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ENVIROMENTAL PERILS
SAN DIEGO REGION

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HOW COMPLETE IS THE PRE-INSTRUMENTAL RECORD OF EARTHQUAKES IN SOUTHERN CALIFORNIA?

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Abstract

Instrumental earthquake catalogs for southern California begin in 1932; before that time most data come from felt reports. Because of the rapid growth and uneven distribution of population, the usefulness of these for detecting and locating large earthquakes is very complex. To look at this more closely, this paper examines the question of how late the intensities computed for certain earthquakes on the most active faults could have escaped being recorded. From about 1790 (the beginning of substantial buildings by the missionaries) to the American conquest, what earthquake reports exist are largely a by-product of Hispanic colonial bureaucracy (with fewer in the Mexican period); after 1850 the newspaper and the weather observer (both greatly increasing in number in the 1880s) become a reliable if sparse source of data, though ones not always used in the existing catalogs. The intensity patterns reported for the earthquake of 8 December 1812 are consistent with the location on the San Andreas found from tree-ring studies, and shows what size event would have gotten into the early records. Events of magnitude 6.5 on the southernmost San Andreas, or the Anza segment of the San Jacinto, could have escaped notice as late as 1870-1880, but probably would have been recorded (albeit with too little information for a clear location) at dates after this.

1. Introduction

Because the time-span of instrumental earthquake records is much shorter than the time required for a complete record of large events, we often wish to extend any catalog further into the past by using felt reports of shaking. Even if very incomplete, such reports can demonstrate that some region now aseismic has experienced large earthquakes in the past, and so might again someday. From sufficiently complete reports we may construct an extended catalog, though to use such a catalog in a statistical study of seismicity we must be able to estimate its completeness at different magnitude levels. My goal here is to make such an estimate for southern California, though looking not at overall completeness but rather at completeness for different specified sources.

The motivation for looking at completeness in terms of sources comes from the development of time-dependent forecasts for faults in California, first by Sykes and Nishenko (1984) and later by the Working Group on California Earthquake Probabilities (1988, 1990). A parameter needed for such forecasts is the time since the last large ("characteristic") earthquake on some part of the fault. Sometimes the time of the last earthquake is known from a catalog or from paleoseismic studies; but if it is not, the question then arises of how recently any particular characteristic earthquake could have happened without appearing in any existing catalog. As we will see, "appear" can have two meanings; given the geographically uneven distribution of population in southern California, felt reports may well show that an earthquake has occurred, but be insufficient for us to estimate an unambiguous location.

Establishing the completeness of felt reports is always a multi-disciplinary exercise (see Ambraseys and Melville, 1982, for an exemplary study) and this one will be no exception. My primary goal is to show how to estimate latest possible dates for specific earthquakes, with southern California being a particular example; but in order to make the example fully useful I have treated the historical issues in some detail, both because these are unfamiliar to most scientists, and because only through the details of the history is a proper understanding of the issues possible.

The methodology I shall use is to predict the intensity pattern for the earthquake being considered, and then try to judge how likely it is that, at the places where records were kept at some date, the fact of shaking would have gotten into them. If the shaking might well not have been recorded, we may say that the earthquake could have occurred as late as this date. There are obviously two parts to this procedure: one is the seismological problem of predicting intensities, which I discuss in Section 3, and the other is the historical problem of records creation and preservation, to which I now turn.

2. Sources of Information

In order for a report of earthquake shaking to appear in a catalog, three steps have to occur: the report must be written down, the record thus made must be preserved, and the record must be used by a catalog compiler; these steps of course can sometimes be conflated, as when a cataloger records direct oral testimony. I begin by discussing what sources were created and preserved (whether previously used on not), and how well these sources probably record earthquake shaking; this discussion is set within a brief narrative of California history, needed if the development of different records is to be understood. I then turn (Section 2.3) to how previous compilers have constructed their catalogs.

From the nature of what we are trying to demonstrate, there is an asymmetry between positive and negative evidence: if a source mentions earthquake shaking there must have been some,[1] but if we wish to decide that the absence of historical accounts genuinely reflects the absence of an earthquake, we must be sure

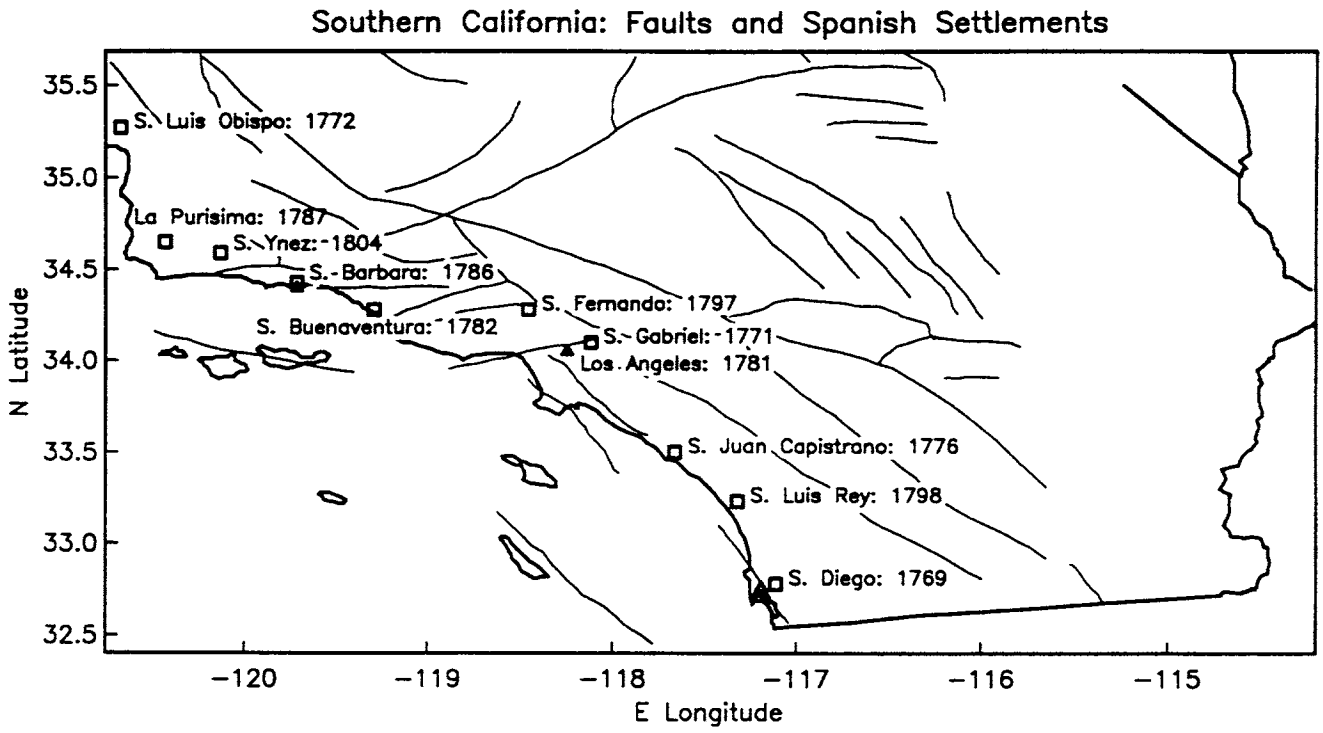

Figure 1. Southern California, showing faults (light lines), missions (squares), with the dates of their founding, and presidios and pueblo (triangle).

that the shaking could not have passed unrecorded, a more problematic judgement. The minimum requirement is that records were at least capable of being made at any time, which means that any place we are concerned with must at least have been continuously inhabited by literate people.[2] Occasional visits (e.g., documents from passing expeditions) cannot be used to rule out seismic activity, since even a short time after intense shaking there would be few signs of it in unsettled country. Of course, that records were capable of being made does not mean that they were; it cannot be overemphasized that in order to judge the constraints our sources place on shaking, we must constantly inquire why any document was created at all. If recording earthquake effects was irrelevant to the purpose of the document we should not expect it to be a source.[3] For the repetitive type of recording we are primarily concerned with, it is also important to know how frequently a source was created or added to; other things being equal, the more frequent such additions are, the better the recording of events such as earthquakes will be. We can expect lower intensities to be mentioned in a daily newspaper than in occasional letters from one of that newspaper's rural correspondents (a common method of news-collection during the nineteenth century).

2.1. Hispanic Period

For Alta California, continuous habitation by literate people begins with the founding of San Diego in 1769 as part of Spain's advance to the northwest.[4] Figure 1 shows the chain of missions eventually established, and also the two military posts (presidios) at San Diego and Santa Barbara, and one town (pueblo) at Los Angeles. The first few years were ones of simple survival, but by 1775 agriculture had begun to succeed (Archibald, 1978), making the missions largely self-supporting in food (though many other items had to be imported); indeed, thanks to their access to cheap labor (Monroy, 1990), farms and ranches held by the missions became the economic basis of California life into the 1820s. Partly because most land was controlled by the missions, but also because of the closing of the overland trail from Sonora by the Yuma uprising of 1781, there was little additional colonization, so that the pueblos grew only through natural increase and the addition of retired presidial personnel. Throughout this period California remained a sparsely-populated region (Figure 2), with a pastoral and agricultural economy that, while sufficient to afford a more than adequate supply of food,

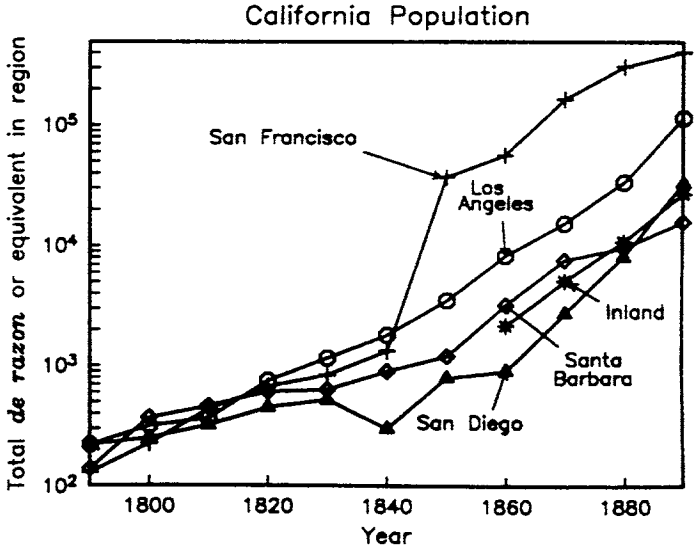

Figure 2. Population (non-Indian) of several regions of California, 1790–1890. The regions before 1850 are as used by Bancroft (1886), and for the period 1850 have been taken to match the pre-1850 ones as closely as possible. (For eaxmple, the San Francisco region includes San Jose). The Inland region is the area east of Los Angeles, basically unpopulated in the Hispanic period.

was not able to provide general wealth, partly because of the prohibition of trade with foreigners.

For us, the important question is what kind of earthquake records the inhabitants produced. The dominant factor is that, even among the *gente de razon* (the official term for the non-Indian population) the rate of literacy was very low. Most of the colonists were from the northern frontiers of Mexico, and, like frontiersmen everywhere, found little reason to pursue even an elementary education; and like many other early modern governments, the Spanish Crown did not necessarily regard the provision of such instruction as part of its task.[5] Those inhabitants who were literate usually put pen to paper for purposes demanded by their official position. A great many such demands were made, but, like those of any government, they were mostly concerned with administrative, commercial, and fiscal matters. The study of the natural world was viewed as at best a very minor concern; in this respect California was but a reflection of the scientific laggardliness of Spain in Europe.

A good example of the kind of bureaucratic documents produced is the series of annual reports of the missions. Perhaps because of their regularity and the presence of some earthquake data in them, these reports are sometimes assumed to be a kind of chronicle that can be relied on for earthquake data; but while they may be our best source of information the reason for this is somewhat complicated. The demand for annual reports first came from the Viceregal Council in Mexico in 1772; after some confusion a style was settled on by 1777 (Archibald, 1978), though, as I discuss below, reports from this early period have mostly not survived. The reports were prepared at the end of each year (they are usually dated 31 December or 1 January), and included a census and a report on agriculture, livestock, and buildings. The result was more like a present-day corporate annual report than any chronicle. The only reason why earthquakes were mentioned at all was the requirement to report on buildings: if these had been damaged and not yet repaired, this fact would be included in the report. We thus can expect earthquake shaking to be reported only if it caused major damage to a substantial structure, though late in the year minor damage might be reported as well. The same is true for the presidial annual reports. In the earliest years there were no substantial structures at either the missions or the presidios, many buildings being constructed from earth with tule roofs. Much of the change away from this to the style now associated with the missions came from the artisans whom the Crown imported in 1790 to train the mission Indians (Archibald, 1978), so that the lack of reports of damage before 1800 simply reflects the absence of many damageable structures.

The Spanish rule of California was eventually succeeded by the Mexican one; though California played no role in fomenting the rebellion against Spain, it was certainly affected by it. The first consequence was the disappearance of the annual supply ship from 1811 on. This made the military more dependent on the missions for supplies and tended to enhance the potential for contraband trade with foreign vessels (mostly Anglo-American) seeking sea-otter pelts (Ogden, 1941); while a number of logs from these survive, ships at sea are an inherently poor place to record earthquake shaking.[6] The Mexican period formally began in 1822 (Weber, 1982). It did not initially involve any major change in officials or reporting styles, but the ties to the central government definitely weakened with time. The Mexican government initially adopted a federal system, in which Alta California, as a territory, had less autonomy than the Mexican states. The governor appointed in 1831 was unpopular enough to provoke a local revolt; this behavior was continued when a more centralist administration took power in Mexico in 1836, leading some of the local populace to declare independence and start a series of insurrections, which lasted up to the American conquest. This instability of the government is very likely to have led to a decline in the regularity of recordkeeping.

The basis of the economy was much altered by the making of large land grants to individuals. Few such grants were made during the Spanish period, and not many more in the first few years of the Mexican era. Though Mexican law (unlike Spanish) allowed private grants, much of the best land was held by the missions (Cleland, 1951). This created much pressure to secularize them, releasing their lands (and their Indians). Although a law enjoining this had been passed in 1817 in Spain, before independence, California officials were slow to implement it because of the economic importance of the missions. For complicated reasons secularization was eventually done abruptly, in 1833-1834; their economic base lost, most missions soon fell into ruin (though their Indian population was already in decline). This of course meant the end of the series of mission annual reports. The mission properties were then re-granted to private individuals, leading to the (rather brief) rancho era in southern California; the resulting movement of the population onto these newly-available lands probably broadened the area over which reports of shaking might come—except that few rancheros would have had any reason, or probably the ability, to write such reports.

The Mexican government also liberalized the import-export policy, which allowed a significant trade in hides and tallow (Ogden 1927, 1929) and greater prosperity than had been seen before. This led to a greater foreign presence, and a wider circulation of California news, as is evident in the accounts of the 1836 and 1838 earthquakes collected by Louderback (1947), one of which came from Hawaii. The possible sources from 1833 to the American conquest in 1847 thus become much more diffused and more capricious in terms of their likely response to earthquake shaking; while extensive damage at Los Angeles, Santa Barbara, or San Diego would probably have entered the records somehow, it is not clear that anything less would have; and the years since 1850 have shown such shaking to be rare.

Having examined (very briefly) the nature of Hispanic California society and the likely earthquake records to which it would give rise, we also need to consider how these records have come down to us. Bancroft (1886, vol. 1) and Engelhardt (1913, vol. 2) give early summaries, still worth reading, of the sources, while Beers (1979) gives a very full and more current summary of archival records; Bowman (1982) has the most details on the official records. The records of the governments of Alta California were stored in several places, and most survived the American conquest; several collections of them were made, most fully in 1858 as an aid to adjudicating land-grant claims. This final collection, called the California Archives, was about 250,000 pages in about 300 volumes, including all types of government records: in Bancroft's words (1886, vol. 1, p. 46), "orders, instructions, correspondence and act-records of the authorities, political, military, judicial, and ecclesiastical; national, provincial, departmental, and municipal." Hubert Howe Bancroft had extensive transcripts made of the California Archives, in effect creating an abridged version of about 25,000 pages; some documents were copied in full, others abridged, while for others only the title is given; the best summary of the procedure is in Chapter 20 of Bancroft (1890). These transcripts were used in Bancroft's *History of California*. and now form the basis of all studies, since they survived the fire caused by the 1906 earthquake, but the original documents did not (except for

some land records). Most of the documents in the California Archives were not likely to record earthquake shaking; but these archives also included many of the mission and presidial annual reports as well as some other documents. No examination of what Bancroft did and did not transcribe (possible because titles of all documents were copied) appears to have been made; Bancroft (1890) stated that much of the compression was done by the omission of duplicates and verbiage, though Bowman (1982) characterizes the transcription as not very uniform.

While the California Archives were the largest single array of records created in Hispanic California, they certainly were not the only one; Beers (1979) lists many others. The most important is probably the archive of Mission Santa Barbara, where most of the mission records were collected; this archive also includes transcripts from the California Archives taken in 1904 by Fr. Zephyrin Engelhardt for his history of the missions. Geiger (1947) gives a list of the documents then present. Copies of mission documents in other archives (cf. Engelhardt, 1913, vol. 3, and Beers, 1979) are also often held in Santa Barbara.

The availability of mission annual reports is a good illustration of the vicissitudes of the records. Normally (Bowman, 1982) four copies of these were made, one being retained, and one each being sent to the Father-President of the missions (one of the missionaries, at whichever mission he was resident), the provincial Governor, and the parent organization of the California missions (the College of San Fernando in Mexico City). The papers of the College have been scattered, and those of the Governor became part of the California Archives. The other two copies were what could be collected at Mission Santa Barbara (the only one to survive secularization) by the Franciscans following secularization. This mission thus has a complete set of its own reports, starting in 1786, but for most of the other missions Geiger (1947) shows that annual reports are available at Santa Barbara only from 1810 through 1832, except for San Juan Capistrano, no reports from which reached that archive; though Geiger (1967) reports the finding of the reports for 1779 through 1795 in the Archivo General de la Nación in Mexico City.

The Santa Barbara archives, and many others, were transcribed by Bancroft for his history project; indeed, his extensive trawl through the documents was intended to be all-inclusive. (Bancroft, 1890 and Caughey, 1946, describe his collecting in detail.) This does not, of course, mean that Bancroft collected or transcribed everything there was; additional documents have since come to light, and there are a number of private collections (e.g., the Stearns MSS now in the Huntington Library) to which Bancroft had no access (Beers, 1979). What is important about the Bancroft collections is that Bancroft had them fairly thoroughly indexed by subject in preparation for the histories that he produced (in the cinematic rather than the literary meaning of this term); Bancroft (1890, pp. 238-244) describes the indexing process. Only through such an index was it possible to find occasional mentions of phenomena (such as earthquakes) in the mass of material available.

2.2. American Period

The American conquest of California, and even more the Gold Rush, changed the state drastically; though, as Figure 2 shows, much less in the south than in the north. The incoming Anglos were more often literate than the Hispanic inhabitants,[7] and, even more important, brought with them the belief (not always justified by events) that every town could support a newspaper, and also a government that regarded the recording of natural events as at least a small part of its activities. The newspaper and the weather observer now become the largest source of earthquake data, supplemented in a few cases by diarists and very occasionally by scientists.

Figure 3 summarizes the locations of the two main sources over the next forty years; detailed information comes from Dawson (1950) and Gregory (1937) for newspapers, and Darter (1942) and Pinkett *et al.* (1952) for weather records. Some historical background may help in understanding the trends shown here.[8] The Gold Rush created a second-order economic boom in the south, with the demand for beef increasing the sale price of cattle (the only local industry) by an order of magnitude. This prosperity lasted through the 1850s but in the next decade was ended by decreasing beef prices and the destruction of the herds by the floods of 1862 and the drought of 1863-64. The resulting financial crisis broke up the ranchos, and so created the seed for the agricultural developments that brought increasing growth through the 1870s and early 1880s, especially after a rail link to the rest of California was completed in 1876. The completion of a second competing link in 1885 touched off a railway rate war which in turn created the first of southern California's great real estate booms, from 1886 through 1888; the population of the Los Angeles area tripled between 1880 and 1890. This growth brought with it an increase in towns large enough to support at least a weekly newspaper, as Figure 3 shows. The one subsequent development of importance to earthquake reporting was the settlement of the Coachella and Imperial valleys; while the railroad line through this region was completed in 1877, settlement did not begin until the development of irrigation in the Imperial Valley and the discovery of artesian water in the Coachella Valley, both around 1900 (Mendenhall, 1909).

The newspapers that grew up with this increased population certainly viewed the reporting of earthquakes as part of their job, at least for those somewhat in the news business as opposed to being mere political organs. Very often newspapers would provide accounts of shaking in less-populated areas nearby (though with some delay as travellers and correspondents reported in), and the reprinting of items from one paper in another served to spread the initial reports wider and often to preserve them. Intensity V (felt by all) would almost certainly be reported in any daily paper, and very likely in many weeklies (especially if it was a slow week for other news); intensity VI would almost certainly be in both types. The accuracy of this reporting is of course another matter; just what "slight," "strong," and "severe" actually are usually admits of a wide conjecture.

The taking of meteorological data in 1850 was sponsored by two organizations: the Smithsonian Institution, which supported a large network of voluntary observers (though none in southern California), and the Army Surgeon-General, who had surgeons at Army posts collect weather data. There were from 1851 on several such posts in southern California, notably at San Diego, Fort Yuma and around Los Angeles (including Fort Tejon). A major change in weather reporting was the establishment in 1872 of a national weather service as part of the Army Signal Corps. This organization initially focused on rapid reporting from a few stations for forecasting purposes, rather than spatially detailed coverage; in southern California it operated stations at Los Angeles, Campo, San Diego, and Yuma. It also took over the Smithsonian's network of volunteers, most of whom then dropped out (something not visible in Figure 3 because there were no such observers in southern California to begin with), and collected the Surgeon-General's data as well. After 1880 the Signal Corps made more of an effort to get data from volunteers; this policy (continued by the Weather Bureau

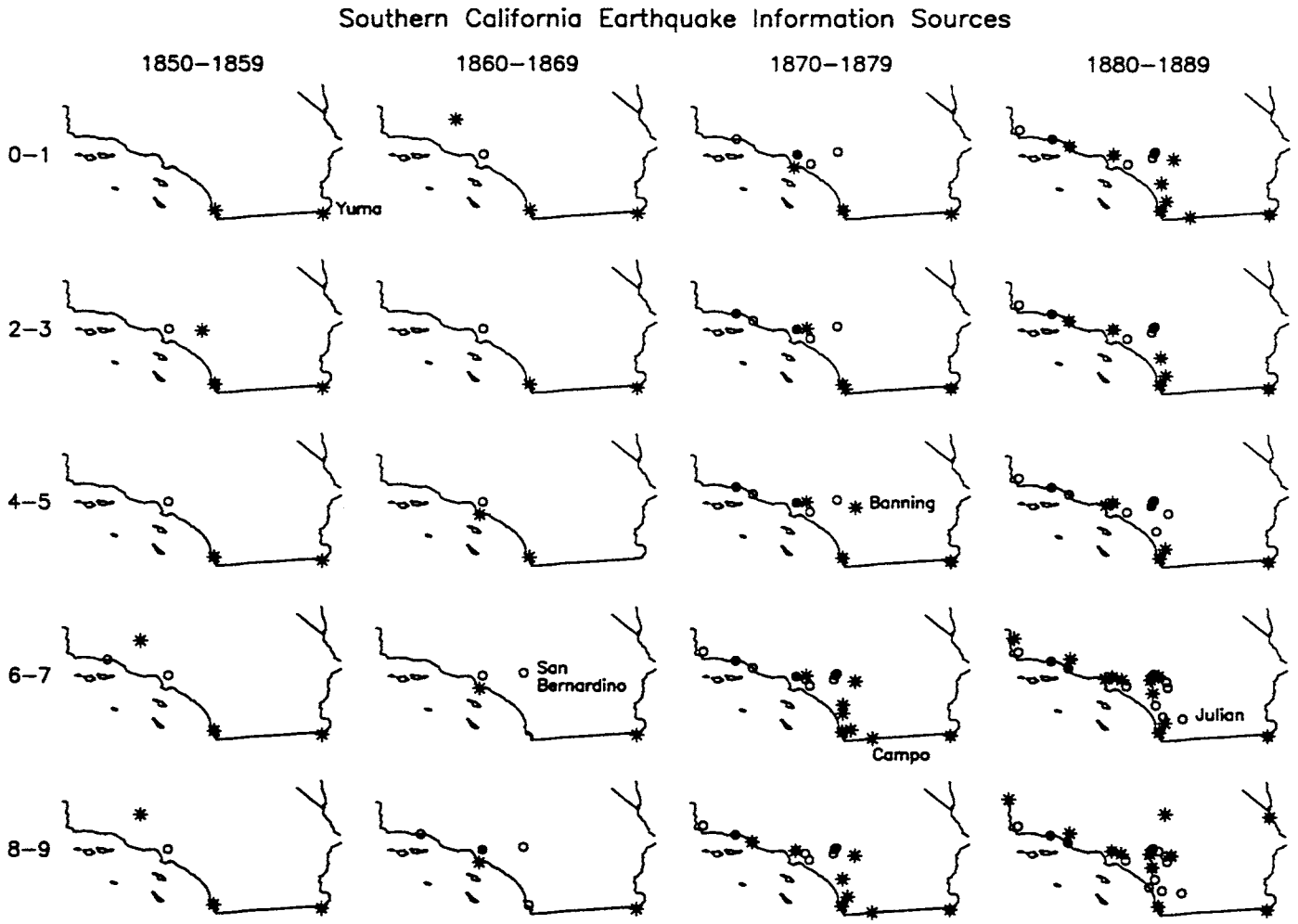

Figure 3. Locations of newspapers (open circles for weeklies, solid for dailies) and weather stations (stars) in southern California, 1850 through 1889, shown two years at a time. Only those operating for more than one year in each interval are plotted, and not all newspapers have been shown for the immediate Los Angeles area in the 1880's.

when it assumed the Signal Corps' function), and the real-estate boom of 1886-87, are the causes of the great increase in weather stations in the last four years shown.

Again, we have to judge what intensity of shaking would *not* be recorded by the weather observers. The forms filled out by the Smithsonian observers, and some of the Surgeon-General's forms, specifically requested earthquake information, while many of the other forms did not. Most weather forms however did contain space for general remarks, and most observers used this to put down at least brief notations about earthquakes. Most of these forms were preserved first by the sponsoring agency and later by the Signal Corps, the Weather Bureau, and finally the National Archives; they are available on microfilm. The regular stations also had daily journals in which to record events; these journals (now held in the National Archives) often provide fuller accounts of earthquake shaking than the terse comments on the forms. My own judgement is that shaking of intensity V or above would almost certainly have been recorded, and even lower intensities could well have been, depending on the alertness of the observer.

2.3. Existing Catalogs

Since 1927 felt reports of California earthquakes have been published by the Coast & Geodetic Survey (and recently the Geological Survey) in the series *United States Earthquakes*, and since 1932 an instrumental catalog is available. The available reports before 1927 were collected by Townley and Allen (1939) from a variety of sources. For the period after 1907 they relied on primary sources, a notable increase in which occurred in June 1914 when the United States Weather Bureau was specifically charged with collecting seismological data (Palmer, 1915), a task that was assumed by the Coast and Geodetic Survey in 1925. Townley and Allen could also benefit from studies of particular earthquakes conducted (after 1910) by members of the Seismological Society of America. For earlier periods Townley and Allen relied on previous catalogs: McAdie (1907) for years 1897 through 1906, and Holden (1898) for the years through 1896. While Townley and Allen altered some of the descriptions in these catalogs considerably, they did not attempt to rework these lists in detail, and so added very few earthquakes to those already listed. The same is true of the extremely valuable effort of Toppozada *et al.* (1981), which, while adding greatly to our knowledge of the larger earthquakes listed by Townley and Allen, avowedly used their list as a starting point.

My concern here is with the record before 1890, and thus with the catalog of Holden (1898); while an earthquake catalog might seem an odd project for an astronomer, such a task accorded well with Holden's bibliographical bent (Osterbrock,

1984). Figure 4 shows the sources Holden used, for all of California before 1850 and for southern California from 1850 through 1890. For the years from 1887 through 1896 Holden's catalog is basically a reproduction of the annual seismicity reports produced by staff members of the Lick Observatory and published as *Bulletins* of the U.S. Geological Survey. These bear the somewhat misleading title *Earthquakes in California*; a fairer indication of their coverage is given by the opening statement in them (e.g., Keeler, 1890), that the list of earthquakes

> contains all the shocks recorded or felt on Mount Hamilton, and all those reported to the Lick Observatory by letter, as well as newspaper reports of such earthquakes as occurred in the State during [the] year. No systematic examination of the newspapers has been made, however, and reports may have escaped notice.

Holden did not make use of the Weather Bureau observers in compiling this catalog; while he offered his records (reluctantly) to the Weather Bureau, he also made it clear that he saw no merit in doing so (letter from E. S. Holden to Cleveland Abbe, 1 April 1897, in the Mary Lea Shane archives, U.C. Santa Cruz). Indeed, Figure 4 shows that only newspapers were used as sources for the last few years of the 1880s; though Holden's data-collection efforts probably improved earthquake reporting around the San Francisco bay area, it is not clear that they did in the south. (It should be noted that the McAdie catalog for the 10 years following the end of Holden's (1897-1906) drew on a very different set of sources, since McAdie, as head of the Weather Bureau in California, would naturally have used its records.)

For the years before 1886 Holden drew mostly on previous compilations, without having gone very deeply into the primary sources himself. For the period from 1873 through 1885, he used the compilations of C.G. Rockwood of Princeton (Davison, 1927) and, for 1878 through 1886, earthquake reports of weather observers, which were at that time published in the *Monthly Weather Review*. For the 1850s, especially 1855 through 1860, a major source was the catalogs of John B. Trask, a California physician and amateur geologist (Leviton and Aldrich, 1982); Trask's records were less full for the early 1860s (during part of which he served a doctor in the Union army) and ceased in 1864. The 1850s also include a great many entries from the catalogs of Alexis Perrey of Dijon (Davison, 1927), who devoted much effort to compiling lists of earthquakes all over the world, though his scope often affected his accuracy for the worse (Vogt, 1991). Perrey's annual lists cover the years 1843 through 1871 with generally increasing completeness; I do not know why his list was less used by Holden for the 1860s than the 1850s.[9] From about 1860 to the early 1870s Holden had no published catalog (other than Perrey's) to draw on, and used primarily a list provided to him by H. H. Bancroft. Bancroft was also the source for most of Holden's entries before 1850, partly through this list but even more through the information published in his *History of California*. Holden also drew on a few other histories (notably that of Theodore Hittell) for this period.

Those of Perrey's and Rockwood's lists that I have examined do not give sources, though sometimes these can be guessed at from the nature of the report. For example, a number of Rockwood's lists for the later 1870s mention earthquakes felt at Campo; since this place (shown in Figure 3) was not then and is not now a center of population, but was from 1875 through 1882 a Signal Corps station, it seems likely that Rockwood used reports supplied to him by this agency. The most plausible source of information for Trask, at least for southern California, would have been newspapers, often as reprinted in the San Francisco newspapers, though on some occasions he made personal observations while on geological excursions through the state (as in Los Angeles in 1855); and his paper on the great 1857 earthquake (Trask 1858) shows that he sometimes made direct inquiries of local observers. Newspapers are the most likely source for Bancroft's list; as a historian, he found the newspapers to be source material but would have had no reason to collect the weather data. Bancroft compiled numerous books of newspaper clippings (Bancroft, 1886, p. xxx), one of which was devoted to earthquakes; I have examined this and found that many of its entries correspond to those in the Holden catalog. It

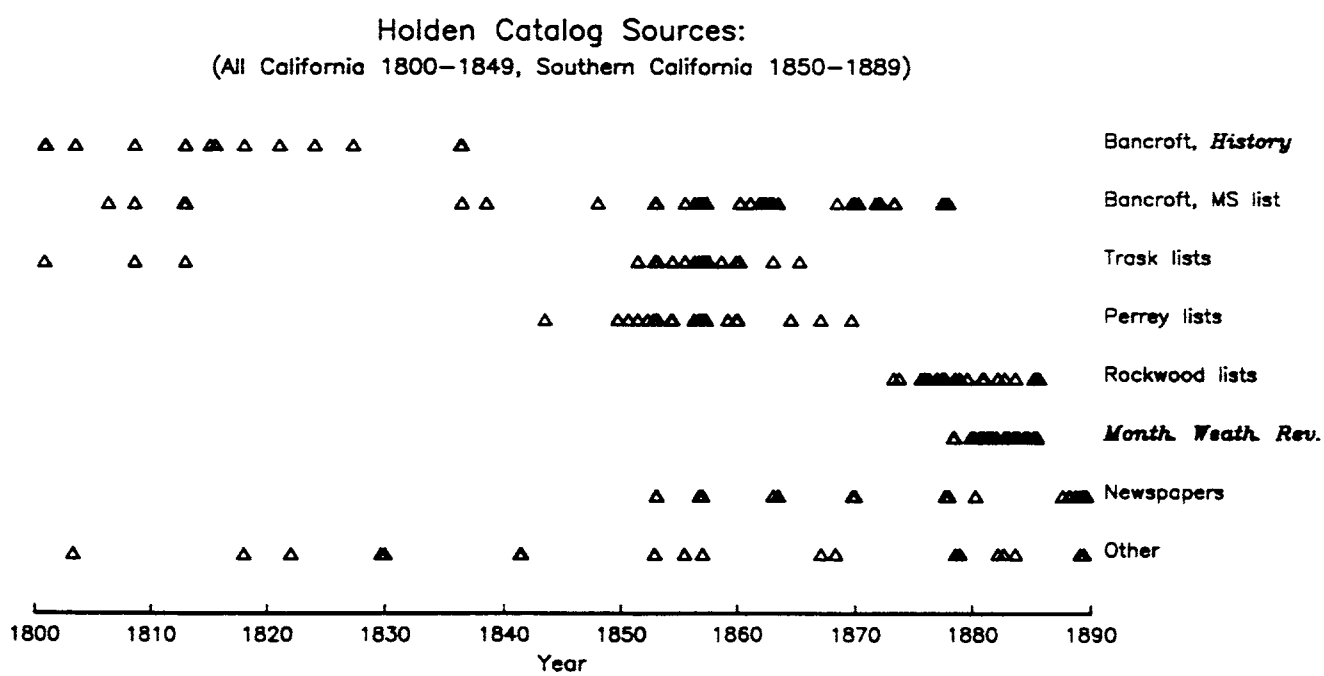

Figure 4. Sources of the earthquake data given in the catalog of Holden (1898). See the text for more information.

thus would appear that, for southern California at least, newspaper data were the primary source for 1850 through 1872 and 1886 through 1896, data from weather observers also being used for the years 1873-1885 and after 1897.

Fortunately we have a way of checking the completeness of the Holden catalog, in the form of the list of earthquakes felt in San Diego that was compiled by Agnew *et al.* (1979) from newspaper reports, local diaries, and data from weather observers. As Figure 3 shows, San Diego has had near-continuous coverage since 1851 from these sources; it is worth noting that extracting earthquakes from them was only practicable because the local newspapers had already been fully indexed for this period by staff at the San Diego Public Library, something that has not been done for any other place in southern California (Nunis and Lothrop, 1989). Table 1 gives the results for different reporting periods (as defined by Holden's use of sources); all of Holden's accounts are of course included in the later catalog.

This table shows that the reporting of felt shaking by Holden was about 50% for the whole of the later period of his catalog. The results for 1861-1871 are perhaps somewhat biased by the great number of aftershocks of the 1862 earthquake recorded locally; because of Trask's absence from the state, the only source for Holden was the Bancroft list (in this case perhaps partly drawn from the diaries of Judge Benjamin Hayes, a San Diego resident). The poor rate for the later 1880s is somewhat startling, and probably reflects Holden's focus, already noticed, on listing events around Lick Observatory. Most of the reports that Holden missed were of course of light shaking reported only from San Diego; but at least two large events were omitted as well. One of these (15 November 1875) destroyed adobes in the Imperial Valley, and was intensity V-VI at Yuma and IV-V at San Diego; the other was on 31 July 1891, centered in the Colorado Delta south of the international border, where it was very destructive, with intensity IV-V at Yuma and San Diego. In both these places local newspapers and the weather observers recorded both events, but the transmission to the final catalogs did not occur. This is probably a worst-case situation, since both events were in some of the least-populated areas of California; but it should serve as a warning not to assume that the catalogs, for all their numerous entries, have exhausted the sources.

3. Computation of Intensities

Having dealt at some length with the historical issues, I now turn to the question of how to compute the intensity of shaking for some hypothetical earthquake. The problem of estimating strong ground motion has of course been a subject of much research, and there are a variety of choices available. For this application the most logical one seemed to be an algorithm that computed intensity directly. One has been developed by Evernden *et al.* (1973) and Evernden (1975), with further refinements by Evernden *et al.* (1981) and Evernden and Thomson (1985). This algorithm has been extensively compared with observed intensities in California; it may thus be taken as empirically sound for predicting future ones.

Table 1. Completeness of the Holden Catalog (San Diego Area)

Dates	Number in Agnew *et al.*	Number in Holden	Fraction in Holden
1850–1860	17	8	47%
1861–1871	29	13	45%
1872–1885	35	24	69%
1886–1891	23	6	26%
1886–1896	46	24	52%

In computing intensities I have used an algorithm based on that found in the computer program used by Evernden *et al.* (1981) and Evernden and Thomson (1985), which I have verified by replication of a detailed intensity map given in of Evernden *et al.* (1981). Since the algorithm in this program is not exactly what was given in those publications, I first describe it. We assume a fault (planar or curved) of total length L, whose geometry is described by the latitudes and longitudes of N points; since each of these is assumed to radiate equal amounts of energy, we take them to be equally spaced. The magnitude of the earthquake is given by $M = 4.59 + 1.41 \log_{10} L$, and the intensity is calculated as:

$$I = 8.95 + 1.125 M + 0.75 \log_{10}\left[\sum_{i=n_1}^{n_2} (r_i^2 + C^2)^{-2k}\right] - 0.75 \log_{10} N$$

where r_i is the distance from the point of observation to the i-th point on the fault. The limits of the sum are taken to be all points within a distance of $DV/2$ of the one closest to the point of observation, D being an assumed duration for major shaking and V the rupture propagation. The parameters C and k (depth and attenuation) control the dieoff of intensity with distance. Following the usage of Evernden *et al.* (1981), I have used 10 seconds for D, 3.5 km/s for V, 25 km for C, and 1.75 for k.

The intensity I so computed is taken to be the Rossi-Forel intensity on water-saturated alluvium; adjustments for local geology are made by subtracting an offset from this amount that depends on the local materials (to a decrement of –2.5 units for granite or metamorphics), after which the value is mapped to Modified Mercalli units. These two steps treat intensity as a continuous variable rather than a series of classes; while this is a somewhat nonstandard approach, it seems to me a perfectly valid one, since one can imagine an infinite range of amount of shaking; the problem is that we can define only a few steps in the field. In the tables of intensities below I have rounded all computed values to the nearest half-unit; while this is certainly finer resolution than any historical data permit, it should help in comparing intensities between places. Summaries of the different intensities are that IV means felt by some people; V means generally felt, with no damage to buildings; VI means felt by all, with some panic and minor cracking in adobe or weak masonry (the only kind present in southern California before 1900); VII means significant damage to such structures, and VIII very serious damage, perhaps total collapse (Richter, 1958).

4. Case Histories

I now turn to an examination of several specific events. One could consider a large number of hypothetical earthquakes, but for most faults the restriction on latest possible date that might be found would have little effect on any time-dependent prediction. For example, for the Rose Canyon fault, with a repeat time in the hundreds or thousands of years, it matters little whether we say that the last earthquake was in 1750 or 1850. I therefore focus on the two most active faults in southern California, the San Andreas and the San Jacinto. I begin with an earthquake known to have occurred to show the ambiguity of historical data on shaking, then progress to one less well-known, and conclude with three hypothetical events.

4.1. Earthquake of 8 December 1812

It has long been known that southern California experienced severe earthquakes in December 1812. Holden (1898) had some account of this, drawn largely from Bancroft's *History*, and this was corrected by Townley and Allen (1939) using the materials published by the historian of the missions Fr. Zephyrin Engelhardt; but no one seems to have published the original accounts prior to Toppozada *et al.* (1981) having done so. These are exceptionally full, very probably in part because many of the documents (the required annual reports) were written within a few weeks of the events. Had these earthquakes occurred in February we would probably know much less about them. I shall not discuss (except as in note 6) the second of these events, on 21 December, which was probably located in the Santa Barbara channel; the intensities from it have been studied by Evernden and Thomson (1985).

The event of interest is rather one which occurred on 8 December. It was long remembered because of the loss of life (forty) it caused through the collapse of the great stone church at Mission San Juan Capistrano. The main source on this is a transcript by Engelhardt (1922) of a report written by the resident mission fathers that was in the California Archives, according to which the damage was caused by the fall of the tower onto the church, causing the nave to collapse. (The tower was 125 feet high, according to information gathered by H. L. Oak in 1874 (Axe *et al.*, 1981), and at the southeast end of the church, over the entrance.) There is good evidence that this damage was in part due to exceptionally poor construction; the master mason brought in to train the Indians died in 1804 and the nave was constructed after this. The roof over the transept and the main alter did not collapse, and indeed was still standing in 1850 (Kelsey, 1987); some of the vaults were blown down by gunpowder in 1865 (Weber, 1976). At San Diego and San Luis Rey there was no damage, according to the annual report of the San Diego presidio (within whose district these missions fell); the San Luis Rey annual report is silent on the subject, and that from San Diego merely says that the new church will be completed despite the earthquakes. The San Gabriel annual report describes fairly severe damage, though short of collapse.[10] That from San Fernando mentions the need for beams to support the church walls, though since it gives no dates it is not clear what event it is referring to. (It is telling, but consistent with the previous discussion, that though the intensity must have been high at the pueblo of Los Angeles there are no reports from there.) Reports from the missions further west and north are dominated by the events of 21 December, though the Ventura report may refer to both events, and there is some evidence that the 8 December event was felt as far away as Mission La Purisima.[11]

The first studies of this earthquake (e.g., Richter (1958), Toppozada *et al.* (1981)), impressed by the damage at San Juan Capistrano, assigned a source near that point. The most thorough attempt to model the observed intensities was by Evernden and Thomson (1985), who included the local ground factor at the different missions. They too concluded that a source near San Juan Capistrano would fit the data, finally settling on the southern half of the Newport-Inglewood fault zone. This eminently reasonable conclusion was soon challenged from an unexpected source: tree-ring studies. Jacoby *et al.* (1988) found 9 trees close to the San Andreas fault in the Wrightwood area (about longitude 117.7°) that showed disturbance between fall 1812 and spring 1813. The pattern of disturbance (seen only in trees right on the fault) implies a rupture in this area, and the temptation naturally arises to identify it with the earthquake of 8 December. Jacoby *et al.* made this identification, and Sieh *et al.* (1989) argue that this event is also visible in disturbed sediments at Pallett Creek and Mill Potrero, the latter being at the southern end of the Big Bend of the fault.

The question then is, are the intensities predicted for a rupture of this part of the San Andreas compatible with the events described in the sources? In Table 2 I give the intensities computed for the missions for three possible ruptures: one from Wrightwood northwest to Mill Potrero (more or less the "Palmdale" segment of the fault identified by the Working Group (1988)), one from Wrightwood southeast to near Yucaipa (more or less the "San Bernardino" segment), and one that includes both segments (the extent of rupture proposed by Sieh *et al.* (1989)). This table gives both the intensity on alluvium and that corrected for local geology; I have used the values of Evernden and Thomson (1985) for this correction, except at San Luis Rey, where the local geology is old alluvium rather than the Eocene sediments that they assumed.

The results in Table 2 show that a rupture to the north cannot give a high enough intensity at San Juan Capistrano to explain the damage there; even with the entire fault rupturing the intensity does not rise much above VI. This is at least not seriously inconsistent with the damage there, though we must assume that the church tower was very close to falling, with the earthquake being the final blow in causing a freak accident. A rupture of the San Bernardino segment does not seem to fit the reports; intensity VI½ at San Gabriel seems too small to explain the general damage there. Figure 5 shows the intensity for a rupture of both segments; comparison of this with Figure 1 shows how one-sided (in every sense) the data are. All this should serve as an object lesson in trying to interpret very sparse and often ambiguous intensity data; where such data seem to point may not in fact be anywhere near the true location.

4.2. "Dos Palmas" Earthquake

On 29 March 1872, following the Owens Valley earthquake, the San Francisco *Daily Evening Bulletin* published (p. 2) the following:

> At Dos Palmas, a water station on the southeastern side of the Colorado Desert, on the trail from San Bernardino and San Gorgonio Pass to La Paz on the Colorado river, four

Table 2. Ground Shaking from Possible Sources of the 8 December 1812 Earthquake

Segment	San Bernardino		Palmdale		Both	
Bounds	−117.0°/−117.7°		−117.7°/−119.1°		−117.0°/−119.1°	
Length	65		135		205	
Magnitude	7.1		7.6		7.8	
	Intensity					
	All.	Grd.	All.	Grd.	All.	Grd.
S. Diego	IV½	III½	IV½	III	V	IV
S. Luis Rey	V½	IV½	V	IV½	VI	V
Capistrano	VI		V½		VI	
S. Gabriel	VI½		VII		VI½	
S. Fernando	VI		VII½		VII½	
Ventura	V	III½	VI½	V	VII	V½
La Purisima	IV		V		V½	

Bounds are the longitude range of rupture along the fault. Intensities are Modified Mercalli, on alluvium and with the local ground condition applied (where this differs from alluvium).

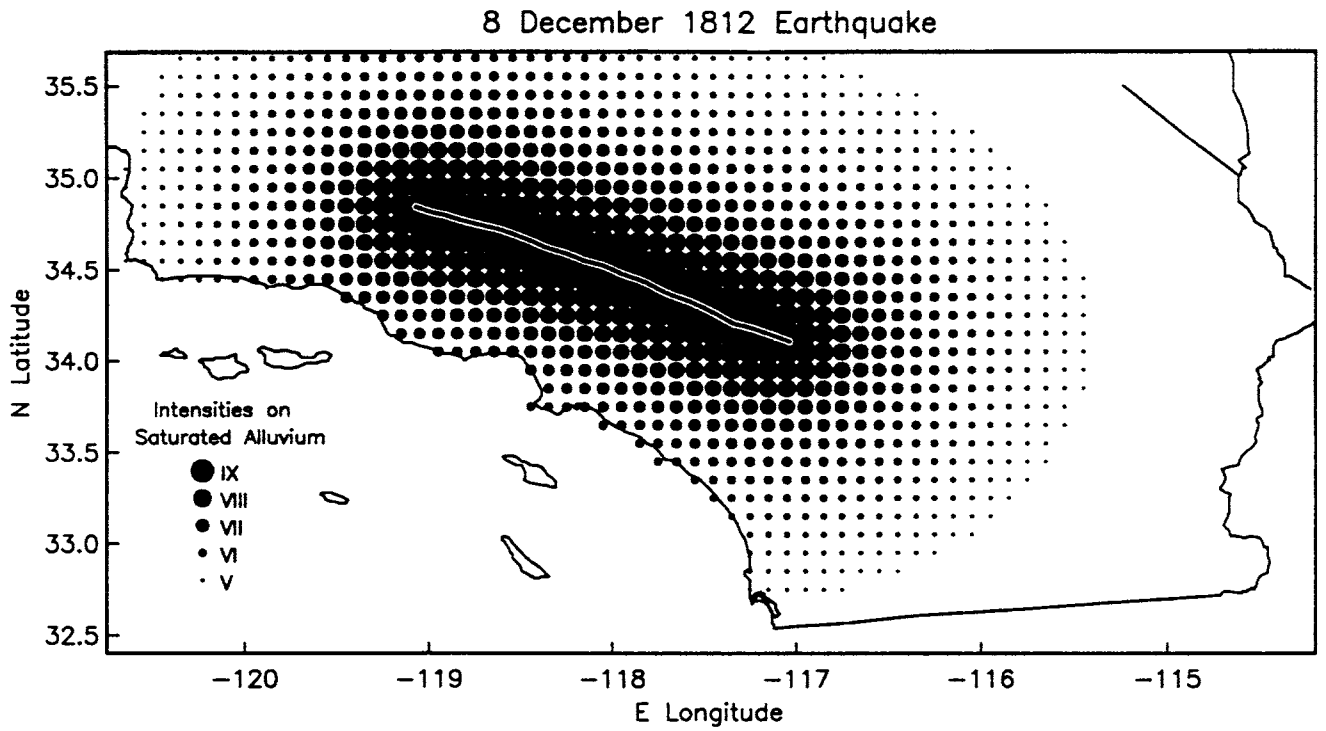

Figure 5. Intensity pattern for an earthquake on the south-central San Andreas fault, rupturing from Yucaipa to Mill Potrero. The rupture is shown by the black-on-white line. The intensities are Modified Mercalli, computed every 0.1° for saturated alluvium as described in Section 3, and are shown by dots of varying sizes. Intensities below V are not plotted.

> years ago in May, a severe earthquake–which was not felt in Northern and Central California–opened a long fissure in the earth, from which a stream of cold water flowed for some weeks. This fissure is but a short distance from the great hot spring at Dos Palmas, which is still flowing, but is said to have grown very much cooler since that event.

This account was duly repeated by Holden (1898), who added no information to it. The location of the earth crack is close to the southern San Andreas fault, nearly aseismic since the start of instrumental recording; the occurrence of even a moderate earthquake there would be of great interest. What, then, can we conclude about this event; in particular, could it have occurred with only this notice to show for it?

The first point to realize is that if a rupture were to occur on this part of the fault, Dos Palmas is where it would have been noticed. San Gorgonio pass and the northern Coachella valley were unfrequented until 1862, when a road was built through both to reach a gold strike in Arizona. Beattie (1925), Cowan (1933a), and Hoyt (1952) indicate that this road ran from the present-day Mecca southeast to Dos Palmas, and thus probably crossing the fault near the present North Shore Park (see Sieh and Williams (1990) for the location of this place). Regular stage service ran over this road; Johnston (1976), who gives the fullest account, states that the stage station at Dos Palmas was occupied in 1866-67 and again in 1870. This is not incompatible with the newspaper account just given; several years after an earthquake (or any other event) it is easy to get the number of years in the past incorrect (though the time of year is usually remembered correctly).

We thus have an event (possibly) on this part of the fault in the late 1860s; what records might we expect from it? Here, as for the 1812 event, our best constraints come from non-historical sources, in this case the study by Sieh and Williams (1990) of recent fault slip. They concluded that in the last 300 years there had been no more than about 0.5 m of slip along this part of the fault. The "Dos Palmas" event, if there was one, could thus not have been a great earthquake; on the other hand, a rupture 25 km long (the length of the 1987 Superstition Hills mainshock) could have produced this amount of slip–enough to produce noticeable surface features–and substantial shaking in the immediate vicinity.

Figure 6 shows the intensity distribution for such an event (parameters given in the caption). Figure 3 shows that the nearest places with records were San Bernardino and Yuma; at both the intensity on alluvium was IV½. We might thus expect that there would be no records, or at best marginal ones, of such an event; unfortunately, this is just the case. Neither the Yuma

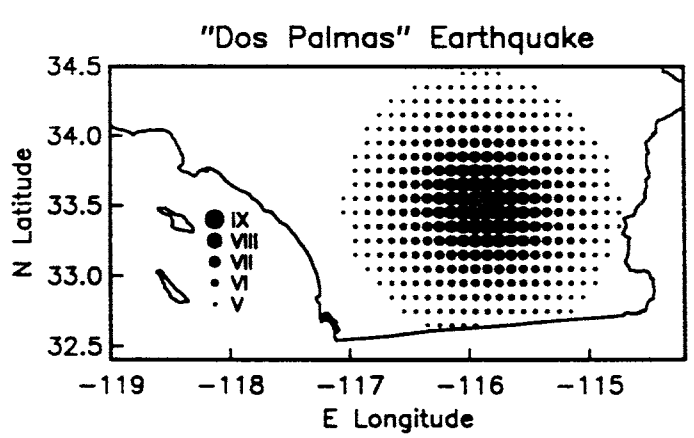

Figure 6. Intensity pattern for a moderate earthquake on the central part of the southern San Andreas fault (longitudes −116 to −115.8, length 24 km, magnitude 6.5). As in Figure 5, the intensities are those for saturated alluvium, computed on a 0.1° grid.

weather records (examined by myself) nor the San Bernardino newspapers (examined by Toppozada *et al.* (1981)) show any events in May 1868. The Yuma records begin in March 1866; from then through March 1872 the only earthquake report is of two light earthquakes on 5 September 1869. We are thus left with the conclusion that earthquakes of magnitude 6.5 could have occurred in this region into the 1870s without necessarily being recorded; even in Banning, the Dos Palmas event would have given no more than intensity V. In 1877 the Southern Pacific line to Yuma through the Coachella Valley was completed; given such a well-used route it is unlikely that magnitude 6+ earthquakes on this part of the San Andreas would have escaped notice after then

We thus have to leave the possibility of a magnitude 6.5 event here in the last century in the category of possible but not proven. Prior to the slip-rate studies of Sieh and Williams (1990) the same would have had to be said of a much larger event rupturing this whole segment of the San Andreas Fault. Such an event, with magnitude 7.4, would have caused intensities of no more than V½ at any of the missions (the highest being again at San Juan Capistrano), and so could easily have been unrecorded before 1850; even for some years after that, with intensities no more than V at San Diego, San Bernardino, and Yuma, it would have been hard to locate definitively. As this is the highest-probability great earthquake in southern California according to the Working Group (1988), I show as a matter of interest the intensity map for it in Figure 7.

4.3. San Jacinto Fault Earthquakes

Continuing with hypothetical earthquakes, I next discuss two events on the central San Jacinto fault. As was first noticed by Thatcher *et al.* (1975), this part of the fault lies between two areas of known rupture: the 1899 and 1918 events to the north and the 1968 Borrego Mountain event to the south. This section of the fault thus constituted a "slip gap" (as did a section further south, which ruptured in the 1987 Superstition Hills earthquake), with a relatively high probability of producing a large earthquake in the future. Thatcher *et al.* took the latest possible date for an event on this section to be 1890; the question then arises of how the information I have given above might change this.

Figure 8 (top panel) shows the intensity pattern predicted for an event rupturing all of this segment; I have extended it slightly further north than did the Working Group (1988), for a total length of 60 km and a magnitude of 7.1. Table 3 gives the intensities (on saturated alluvium) at a number of the locations named in Figures 1 and 3. Certainly in the Hispanic period this event could have passed unnoticed, and in my opinion might well have been missed even in the next decade; but after about 1860 or at the latest 1870 the growth of population in the inland areas was so great that it would have left some trace. Indeed, there are even possible candidates: notably a shock on December 16, 1858 (Toppozada *et al.*, 1981), which caused damaging shaking in the San Bernardino area, but is not reported elsewhere; it could, of course, have originated from a number of other possible faults.

However, as in the Coachella Valley, recent paleoseismological work may have put tighter constraints on the time of the last event than do the historical data. Rockwell (pers. commun.) has excavated a marsh at Hog Lake, in this segment of the fault, and found no sign of any rupture in the last few hundred years. This would appear to rule out the event just described, though of course the Loma Prieta earthquake has shown that ground rupture can be absent even for magnitude 7 events. I therefore also consider, as with the "Dos Palmas" earthquake of the previous section, a smaller event, rupturing from Hog Lake south. Table 3 again gives some spot intensities, which are mapped in Figure 8 (lower panel); I term this the Anza "seismic gap" earthquake because it would fill in an aseismic area that occupies part of this section. This event would have created newsworthy shaking, though only just barely, in San Diego, San Bernardino, and Riverside; it might have been ignored in 1870, but probably

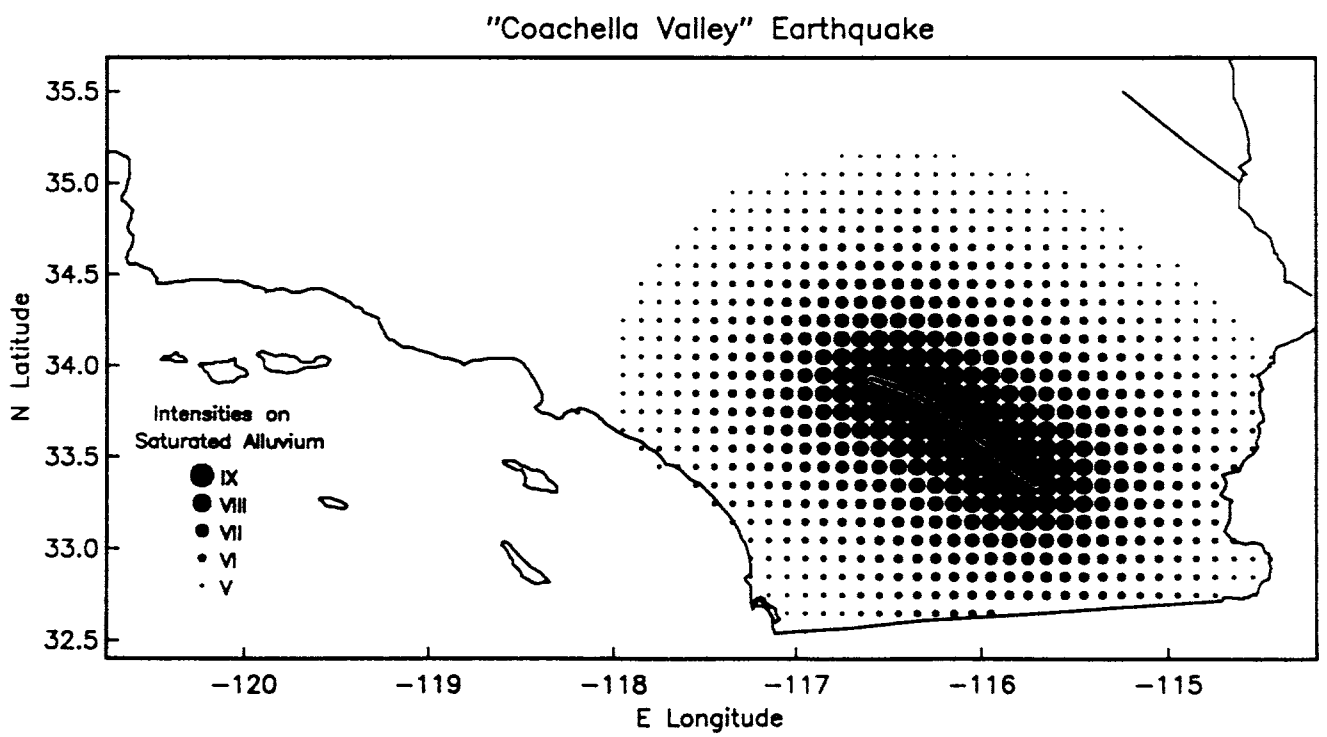

Figure 7. Intensity pattern for an earthquake on the southern San Andreas fault, with the rupture from Whitewater to Bombay Beach (longitudes -116.6 to -115.7, length 105 km, magnitude 7.4). Intensities as in Figure 5.

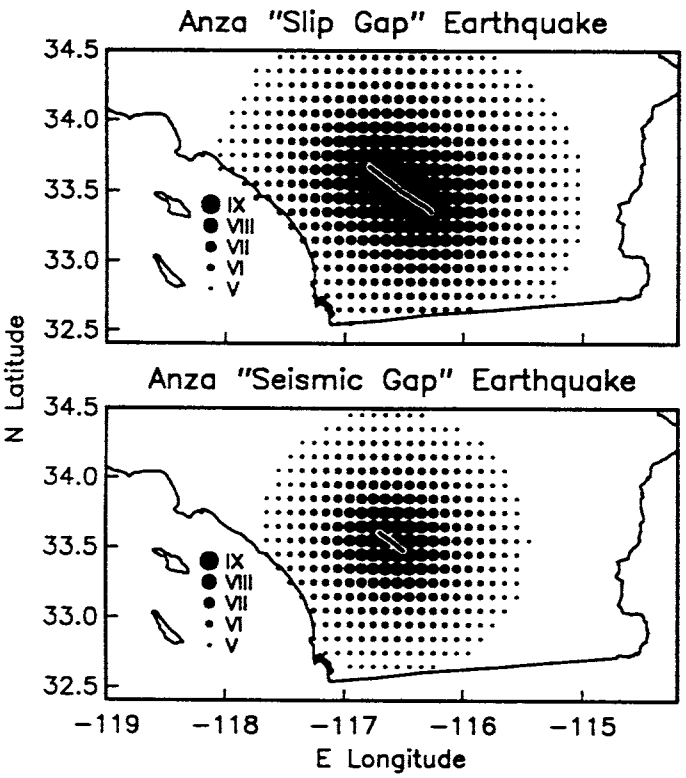

Figure 8. Intensity patterns for earthquakes on the central San Jacinto fault. See the text, and Table 3, for details.

would have been recorded in 1880. Whether it could be identified is another matter; indeed, there are events on 9 February 1890 and 28 May 1892 which might be consistent with a source of this type, or even a little larger.

5. Discussion and Conclusions

To summarize, how complete may we feel the present catalogs to be, and how much more might be found?

I would hope that the previous discussion has shown that any general statement of catalog completeness is simply not possible unless applied to limited areas: what we can say about (for example) the city of Santa Barbara in 1800 we cannot say about the Coachella Valley until roughly 70 years later. My own belief is that though not all of what may have been recorded has been included in the existing catalogs most of the larger events have been–and for the smaller ones the 60-year span of instrumental data now available is infinitely preferable to any collection of felt reports. How late a larger event could occur and not be recorded depends, as we have seen, on where such an event is, with one exception: given the poor preservation of the records and (even more) the state of the buildings, I would not expect any event before about 1790 to have left any record.

As far as collecting further information goes, one of the aspects of dealing with the past is that it doesn't change much–though our interests in it, and our interpretations, often do. Our options for enhancing our knowledge of past earthquakes, and in particular for improving the kind of limits discussed here, are thus more limited than in most normal scientific research. For the Hispanic period our knowledge remains basically dependent Bancroft's *History*, and thus on what his assistants indexed in the 1870s. While we might wish for more documents, the number in existence is so large, and the fraction of mentions of earthquakes so small, that a complete re-investigation of them would be an immense task with no certain reward. A focused search might be possible, but would require the aid of those expert on this time and these documents.

For the later periods the bulk (in newspapers) is even larger and less easily assimilated in the absence of indices. Perhaps the most easily performed extension of previous work would be to go through the weather records completely for all mentions of earthquakes; because of the nature of these records, this would be a large but not unmanageable task. Some searches of diaries might also be useful, though diarists are somewhat uneven recorders.[12] Any events found could then be checked against the existing catalogs, or newspapers, to see if they are purely local or the kind of widespread but low intensity produced by some of the events we have considered. This might yield a few large but currently unmissed earthquakes, and thus improve the most important part of the catalog at minimal effort.

Table 3. Ground Shaking from Possible Earthquakes of the Anza Area

Longitude Range	−116.26° to −116.80°	−116.49° to −116.70°
Length	60	23
Magnitude	7.1	6.5
	Intensity	
San Diego	V½	V
Los Angeles	V	IV½
Yuma	IV½	IV
San Bernardino	VI	V½
Banning	VII	VI½
Campo	V½	V
Riverside	VI	V½
Julian	VII	VI

All values are for saturated alluvium.

Notes

1 For nineteenth-century southern California there are no obvious sources of spurious shaking or sounds which could be mistaken for earthquakes, of the type that Fujita and Sleep (1991) have shown to dominate the Michigan catalog. Hoaxes and tall tales are a possibility, however. For example, the San Diego *Herald* of 17 April 1852 contained a report that on 12 April, an "adobe house, with a tiled roof, situated near the Plaza at Old Town, was destroyed by" a "very severe shock" that "continued some thirty seconds". This earthquake is not mentioned in any other source, nor is any other damage mentioned, so either this account indicates especially poor construction, or the whole thing is some kind of now-obscure local joke.

2 Except for a vague reference to an Inyo event around 1790, no Indian accounts of earthquakes have been used in the existing catalogs, and it does not seem likely that such accounts would be useful for estimating times of earthquakes because of the lack of accurate dates characteristic of most oral tradition (cf. Finley (1965) for some relevant remarks about this aspect of Greek epics, and Monroy (1990) for the concept of time amongst the California Indians). Chief Francisco Patencio (1943) of the Desert Cahuilla tribe (near Palm Springs) recounted in 1939 a tale of a very great earthquake which occurred when he was very young; from the other biographical information there given, he must have been born in the 1850s, so that this could be an exaggerated account of the 1857 Fort Tejon event. It is notable that he also indicates that the Cahuilla remember three inundations of the Salton Sink (before the Salton Sea); the chronology of Waters (1983) shows just this number of Lake

Cahuilla fillings and complete dessications since A.D. 1, evidence that the Cahuilla tradition, even if lacking dates, could be accurate over remarkably long times.

[3] I do not think intentional bias is a major problem in the sources. Though there may have been some attempts by the newspapers to downplay earthquakes in the name of boosterism, most newspaper reports that I have seen do not hint at this problem; the reporting of earthquakes in California was never the politically difficult issue that the reporting of eclipses in China may have been (see Needham, 1959, pp. 417-420 for a discussion of this topic). Rowntree (1985) discusses possible biases in mission reports of droughts, some of which may also have applied to earthquakes, both being convenient examples (when appropriate) of the wrath of the Creator.

[4] Nunis and Lothrop (1989) provide a summary of the literature for this and other periods, and some guidance to the archives as well. Two books that are especially valuable in placing Hispanic California in the context of northern New Spain and Mexico are Bannon (1974) for the Spanish period and Weber (1982) for the Mexican one; the latter has full coverage of social and economic issues. The recent book of Monroy (1990) sets the social atmosphere of the Hispanic era most usefully, while Archibald (1978) is basic for the economic workings of the missions.

[5] Bancroft (1889) discusses education in Hispanic California. Several schools were founded in the years 1795-1799 in response to a Viceregal directive, but all lapsed within a few years. Only one was founded in the years from 1800 through 1820. Under the pro-education policies (and greater prosperity) of the Mexican regime, more were begun in the 1820s with the largest number starting in the 1830s (see also Weber (1982), pp 230-235).

[6] One debated piece of evidence for the offshore nature of the earthquakes near Santa Barbara on 21 December 1812 is the persistent tale of a ship that was carried ashore and back out by a huge wave. Bancroft (1886, vol. 2, p. 268) comments that a newspaper account of this, in which the captain's name was given as George Washington, was probably due to Alexander S. Taylor, renowned among historians of California for his fancifulness (Cowan, 1933b). There was in fact a ship, the *Mercury*, captained by George Washington Ayres (also spelled Eayrs) along the California coast in the years 1812-1813, but Ogden (1941) indicates that she was at Sitka in December 1812.

[7] Weiss (1978) has shown from census records that the literacy rate of the adult Latino population of Los Angeles in 1850 was 40%, and 20% for adult Latinas; for Anglos the rate was essentially 100%. While the definition of literacy used is unknown (and probably not very demanding), there is no reason to suspect bias in its application.

[8] The best general introduction to the history of southern California until 1880 is still Cleland (1951), though Monroy (1990) is also useful. Dumke (1944) gives a full description of the boom of the later 1880s. For the history of newspapers Kemble (1962) gives a good summary of the whole state for the first few years, and Dawson for southern California for the years up to 1875. Rice (1947) is an extremely valuable discussion of the leading (and often sole) Los Angeles newspaper of the 1850s, with much useful information on how such a newspaper was run and what it printed.

[9] Perrey retired from his post at Dijon in 1867, moving to Lorient, where he had much poorer access to libraries. He attempted to make up for this by contacting local correspondents directly, usually with improved results (Davison 1927); it may be that he was unable to find such a person for California, causing his records for that region to become less full.

[10] A number of writers have mentioned severe shaking from this event in the San Bernardino area; for example, Toppozada *et al.* (1981), drawing on Crafts (1906) as a source. The latter is however (for this story) a direct copy of Caballeria (1902), in which the earthquake is said to have caused an Indian uprising that destroyed a chapel established by the Dumetz expedition in 1810. There is no evidence for this beyond Caballeria's account, which Harley (1988) has shown is almost certainly a fabrication, including the sources used; though it was adopted (warily) in the standard history of the area (Beattie and Beattie, 1951), it was not accepted by the most knowledgeable student of the subject, Fr. Engelhardt.

[11] Bancroft (1886, vol. 2, p. 367) mentions this in a footnote, giving as the source a 22 December 1812 letter from Fr. Mariano Payeras, with the reference being *Sta. Barb. Arch*, vol. 6, pp 185-185, along with the mission annual report. However, the annual report of 31 December 1812, (copy supplied by the Santa Barbara Mission Archives; their document number CMD 941) mentions only the damage to buildings at La Purisima. This leaves the letter cited by Bancroft as the only source, but the calendar of documents in the Santa Barbara Archives (Geiger, 1947) shows no such letter. (It does however mention a transcript of a letter from Payeras on 31 December 1812 (#590); I have not seen this, and do not know whether or not it is the source of Bancroft's statement.)

[12] The diary of Jacobs (1974) is a good example; it covers the period from June 1856 through February 1857, during which San Diego twice experienced intensity V shaking. Even though the diary covers some local events in addition to its primary theme of her forthcoming marriage, neither case of shaking is mentioned.

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