segments closest to one of the most densely populated areas in the United States.

Seismic Gap theory is the idea that if a certain segment of a known fault is observed to have remained quiescent over a long period of time, it is reasonable to assume that portion of the fault line to be locked tight. As time goes on the tension only increases in these locked segments, as do the probabilities for an eventual seismic explosion. Data regarding the normal rate of movement between the plates in question, the size of the earthquakes usually produced, and the history of seismic activity all along the length of the entire fault line give seismologists a way to roughly forecast where the next temblor might occur. A group of scientists did just that with regard to the San Andreas Fault in the 1980s. The Working Group on California Earthquake Probabilities studied the lengths of the fault and published probability estimates connected with the likelihood of a large earthquake being produced in each segment. The map that follows shows where the Working Group established the highest hazard warnings: the Mojave and Coachella Valley Segments.

The figures speak as starkly as the map: a 33 percent chance for seismicity on the Mojave Segment between 1988 and 2018, and an almost 50 percent chance for the same on the Coachella Valley Segment. (Only the very short Parkfield Segment had a higher hazard rating).

In recent years a more transparent tenor has been adopted by civil and scientific authorities regarding this matter. The *Los Angeles Times* reported on April 13, 2008, in an article entitled "Likelier Here: the Next Big One" that the United States Geological Survey (USGS) was predicting that Southern California "stood a much greater chance of a huge temblor than Northern California," and quite outside the bounds of this agency's usually reserved statements, declared that the temblor would be "virtually certain" to strike before 2028.

If such an earthquake is virtually certain to strike, and within the next few years, what might reasonably be expected to happen when it does? The conservative scenarios are enough to cause anyone living in Southern California to re-read their earthquake preparedness pamphlets. According to USGS's figures, a 7.8 earthquake on the San Andreas near Greater Los Angeles should shake the entire region for a mind-numbing duration of three full minutes. Some freeways will come down; some high-rise buildings will collapse. Injuries could be in the range of 50,000 casualties, absolutely swamping hospitals throughout the Southland, and deaths might be in the range of 1,800 fatalities. About a thousand of those deaths should result not from the earthquake itself, but from the 1,600 fires that will rage out of control, immediately stretching Southern California's firefighting apparatus to the breaking point and far beyond.

This, however, is not the "worst case scenario" USGS geophysicist Kenneth Hudnut cautioned, but only one with a "plausible narrative that would have major consequences." The San Andreas Fault is capable of producing earthquakes bigger than 7.8. The sections of the San Andreas in question, abutting Greater Los Angeles, have been loading more and more seismic energy, century after century, and yet still have not ruptured. USGS says it is "primed to break." Indeed, that is an apt description. It is estimated that the last seismic relief along some stretches of the fault line was around 1690, which is some duration of time. Insofar as San Diegans are concerned, and especially those residents in the northern and eastern sections of the county nearest to the Coachella Valley segment, it might be well to put into historical perspective how long it has been since that section has sundered. Some estimates actually date the last event on the sector of the San Andreas nearest San Diego at a time just before Columbus landed.

No power on Earth or elsewhere is going to impede the unstoppable progress of two incomprehensibly massive plates. That, however, is no reason for West Coast residents to wait passively for the inevitable. The human race has faced down far greater foes than the San Andreas, and been bested by none of them. The bubonic plague depopulated whole continents in its time, yet is to be found now on the verge of extinction, hiding from our antibiotics, infecting the odd rodent here and there on the Eurasian steppes. It is much the same for a long

list of former terrors that used to hold us in thrall but have since been forced to surrender to the implacable courage and intelligence of our forebearers. It is hoped that Californians will make their opinions known in Sacramento insofar as convening the appropriate body of experts to pass judgment on the data published in this paper. The first tentative steps toward a rudimentary seismic advisory may be the result if, after formal investigation, a verdict of viability is returned. The greatest weapon any enemy possesses is that of surprise. Such an advisory would at least give a modicum of defense, so that when the San Andreas or some ancillary fault radiates its next burst of city-shattering power into some sleeping community on the West Coast in the quiet hours around dawn, it may be that some of the citizenry will be found awake, prepared—alert.

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