76.

PAGEOPH, Vol. 135, No. 2 (1991)

0033–4553/91/020261–99$1.50 + 0.20/0

Intraplate Seismicity of the Pacific Basin, 1913–1988

MICHAEL E. WYSESSION,[1] EMILE A. OKAL[1] and KRISTIN L. MILLER[2]

Abstract—We establish here a comprehensive database of intraplate seismicity in the Pacific Basin. Relocation and analysis of 894 earthquakes yield 403 reliable intraplate earthquakes during 1913–1988. These numbers do not include earthquake swarms, which account for another 838 events. Most of the remainder (304 events) are actually plate boundary earthquakes that have been erroneously located in intraplate regions. A significant number occur in recent years when location capabilities should have guarded against this situation. Relocations involve a careful linear inversion of *P* and *S* arrivals, accompanied by a Monte Carlo statistical analysis. We have also attentively removed the high number of clerical errors and nuclear tests that exist in epicenter bulletins.

A geographical examination of the relocated epicenters reveals several striking features. There are three NW-SE lineaments north of the Fiji Plateau and in Micronesia; diffuse seismicity and incompatible focal mechanisms argue against the southernmost, discussed by OKAL *et al.* (1986) and KROENKE and WALKER (1986), as the simple relocation of the Solomon trench to the North. Besides another striking lineament, along the 130°W meridian, there is also a strong correlation between seismicity and bathymetry in certain parts of the Basin. In the Eastcentral Pacific and Nazca plates there are many epicenters on fracture zones and fossil spreading ridges, and hot spot traces like the Louisville, Nazca and Cocos Ridges also display seismicity.

Key words: Intraplate seismicity, Pacific Basin, historical earthquakes.

1. *Introduction*

This paper presents an extensive evaluation of the intraplate seismicity of the Pacific Ocean Basin over the 75 years since seismological data has been compiled systematically. We are motivated in this endeavor by continued interest in stresses released during intraplate oceanic earthquakes. In particular, the nature, orientation, and magnitude of these stresses provide important constraints on the deep rheology of the plates, and on forces driving them (see STEIN and OKAL (1986) for a review). Our investigation, involving the systematic relocation of more than 500 earthquakes, both historical (pre-1963) and recent, shows that less than one-half of the catalog listings of intraplate events can be regarded as genuine (see Figure 1). Most of the rest become plate boundary earthquakes mislocated to the interior of

---

[1] Department of Geological Sciences, Northwestern University, Evanston, Illinois 60208, U.S.A.
[2] Department of Mathematics, Wheaton College, Wheaton, Illinois 60187, U.S.A.

the plates for a variety of reasons. This result casts an ominous shadow on any attempt to reach quantitative conclusions regarding the magnitude of intraplate oceanic stress release based on existing, unrelocated catalogs. In addition, on a more local scale, the correlation of seismicity with existing bathymetric features, in the context of the possible existence of "weak" zones featuring preferential stress release, is even more dependent on an accurate knowledge of seismic epicenters. In both respects, then, the magnitude of the casualty rate among alleged intraplate events serves as an *a posteriori* justification of our present study.

Previous Work

Interest in intraplate seismicity can be traced back to GUTENBERG and RICHTER'S (1941) monumental compilation of the earth's seismicity. Inside the Pacific Basin, which they recognized as one of their "stable masses", they identified

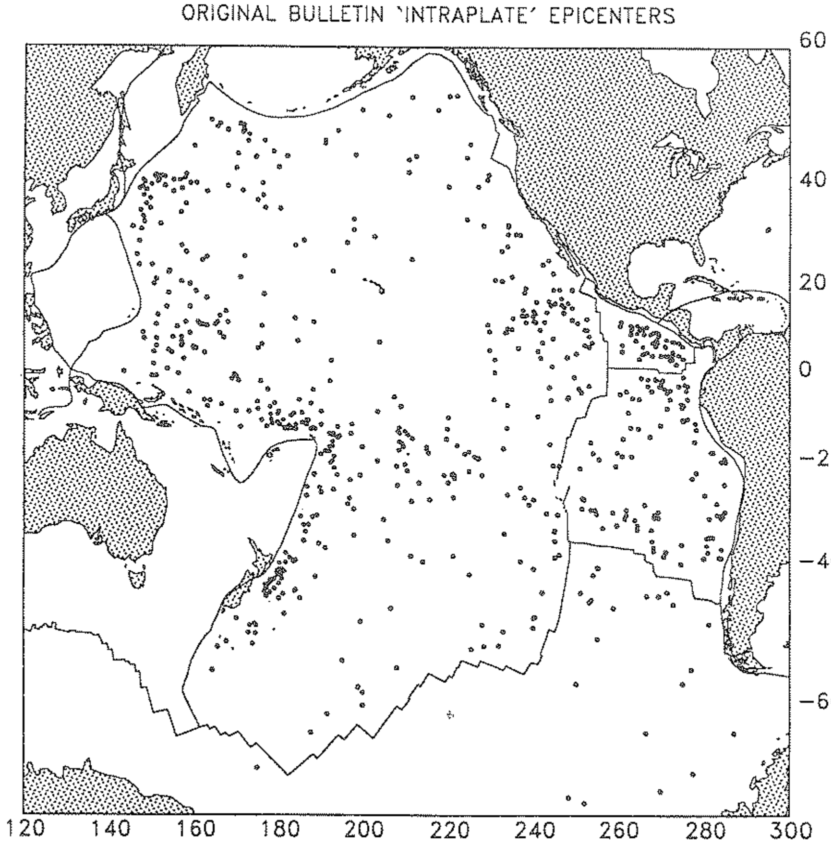


Figure 1a
Map of epicenters with Pacific Basin Intraplate locations, taken from original bulletins.

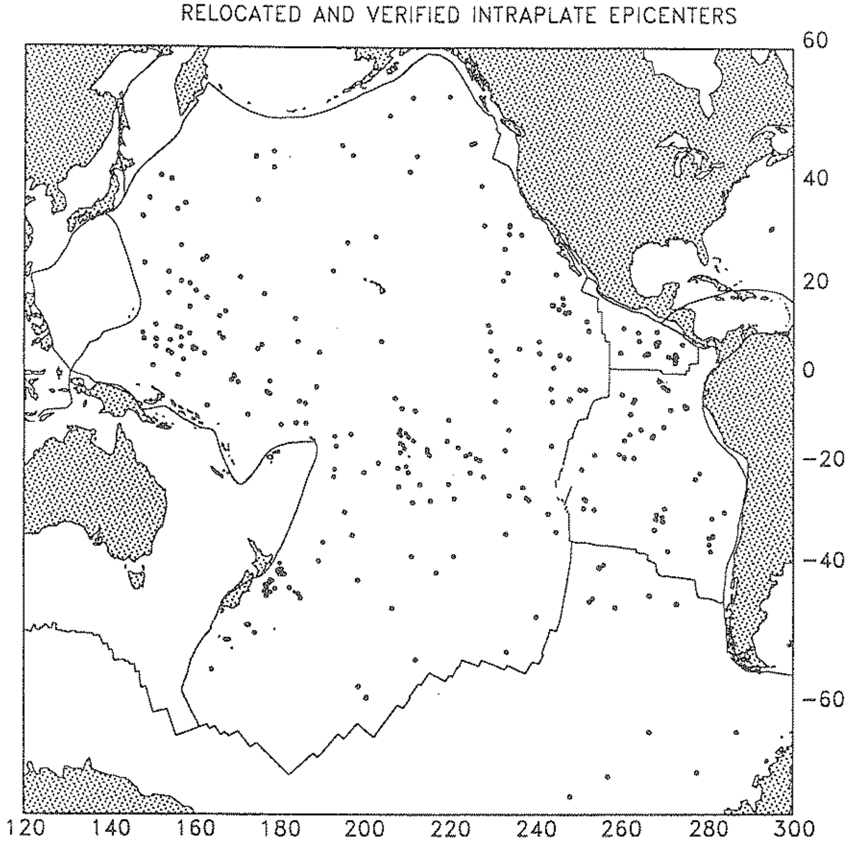


Figure 1b

Map of intraplate epicenters that we consider to be reliable, after either relocation or verification. Note that the large number of events near the Tonga, Japan, Aleutian and Central American trenches has been greatly reduced.

22 earthquake listings by the ISS, and concluded that at most 2 could be correct. By the time of their last edition (GUTENBERG and RICHTER, 1954), they had come to the conclusion that none of the 22 could be trusted as intraplate. We will see that our relocations suggest that 5 out of 21 are indeed intraplate events, including the two these authors initially recognized (the 22nd event is listed in the Caroline plate, beyond our study area).

In more recent years, studies of intraplate seismicity can be classified in two categories. The first type, motivated by the investigation of the dynamic state of stress of the oceanic lithosphere, was concerned with retrieval of earthquake focal mechanisms and quantitative evaluation of the actual energy released. For these reasons, these studies were, in general limited to the homogeneous dataset provided by the WWSSN, and did not involve historical events. Benchmark papers include

SYKES and SBAR (1974), RICHARDSON *et al.* (1979), BERGMAN and SOLOMON (1980, 1984), and WIENS and STEIN (1983, 1984).

The second type of study was generally of a more local nature, and was motivated either by the sudden occurrence of intense seismic swarms (e.g., FILSON *et al.*, 1973; LAY and OKAL, 1983; WIENS and OKAL, 1987), or even of a single event (STEIN, 1979; OKAL, 1980); or by the existence of a regional network providing improved detection capabilities over a limited spatial (and occasionally temporal) extent (TALANDIER and KUSTER, 1976; OKAL *et al.*, 1980; TALANDIER and OKAL, 1984a, 1987; WALKER and MCCREERY, 1985).

In addition, some investigations of a more global nature did address, at least partially, the question of intraplate Pacific seismicity, for instance in the framework of a general discussion of historical records (e.g., MIYAMURA, 1988).

At least three studies have attempted to compile the complete seismicity of all or part of the Pacific plate: OKAL (1981) listed 21 earthquakes belonging to the Antarctic plate, including 16 in the Pacific Basin; OKAL (1984) presented a compilation of the seismicity of the Pacific plate south of the Equator; more recently, WALKER (1989) has published a list of 406 reportedly intraplate earthquakes in the 4 main plates making up the Pacific Basin.

The present paper can be viewed as an extension of the work of OKAL (1981; 1984) in several directions: (i) full coverage of the entire Pacific Basin, including North of the Equator, and inside the Cocos and Nazca plates; (ii) more systematic relocation of all historical earthquakes, capitalizing on a more complete database; (iii) systematic examination of the statistical significance of the solution, *including for recent earthquakes.*

2. *Data Base*

As an initial working dataset we have tried to obtain for analysis all Pacific Basin intraplate earthquakes from 1913 through 1988. We have taken as intraplate events that are more than 2° from a plate boundary, and defined the Pacific Basin as being the full interiors of the Pacific, Nazca and Cocos plates, and the part of the Antarctic oceanic lithosphere that extends from 160°E (the Pacific-Australian-Antarctic triple junction) to 68°W (the southern tip of South America).

We have chosen a 2° buffer around plate boundaries for two reasons. There is a degree of uncertainty in the exact locations of earthquakes, both from errors and limitations in choosing travel times and from mantle heterogeneities between events and stations. A 2° buffer will certainly avoid the erroneous inclusion of most poorly located plate boundary earthquakes. Secondly, there are documented cases (e.g., CHEN and FORSYTH, 1978) where earthquakes, associated with plate bending, have occurred seaward of trenches, and while these are technically intraplate, they are associated with boundary tectonics and should not be part of this study.

It is certainly inevitable that in steadfastly choosing a 2° buffer around all plate boundaries we will omit certain verified intraplate earthquakes. Such an example is the January 21, 1970 event just south of the Siqueiros Fracture Zone, which had a $M_s = 6.8$ and a thrust mechanism determined by BERGMAN and SOLOMON (1980). But hopefully, enforcing this stipulation will give us a better understanding of truly intraplate stresses, removed from the immediate influences of plate interactions.

Geographical Limits of Study

We have made certain exceptions to our intraplate regionalization, with the most notable being Hawaii. In the National Earthquake Information Center database of world seismicity (the "NEIC tape") there are 977 listings for Hawaii between 1868 and 1988. This is actually very small compared to the seismicity tabulated by the Hawaii Volcano Observatory, which recorded over 70,000 earthquakes during 1962–1983 (KLEIN *et al.*, 1987). While this seismicity is certainly intraplate, its huge amount connected with hot spot volcanism makes it unreasonable as an inclusion in this study.

Approximately half of the total Pacific intraplate seismicity has occurred in the form of swarms located in less than a dozen distinct regions. A notable example is at the Gilbert Islands, where 224 earthquakes were detected teleseismically between 1981 and 1983 (OKAL *et al.*, 1986). A discussion of these swarms appears in Appendix A, but will be brief because they have been studied elsewhere in more detail. The majority of our attention will focus on 894 independent events listed by previous agencies as having occurred in the intraplate regions of the Pacific Basin before 1989.

In most cases the geographical determination of a 2° buffer was straightforward due to the numerous well-defined plate boundaries in the Pacific region. On the basis of bathymetry, seismicity and numerous studies of plate motions, major subduction zones and mid-oceanic ridges and transforms can be clearly identified. There are areas, however, where sharply delineated plate boundaries do not exist, and we have excluded them from our study.

Perhaps the most seismically active of these is in the Caroline Islands region, whose scattered seismicity WEISSEL and ANDERSON (1978) describe as the diffuse plate boundary of a Caroline miniplate. A similar situation holds for the Fiji plateau, as described by CHASE (1971) and HAMBURGER *et al.* (1990).

We have also avoided the northernmost part of the Gulf of Alaska as it displays unusually high seismicity (including two recent $M_s = 7.6$ intraplate earthquakes with aftershock distributions extending away from the coast) and seems to represent a fragmentation of the intraplate lithosphere and the establishment of a new plate boundary (LAHR *et al.*, 1988).

Similarly, though the Shackleton Fracture Zone marks the proper boundary between the Antarctic and Scotia plates, we limit our study to events west of 68°W because the region between here and the Shackleton FZ is described by PELAYO and WIENS (1989) as a diffuse seismic zone.

The Juan de Fuca plate is also excluded, for though its boundaries are well defined, its seismicity seems to suggest that it is undergoing internal deformation (STODDARD, 1987).

Sources

Our study, involving relocation and analysis of previously listed epicenters, is entirely dependent upon other supplying agencies for the original information. There are two requirements for these intraplate earthquakes which enable us to carry out relocations: they must have been located by a reporting agency (primary source) based on arrival times available at the time, and these epicenters must then be retrievable on a geographical basis from a presently accessible catalog (secondary source). In carefully reexamining these epicenters, our work represents the third stage.

Our main two sources of initial epicenters were the chronological NEIC tape and the database of WALKER (1989). Both sources, like the ISC, perform at two levels: they are responsible for some locations themselves, but also catalog earthquakes from other agencies. Taken as a whole there were several primary agencies from which we began our analyses, identified in Tables 1–13 by the following codes.

ISS = The International Seismological Summary (1913–1963). This was our preferred primary source for events through 1963 (when the ISS became the ISC), as it listed all arrival times received for a given earthquake as well as the location (though only through 1955, after which locations and arrival times were listed only for larger events). Their locations were often very unreliable as this was before the proliferation of computers and in early years they used the arrival times of surface waves to constrain locations. In many cases where they were unable to determine an epicenter but still listed enough body wave arrivals, this information was sufficient for us to determine a reliable location.

ISC = International Seismological Centre (1964–1988). This was the preferred primary source for events after 1963. They use a standardized location algorithm, many arrival phases are listed (though only P arrivals are used in locations), they supply magnitudes, standard deviations of the arrival time residuals and error estimates for the hypocenter parameters. Though there were many cases of ISC mislocations, for the most part their epicenters were reliable and within the standard error of our locations. The ISC performs both as a primary source (e.g., MUIRHEAD and ADAMS, 1986) and as a cataloging agency, publishing the listings of other agencies' solutions.

G = Gutenberg's personal annotated copy of the ISS (Seismological Society of America, 1980), and

G–R = Gutenberg and Richter (1941, 1954). The majority of these relocated as genuinely intraplate.

BCIS = Bureau Central International de Séismologie. This bulletin listed arrival times for its own locations as well as those of other agencies, and was therefore very useful, especially during 1956–1963, the lean years of the ISS.

The following seven sources are all agencies of the United States government. Name changes often reflect no more than administrative reorganizations.

CGS = United States Coast and Geodetic Survey.

NEIS = National Earthquake Information Service. Formerly known as the CGS.

NGDC = National Geophysical Data Center.

PDE = Preliminary Determination of Epicenters. Published by NEIC.

ERL = Environmental Research Laboratories.

NOS = National Ocean Survey. Four earthquakes are referenced to the NOS, all occurring on May 9, 1971 in the Northern Antarctic plate.

GS = United States Geological Survey.

USE = United States Earthquakes Bulletin. Of the 16 references to USE by the NEIC tape, 15 were blatant typographical errors.

PPT = Laboratoire de Géophysique, Papeete, Tahiti.

OBS = Ocean Bottom Seismometer Array. From Walker (1989).

WIA = Wake Island Array. From Walker (1989).

W, E = Wake and Enewetak Arrays. From Walker (1989).

LAO = Large Aperture Seismic Array (LASA). The determinations by LASA were the least reliable of the primary sources. Most of these locations are obtained from an interpretation of apparent slowness vectors across a small array. Modern work (e.g., Capon, 1974; Okal and Kuster, 1975) has shown this procedure to be susceptible to errors from local crustal structure. Though there are few actual references to LAO, many epicenters credited to the ISC were actually LASA determinations, and the relocations for these events often moved the epicenter great distances.

WEL = Wellington, Seismological Observatory. Of the 28 references to local Southwest Pacific epicenters, 19 were genuinely intraplate, and our relocations usually would not change them.

TAC = Tacubaya, Instituto de Geofisica. The NEIC tape references TAC for five South American coast events, all of which relocate to the Central American trench.

The following three agencies were each referenced once by the NEIC tape, and in each case with a mistranscription.

JMA = Japan Meteorological Agency.
MOS = Moscow, Institute of Physics of the Earth.
PAS = Pasadena, California. Code reserved for local events in Southern California.

The number of citations is by no means representative of an agency's ability to detect Pacific intraplate events, but rather of our preferences and those of NEIC and WALKER (1989) in selecting primary sources for an event. The agency listings are not independent, and most events are recorded by at least two agencies. In some cases the NEIC tape itself would have multiple listings (which we removed) for a single event because they differed enough in location and/or origin time (e.g., ISS, CGS and G + R).

The NEIC database that we used is the worldwide global set ($m_b \geq 3.0$) in TAGGART *et al.* (1988). The WALKER (1989) dataset is a list of Pacific intraplate earthquakes that he considers to be reliable. Its strength lies in its access to local Micronesian arrays and ocean bottom seismometers. The difference between our study and WALKER'S (1989) must be strongly stressed. Outside of the earthquakes he has located through local arrays, his study is only a compilation of other events, however carefully they may be chosen. Our study critically analyzes each individual earthquake, relocating it if necessary. This fundamental difference is best illustrated by the result detailed in Section 5 that only 48% of Walker's events will be found genuinely intraplate by our standards.

The main two sources, the NEIC tape and WALKER (1989), had surprisingly little overlap in their events: 24% before 1963, and 11% post-62. While events listed by both tended to fare well in our relocations and were most often genuinely intraplate, they were a small percentage of the total. Some of this lack in overlap is expected, but its magnitude is surprising. One would expect the NEIC dataset to be included in the ISC, since it is prepared as much as a year earlier than, and is available to, the ISC. The dataset of WALKER (1989) is primarily from the ISC, but he uses a very conservative and somewhat arbitrary parameterization of the intraplate region of the Pacific, resulting in a significant lack of overlap between our two main sources.

In certain regions we also used the ISC regional catalog as a source for epicenter listings. While WALKER (1989) uses primarily ISC locations, his parameterization of Pacific plate boundaries uses latitude and longitude gridding on a scale ranging from 3 to 10°, causing certain large intraplate regions to be overlooked. As an example, 27 post-1963 intraplate epicenters had to be taken from the ISC regional catalog east of the South Island of New Zealand, which is omitted from his regionalization. Most of these relocated as genuinely intraplate.

The largest other contribution to our dataset was for Polynesian events recorded by the Polynesian Network (OKAL *et al.*, 1980; updated by J. TALANDIER, pers. commun., 1989) in an area mostly, but not totally, boxed out by WALKER (1989). Several events were also found in MIYAMURA (1988).

Our analysis begins with events occurring in 1913, because the International Seismological Summary (ISS) began publication then, printing original arrival times as well as hypocenters. We have also retained in our database two events from 1905 which, though without available arrival time information, were retained by both WALKER (1989) and MIYAMURA (1988). There were 10 other "intraplate" events referenced by MIYAMURA (1988) from before 1913 (mostly from the work of DUDA (1965)), but their proximity to the Tonga, Japan and Kuril subduction zones and their high magnitudes (7.0–8.0) suggest poorly located trench events.

3. Procedure

In relocating an event that has already been located, we seek to improve the reliability of the epicenter. Our ability to do so comes through the inclusion of more data, primarily by adding *S* arrivals to the relocation technique, through rejecting incompatible data more efficiently (notably by using data importances (MINSTER *et al.*, 1974)), and through performing time-intensive computer-modeled statistical analyses. The large relocation vectors resulting from our analyses justify our efforts.

In determining an accurate database it was our hope at the onset that while events before 1963 would have to be relocated, events after this date would be found reliable. This was not the case. Many events, even those located in recent years, began as intraplate but ended as interplate after careful relocation, and of the 738 events considered (not associated with swarms or located by local networks) only 52 had hypocenters which we considered reliable enough not to warrant a relocation.

Our relocation was done through an interactive least-squares iterative regression of both *P* and *S* arrival times. This is different from the ISC inversion, which only uses *P* arrivals. The depth was usually kept at 10 km, except in cases where there were enough arrivals, including those at nearby stations, to constrain it accurately. This is because, for Pacific intraplate events, most stations are at great teleseismic distances, resulting in the classic trade-off between depth and origin time. A depth of 10 km was chosen, consistent with the modern default value of the ISC and PDE for oceanic crustal faulting, and with recent studies of intraplate sources (BERGMAN and SOLOMON, 1980; WIENS and STEIN, 1984).

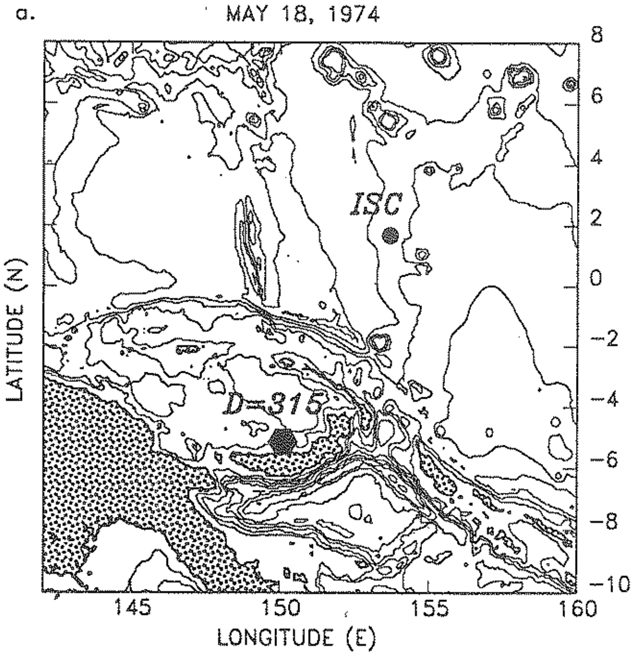
Our travel times are calculated using the Jeffreys-Bullen tables, both for *P* and *S*. This model gives the travel times only for the *Pn* crustal phase at close distances, and being an averaged model, does not accurately represent local crustal structure. Thus there are cases, such as off-shore New Zealand events located by Wellington from local stations, where we feel that local agencies can use appropriate crustal models and additional crustal phases to better constrain the location. In such instances we have kept their locations, after checking their statistical significance.

The following sections detail the methods we used to significantly improve the reliability of our epicenters.

Inclusion of S Arrivals

Perhaps the greatest cause of large epicentral relocations was the inclusion of *S* arrivals in the inversions. Their addition often greatly helped to constrain the solution. *S* arrivals have been weighted by $1/\sqrt{3}$ to compensate for their slower velocities relative to *P*. Even so, errors in *S* wave arrival times were generally greater than for *P*, presumably due to the added complexity of choosing a later arrival.

An example can be seen for the May 18, 1974 earthquake listed by the ISC in the Caroline Islands region (Event 931). As shown in Figure 2, the ISC solution is



b. ISC LOCATION:

ISC 18^d 17^h 39^m 39^s±6^{s}8, 1°7±°56N×153°7±°57E h0°0000 or 33^k, n6, σ6^{s}16/6, 1D, Caroline Islands Region

LAT	Lae	10·74	219	P	17 42 17·6	+3·9
LAT	Lae			S	17 43 09	−65
ESA	Esa-Ala	11·76	194	iP	17 42 29·0	+1·6
LMG	Lamington	11·93	208	P	17 42 26	−4·8
MTN	Manton	26·68	236	eP	17 45 20	+2·8
WRA	Warramunga Ar	28·72	220	P	17 46 30·1	−5·6
BRS	Brisbane	28·97	182	iP	17 46 39·5	+1·7

c. RELOCATION:

5.15°N 150.10°E d = 315 km O.T.= 17:41:11.4

Standard Deviation = 0.16 sec

Arrival		Distance	Residual	Importance
LAT	P	3.46	0.03	0.837
ESA	P	4.63	-0.06	0.608
LMG	P	4.22	0.19	0.416
MTN	P	20.23	-0.06	0.531
WRA	P	21.28	0.11	0.443
BRS	P	22.32	-0.10	0.557
LAT	S	3.46	-0.34	0.608

Figure 2

Example of relocation for Event 931 (May 18, 1974). (a) Map showing the ISC location in the Caroline Islands and the relocation under New Britain. (b) ISC bulletin listing. (c) Relocated hypocenter, with greatly reduced residuals.

very imprecise, with a standard residual of 5.16 s for 6 arrivals, not including the *S* arrival at LAT which is off by over a minute. When the latter is included and the depth is floated, the solution converges very well to the trench. The hypocenter has a depth of 315 km and is located beneath New Britain, a seismically active Benioff zone. Not only is the *S* arrival satisfied, but the *P* residuals are smaller as well, with a standard residual for all 7 arrivals of 0.16 s, as shown in Figure 2c.

Floating the Depth

The case of Event 931 is also an example of how changing the depth will allow the hypocenter to locate in an active subduction zone. In cases like this the depth was varied either by the inversion algorithm itself, or if this proved unstable, by conducting several constrained relocations at discretized depths and selecting the best one. In all cases we accepted an intermediate or deep hypocenter only if it coincided with a known Wadati-Benioff zone.

Removing Emergent Arrivals

Another source of error in bulletin locations is the inclusion of emergent arrivals, listed as *eP* or *eS* in bulletins. In some cases excellent solutions are obtained including all emergent arrivals, but in others these arrivals are clearly wrong and need to be removed from the inversion process. An example is Event 666 of February 7, 1974, which the ISC located 5° east of the Tonga Trench. The ISC solution fits ASP and WRA well but otherwise does a poor job, especially at SPA, which is inaccurate by a minute. This is questionable, because SPA is the only arrival marked impulsive, and even records a polarity. In addition we checked the original SPA record to guard against a clock error. When the two emergent arrivals at LAT and MTN are removed, the solution converges very well to a location behind the subduction zone with a standard residual of 1.13 s for five arrivals.

The process of rerunning the inversion many times after removing arrivals is philosophically similar to a bootstrap technique, simply replacing the randomness of the choice of station to be removed with some better understanding of which arrivals may be suspect.

Fixing Mislabelled Arrivals

An earthquake location can be in error due to the mislabelling of arrivals, either at the station, where a phase is incorrectly identified, or during the location, with the inclusion of an arrival from a totally different earthquake. While the ISC does a very good job of screening out errors for the latter case, some still do slip through. An example is the May 23, 1967, earthquake (Event 664), located by the ISC (from a preliminary determination by LASA) in the Tokelau Island Region. Two entries from the ISC bulletin are shown in Figure 3, the second being a small a.

```
        Preliminary determination given by LASA

  837   May 23d 12h  3m 14±7.8s, Epicentre 8°±1.1°South by 170°±1.1°West, 9 obs
        Depth= 0.0000R or 33 km, SD=2.71s on 9 obs, Mag=4.4 on 5 obs, 1C
        (625) Tokelau Islands Region / (39) Pacific Basin

G C A   Glen Canyon          70.78  46 i 12 14 30.2   +1.3
B M O   Blue Mountains       71.00  37 i 12 14 32.5   +2.4  0.4
D U G   Dugway               71.43  43 i 12 14 34.6   +1.9  0.8
A L Q   Albuquerque          73.71  50 i 12 14 44.5   -1.9  0.6
F G U   Flaming Gorge        74.09  43 e 12 14 48     -0.4

C O L   College Outpost      74.92  10 e 12 14 53     +0.3
L F 3   Lasa F Ring          77.81  39 i 12 15 07.6   -1.8  0.7
WM O    Wichita Mountains    79.71  52 i 12 15 13.8   -6.3  1.1
L P S   La Palma             83.21  75 i 12 15 41.1C  +2.5        S     sP  12 15 58 -597   +5

   SSS  May 23d 12h 15m 21s, 12.8°N 89.0°W, Depth=50 km
        (76) Off Coast of Central America / (6) Central America
  838   The distances and residuals correspond to the position and time given by SSS

S S S   San Salvador          0.90 348 i 12 15 34.7   -2.8        S         12 15 45   -6
```

b.

15.67°S 173.36°W d = 10.0 km O.T.= 12:02:30.3

Standard Deviation = 0.27 sec

Arrival		Distance	Residual	Importance
GCA	P	78.30	0.37	0.269
BMO	P	78.91	-0.51	0.427
DUG	P	79.12	0.35	0.224
ALQ	P	81.02	-0.02	0.231
FGU	P	81.74	-0.14	0.136
COL	P	82.77	0.11	0.929
LF3	P	85.62	-0.04	0.163
WMO	P	86.84	-0.11	0.621

Figure 3

Example of epicenter contamination by arrivals from a different earthquake for Event 664 (May 23, 1967). (a) The *S* arrival at LPS (El Salvador) for this event (top listing) is 597 s early, but LPS *S* and *P* fit the following San Salvador event very well. (b) Removal of LPS from the first event causes it to relocate in the Tonga trench.

local earthquake detected only by San Salvador (SSS). The Tokelau Island event is largely constrained by the *P* arrival at LPS (La Palma, El Salvador), and the solution is only fair, with a standard residual of 2.71 s for 9 *P* arrivals. The clue that something is amiss comes from the LPS *S* arrival, which if taken as an *S* is 597 s early, so the ISC interprets it as an *sP*. If, on the other hand, both LPS arrivals are from the event recorded subsequently by San Salvador, they agree excellently as they are, and the "Tokelau Islands" earthquake relocates to (15.67°S, 173.36°W), square in the trench, with a standard residual of 0.27 s for 8 *P* arrivals.

An example of a phase misidentification would be Event 1404, which occurred on July 2, 1980, and was located by the ISC in the northern part of the Cocos plate at (11.9°N, 96.9°W). The arrival time residuals for the ISC location were poor, with $\sigma = 6.28$ s from 11 observations. We expected the relocation, therefore, to be to the trench near the northeast. Three arrivals from Colombia (BOG, FUQ and CHN) were incompatible with the other stations, all in the United States, which actually gave a superior location on a transform segment of the Galapagos Rise, to the southwest of the ISC location. When the BOG and FUQ arrivals were interpreted as *S* waves instead of *P* waves they agreed with the other *P* arrivals, and the final location ($\sigma = 1.29$ s for 10 observations) was at (3.09°W, 90.03°W), less than 1° north of the very seismically active Galapagos Rise transform fault. The CHN arrival is 20 s late when interpreted as an *S* wave, but comes at the appropriate time when interpreted as *SS*.

Monitoring Data Importances

We tried to guard against mislocations caused by the heavy weighting of particular arrivals in the inversion program. An arrival with a unique back-azimuth will be given a higher data importance and small errors in them can greatly change the epicenter. In suspect cases we both tested the inversion without them and examined the original seismograms, remeasuring the arrival times.

Determining Aftershock Relations

Common sources of mislocations were aftershocks of large interplate earthquakes. Most of the supposed intraplate earthquakes off the coasts of Japan, the Kuril Trench and the Aleutian Trench relocated into swarms of aftershocks from large subduction zone events. An example is shown in Figure 4, where the seismicity for June, 1975 is shown for the trench off the coast of Hokkaido, Japan. The seismicity is fairly quiet except for a large cluster of events centered at (43°N, 145.5°E) containing over 180 aftershocks of the June 10 "tsunami" earthquake (FUKAO, 1979). In Figure 4a the three intraplate listings (1034–1036) are shown with solid circles, but their relocations, accomplished by removing incompatible emergent arrivals, are part of the aftershock sequence shown in Figure 4b.

Monte Carlo Error Ellipses

While the inversion is a straightforward iterative process, using the partial derivatives of the hypocenter parameters with respect to the arrival time residuals to determine the next location, the actual process using real data is more like detective work, as there are many potential pitfalls. With perfect data there would be only one minimum well in the N-dimensional residual space (determined by the number of arrival times) and the iterative inversion would quickly find the hypocenter parameters that yielded travel time residuals corresponding to this minimum. Using actual data, however, with errors from misset clocks, poorly read arrivals, contamination from record noise and arrivals from different events, the residual

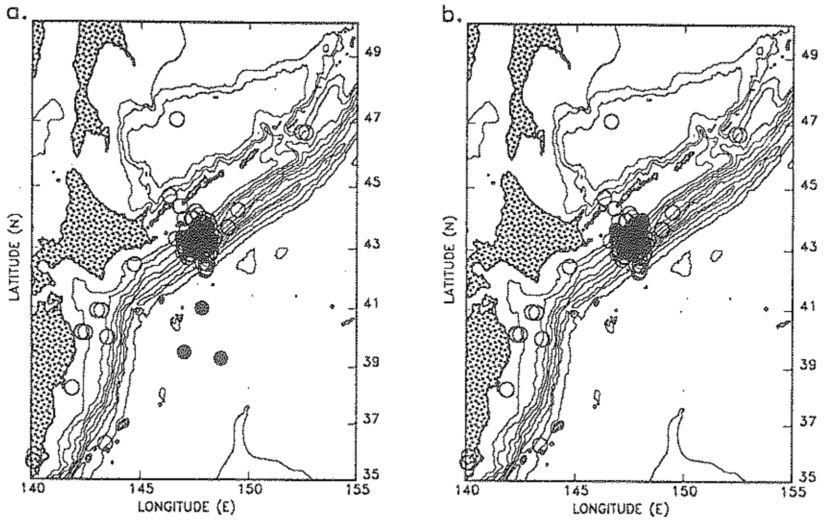


Figure 4

(a) Seismicity (open circles) for June 1975 off the coast of Hokkaido, with the cluster centered around the June 10 "tsunami" shock. The solid circles are three aftershocks of this event mislocated as intraplate. (b) The three events, when relocated, form part of the aftershock sequence. Many events in the Japan-Kuril-Aleutian intraplate areas were aftershocks that relocated to trenches.

space can contain local minima into which the inversion can converge even though they are not the best solutions. A careful way of using the least-squares inversion, however, is to accompany it with a critical statistical analysis.

We use a Monte Carlo statistical simulation to give us an estimate of the reliability of our epicenters. As well as possible pitfalls listed above, another danger with the least squares regression results from having a nonuniform distribution of event-to-station azimuths. A location can be done with a huge number of P and S arrivals, but if they are all at the same azimuth the epicenter will be very unconstrained in a direction perpendicular to the azimuth. Such situations are common in examining small Pacific events which often are only detected by a handful of stations at the nearest coast. The Monte Carlo simulation, generating a confidence ellipse, gives us a quantitative estimate of how well constrained an epicenter is.

The Monte Carlo test is extremely robust because it takes into account the nonlinearities of the inversion method by simply adding noise to the arrival times and rerunning the inversion process hundreds of times. The distribution of new epicenters gives an indication of the reliability of the best fit epicenter. We start each Monte Carlo simulation with the best epicenter and origin time found from our iterative inversion and then add random errors to all the arrival times and iterate the inversion to its best new location. Repeating this procedure a large number of times—we generally used 400—gives a significant distribution, whose covariance matrix we use to obtain a 95% confidence ellipse. Having a confidence ellipse was useful though not always meaningful, as the Monte Carlo distributions were not necessarily Gaussian in latitude or longitude.

We used Gaussian deviates for our random errors, with standard deviations that varied according to the date and quality of the location. For recent events we used a standard deviation of 2 s for the Gaussian deviate errors to the arrival times, but for 1925 we might use 20 s. Because of the somewhat arbitrariness of this standard deviation, it was not so much the absolute size of the error ellipse that was important as the shape of the Monte Carlo distribution in relation to proximate plate boundaries. An example is shown in Figure 5 for the December 2, 1975 earthquake in the South Pacific (Event 443). Though the event locates west of the Pacific-Antarctic ridge, the 95% confidence ellipse, using only a 2 s standard deviation for travel time errors, makes this event unreliable as intraplate. The shape of the ellipse shows that while the epicenter is well constrained in the east-west

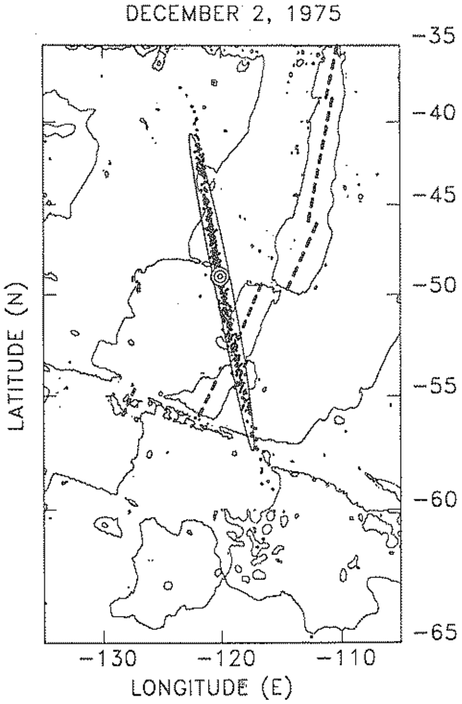


Figure 5
Example of a Monte Carlo simulation for Event 443. The solid dots are the 500 simulation epicenters, done with a 2 s standard error, and the ellipse is the 95% confidence interval through them. The ISC and relocated epicenters are identical (bull's eye) and are 4° from the Pacific-Antarctic ridge (dashed line), but the ellipse crosses two seismically active transform segments of the plate boundary, implying that the event is most likely interplate.

direction, it is very poorly constrained north-south, and is most likely from a seismically active transform segment where the ellipse crosses the ridge. The uncertainty in location by the ISC (±2.2° in latitude) is clearly underestimated.

When the Monte Carlo distribution clearly crossed a plate boundary, the event was considered to be most probably interplate and was rejected.

Relocations to Islands

Earthquake relocations occasionally converge on epicenters in the immediate vicinity of populated islands. Under such conditions, an additional constraint should be the existence, or the documented absence, of felt reports. Several of our events were indeed reported felt (e.g., Event 214 on October 2, 1988, felt all over the Marquesas). In many instances, however, felt and instrumental reports were not correlated: In particular, earthquakes have been reported felt at intraplate locations (e.g., at Pohnpei on April 11, 1911) in the absence of any instrumental reports.

Proposing a relocation in the immediate vicinity of a populated island should not necessarily be contradicted by the absence of a felt report. The situation can be illustrated best on the example of Event 177 (July 17, 1929), whose relocated epicenter is just 25 km NE of Rarotonga in the Cook Islands. Body and surface waves from this earthquake were recorded (although imprecisely) in Australia and America. Thus the event probably has a magnitude of 5 to 5 1/2: Our present-day experience with magnitude 4 1/2 events in the region is that they escape detection outside Polynesia (despite improved instrumentation at teleseismic stations), while magnitude 6 events were better detected and located, even in those times. In the marine environment, and assuming similar source and propagation characteristics, our present-day experience (for example in Hawaii) is that an earthquake of $m_b = 5-5.5$ would be felt, at the most, 150 km away. This distance is less than the half-length of the Monte Carlo ellipse computed for the event, indicating that our relocation does not suggest, at a statistically significant level, that the event had to have been felt. At any rate, and assuming the earthquake would indeed have been felt, we could not identify any newspaper published in the Cook Islands in 1929; a felt report could therefore have simply been lost over the past 60 years.

Similarly, in the case of Micronesia and the Marshall Islands, a number of events (886, 887, 896, 898, 899, 900, 901, 902, 907, 908, 913, 914, 915) were identified as close enough to populated islands that they could have been felt. A systematic search of local newspaper collections around the dates of the events (M. T. Woods, pers. commun., 1990) has failed to yield any report of felt earthquakes, even for Events 902 and 915, reported felt by the ISC.

As a result, we have chosen to list a few events in the immediate vicinity of populated islands, even in the absence of felt reports.

4. Results: Classification of Events

The results of the analysis of the 894 non-swarm earthquakes are shown in Tables 1–13. For convenience we have divided the dataset into 13 parts, treating the Cocos, Nazca and Antarctic plates separately, and subdividing the Pacific into 10 separate regions. These subdivisions do not necessarily reflect distinct tectonic features, but rather facilitate an easier discussion of the Pacific intraplate seismicity with some geographical continuity. Some regions are obviously smaller than others, and feature fewer intraplate earthquakes; this situation is at least partly due to a higher casualty rate in these areas (e.g., Tonga to Samoa, and Japan-Kuriles). The locations of these regions are shown in Figure 6, and detailed descriptions of the regionalizations can be found in Appendix B.

Each table consists of a source code, date, initial hypocenter and magnitude, final hypocenter (where appropriate), processing code, site location (where given) and index number. The events are grouped within each table along geographical lines, in order to more easily recognize any spatial trends in the seismicity. Among casualties, events relocated to the plate boundaries (codes 7, 8, 9 and 10) have been

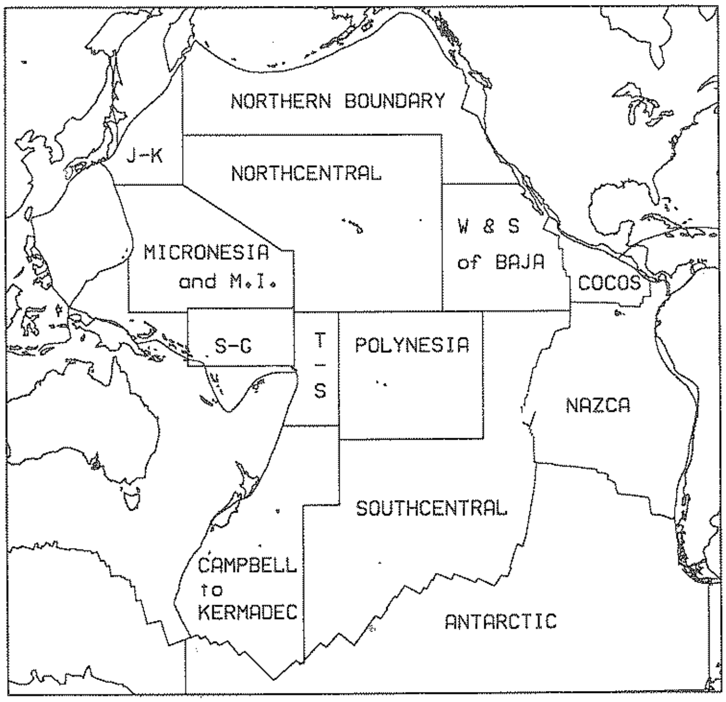


Figure 6
Map of the regionalization of the Pacific Basin used in sorting the dataset into Tables 1–13. "J–K" stands for Off Japan and the Kuriles, "S–G" for Samoa to Gilbert, and "T–S" for East of Tonga and Samoa.

TABLE 1. SORTED DATASET FOR POLYNESIA

Initial Location							Relocation						Code	Site	Index
Sce	Date D M Y	Time (GMT)	Lat. °N	Long. °E	Depth (km)	Mag.	Lat. °N	Long. °E	Depth (km)	Time (GMT)	Ns	σ (s)			
							Intraplate Events								
CGS	25 1 1962	10:03:06.8	-4.60	-152.60	33	4.6 PPT	-4.54	-152.59	10	10:03:05.5	38	1.38	1	LI-0	101
ISC	13 4 1967	14:26:51.0	-6.80	-151.10	37	5.1 mb	-6.80	-151.10	0	14:26:46.0			5	LI-1	102
PPT	27 3 1966	04:26:43.0	-11.70	-151.40	0	4.2 PPT							5	TU-1	103
PPT	24 12 1977	11:08:11.0	-13.00	-151.30	0	2.9 PPT							5	TU-2	104
PPT	04 3 1977	22:00:15.0	-12.50	-150.20	0	3.9 PPT							5	TU-3	105
PPT	21 11 1972	16:28:33.0	-13.30	-149.50	0	3.7 PPT							5	TU-4	106
PPT	18 1 1974	08:01:56.0	-14.10	-148.40	0	2.0 PPT							5	TU-5	107
PPT	02 12 1974	17:23:30.0	-16.00	-145.10	0	3.2 PPT							5	TU-6	108
PPT	10 6 1975	19:35:12.0	-16.60	-145.10	0	2.5 PPT							5	TU-7	109
PPT	24 9 1976	18:29:39.0	-17.30	-144.70	0	3.1 PPT							5	TU-8	110
PPT	06 10 1976	02:58:17.0	-17.30	-144.70	0	2.7 PPT							5	TU-8	111
PPT	05 10 1976	21:00:49.0	-17.30	-144.70	0	2.7 PPT							5	TU-8	112
PPT	07 10 1976	02:06:24.0	-17.30	-144.70	0	2.1 PPT							5	TU-8	113
PPT	10 10 1976	03:40:41.0	-17.30	-144.70	0	2.7 PPT							5	TU-8	114
PPT	10 10 1976	04:09:23.0	-17.30	-144.70	0	2.8 PPT							5	TU-8	115
PPT	09 10 1976	21:35:52.0	-17.30	-144.70	0	2.4 PPT							5	TU-8	116
PPT	10 10 1976	13:10:13.0	-17.30	-144.70	0	3.3 PPT							5	TU-8	117
PPT	16 10 1976	05:10:16.0	-17.30	-144.70	0	2.7 PPT							5	TU-8	118
PPT	21 10 1976	00:57:26.0	-17.30	-144.70	0	2.7 PPT							5	TU-8	119
PPT	23 10 1976	11:30:11.0	-17.30	-144.70	0	2.4 PPT							5	TU-8	120
PPT	01 11 1976	12:06:00.0	-17.30	-144.70	0	3.1 PPT							5	TU-8	121
PPT	12 12 1976	03:55:32.0	-17.30	-144.70	0	2.3 PPT							5	TU-8	122
PPT	10 1 1977	17:13:38.0	-17.30	-144.70	0	2.3 PPT							5	TU-8	123
PPT	26 4 1977	10:37:01.0	-17.30	-144.70	0	2.4 PPT							5	TU-8	124
PPT	13 2 1979	12:36:59.0	-14.20	-140.50	0	3.8 PPT							5	TU-9	125
GS	16 4 1982	02:52:52.1	-15.64	-137.93	0	4.8 mb							5	TU-10	126
PPT	25 2 1986	04:35:32.0	-12.47	-151.71	12	4.2 PPT							5	TU-11	127
PPT	10 7 1969	08:01:21.0	-14.90	-151.40	0	2.4 PPT							5	SC-1	128
PPT	23 9 1969	16:28:52.0	-14.90	-151.40	0	2.5 PPT							5	SC-1	129
PPT	31 3 1972	17:33:26.0	-14.90	-151.40	0	3.0 PPT							5	SC-1	130
PPT	18 10 1972	04:23:48.0	-14.90	-151.40	0	2.1 PPT							5	SC-1	131
PPT	12 5 1973	05:53:02.0	-14.90	-151.40	0	2.6 PPT							5	SC-1	132
PPT	12 5 1973	08:31:56.0	-14.90	-151.40	0	2.5 PPT							5	SC-1	133
PPT	18 7 1973	09:14:52.0	-14.90	-151.40	0	2.5 PPT							5	SC-1	134
PPT	05 5 1974	01:08:57.0	-14.90	-151.40	0	2.5 PPT							5	SC-1	135
PPT	10 6 1975	18:28:25.0	-14.90	-151.40	0	2.1 PPT							5	SC-1	136
PPT	20 3 1976	07:06:57.0	-14.90	-151.40	0	3.6 PPT							5	SC-1	137
PPT	11 9 1977	00:06:01.0	-14.90	-151.40	0	2.3 PPT							5	SC-1	138
PPT	08 3 1978	02:43:46.0	-14.90	-151.40	0	2.4 PPT							5	SC-1	139
PPT	14 8 1971	21:31:55.0	-14.70	-151.30	0	2.1 PPT							5	SC-2	140
PPT	10 9 1971	11:13:19.0	-14.70	-151.30	0	3.2 PPT							5	SC-2	141
PPT	14 2 1974	17:07:55.0	-14.70	-151.30	0	2.5 PPT							5	SC-2	142
PPT	12 11 1985	21:16:05.9	-14.80	-151.30	12	3.9 PPT							5	SC-2	143
PPT	14 11 1979	08:02:49.0	-16.70	-151.40	0	2.4 PPT							5	SC-3	144
ISC	06 4 1979	22:49:53.1	-15.90	-150.50	0								5	SC-4	145
PPT	05 11 1988	14:02:54.8	-15.20	-150.78	12	3.2 PPT							5	SC-5	146
PPT	01 4 1968	14:56:34.0	-19.00	-156.50	0	3.7 PPT							5	NA-1	147
PPT	08 10 1968	17:17:12.0	-20.10	-152.00	0	3.3 PPT							5	NA-2	148
PPT	21 12 1973	10:00:00.0	-20.10	-152.00	0	2.3 PPT							5	NA-2	149
PPT	15 5 1974	16:56:07.0	-20.10	-152.00	0	2.5 PPT							5	NA-2	150
PPT	07 9 1975	02:12:24.0	-20.10	-152.00	0	2.8 PPT							5	NA-2	151
PPT	15 5 1976	09:58:43.0	-19.80	-150.10	0	2.6 PPT							5	NA-3	152
PPT	18 8 1974	07:34:25.0	-21.10	-149.60	0	2.2 PPT							5	NA-4	153
PPT	29 9 1974	05:04:18.0	-21.10	-149.60	0	2.8 PPT							5	NA-4	154
PPT	20 1 1975	03:42:46.0	-21.10	-149.60	0	2.9 PPT							5	NA-4	155
PPT	22 5 1975	05:50:45.0	-21.10	-149.60	0	3.0 PPT							5	NA-4	156
PPT	22 5 1975	05:50:45.0	-21.10	-149.60	0	3.0 PPT							5	NA-4	156
PPT	06 6 1975	20:02:13.0	-21.10	-149.60	0	2.4 PPT							5	NA-4	157
PPT	30 7 1975	02:37:46.0	-21.10	-149.60	0	3.3 PPT							5	NA-4	158
PPT	16 10 1975	09:07:28.0	-21.10	-149.60	0	2.4 PPT							5	NA-4	159
PPT	15 11 1975	20:34:47.0	-21.10	-149.60	0	3.4 PPT							5	NA-4	160
PPT	16 11 1975	10:13:48.0	-21.10	-149.60	0	2.6 PPT							5	NA-4	161
PPT	02 12 1975	12:11:43.0	-21.10	-149.60	0	2.3 PPT							5	NA-4	162
PPT	15 3 1976	21:54:27.0	-21.10	-149.60	0	2.7 PPT							5	NA-4	163
PPT	12 5 1976	02:30:26.0	-21.10	-149.60	0	3.7 PPT							5	NA-4	164
PPT	20 5 1977	13:43:05.0	-21.10	-149.60	0	2.8 PPT							5	NA-4	165
PPT	24 5 1977	06:08:54.0	-21.10	-149.60	0	2.8 PPT							5	NA-4	166
PPT	29 7 1977	02:13:10.0	-21.10	-149.60	0	3.0 PPT							5	NA-4	167
PPT	27 8 1977	01:08:36.0	-21.10	-149.60	0	1.7 PPT							5	NA-4	168

Table 1 (continued)

Sorted Dataset for Polynesia

Initial Location							Relocation						Code	Site	Index
Sce	Date D M Y	Time (GMT)	Lat. °N	Long. °E	Depth (km)	Mag.	Lat. °N	Long. °E	Depth (km)	Time (GMT)	Ns	σ (s)			
PPT	07 9 1977	14:23:46.0	-21.10	-149.60	0	2.6 PPT							5	NA-4	169
PPT	13 9 1977	03:11:49.0	-21.10	-149.60	0	3.4 PPT							5	NA-4	170
PPT	02 11 1977	03:38:55.0	-21.10	-149.60	0	2.8 PPT							5	NA-4	171
PPT	22 12 1977	05:58:57.0	-21.10	-149.60	0	2.8 PPT							5	NA-4	172
PPT	05 8 1978	09:49:45.0	-21.10	-149.60	0	2.8 PPT							5	NA-4	173
PPT	14 4 1979	09:19:48.0	-21.10	-149.60	0	2.8 PPT							5	NA-4	174
PPT	14 10 1979	13:07:00.0	-21.10	-149.60	0	2.3 PPT							5	NA-4	175
PPT	18 10 1979	23:54:20.0	-21.10	-149.60	0	3.2 PPT							5	NA-4	176
ISS	17 7 1929	19:52:12.0	-22.00	-160.50	0		-21.08	-159.76	10	19:52:18.3	4	2.55	1	NA-5	177
PPT	03 2 1970	14:47:51.0	-24.10	-151.80	0	3.5 PPT							5	AU-1	178
PPT	20 5 1970	16:31:53.0	-24.10	-151.80	0	3.5 PPT							5	AU-1	179
PPT	04 8 1970	11:02:23.0	-24.10	-151.80	0	4.0 PPT							5	AU-1	180
PPT	13 8 1970	12:04:31.0	-24.10	-151.80	0	4.4 PPT							5	AU-1	181
PPT	14 5 1970	09:35:52.0	-27.40	-148.60	0	4.5 PPT							5	AU-2	182
PPT	24 4 1977	16:31:03.0	-27.40	-148.60	0	3.4 PPT							5	AU-2	183
PPT	20 5 1977	20:30:53.0	-27.40	-148.60	0	3.3 PPT							5	AU-2	184
PPT	28 6 1977	03:37:01.0	-27.40	-148.60	0	4.1 PPT							5	AU-2	185
PPT	29 6 1977	05:27:41.0	-27.40	-148.60	0	3.6 PPT							5	AU-2	186
PPT	16 9 1977	16:08:46.0	-27.40	-148.60	0	3.1 PPT							5	AU-2	187
PPT	20 9 1977	12:33:40.0	-27.40	-148.60	0	3.0 PPT							5	AU-2	188
PPT	12 10 1977	19:09:17.0	-27.40	-148.60	0	3.3 PPT							5	AU-2	189
PPT	20 10 1977	02:37:29.0	-27.40	-148.60	0	3.5 PPT							5	AU-2	190
PPT	15 11 1977	18:57:16.0	-27.40	-148.60	0	4.6 PPT							5	AU-2	191
PPT	31 1 1978	11:10:06.0	-27.40	-148.60	0	2.9 PPT							5	AU-2	192
PPT	14 2 1978	01:33:26.0	-27.40	-148.60	0	3.2 PPT							5	AU-2	193
PPT	08 3 1978	10:10:26.0	-27.40	-148.60	0	3.2 PPT							5	AU-2	194
PPT	25 3 1978	06:44:09.0	-27.40	-148.60	0	3.1 PPT							5	AU-2	195
PPT	31 3 1978	23:48:24.0	-27.40	-148.60	0	3.1 PPT							5	AU-2	196
PPT	05 5 1978	13:29:00.0	-27.40	-148.60	0	2.8 PPT							5	AU-2	197
PPT	21 5 1978	07:12:17.0	-27.40	-148.60	0	3.7 PPT							5	AU-2	198
PPT	08 6 1978	20:40:00.0	-27.40	-148.60	0	3.3 PPT							5	AU-2	199
PPT	09 6 1978	17:06:46.0	-27.40	-148.60	0	3.3 PPT							5	AU-2	200
PPT	09 6 1978	16:54:04.0	-27.40	-148.60	0	3.3 PPT							5	AU-2	201
PPT	10 6 1978	12:01:15.0	-27.40	-148.60	0	3.2 PPT							5	AU-2	202
PPT	10 6 1978	13:19:53.0	-27.40	-148.60	0	3.4 PPT							5	AU-2	203
PPT	12 6 1978	01:09:11.0	-27.40	-148.60	0	3.0 PPT							5	AU-2	204
PPT	12 6 1978	15:01:58.0	-27.40	-148.60	0	2.9 PPT							5	AU-2	205
PPT	16 5 1979	02:36:56.0	-27.40	-148.60	0	3.6 PPT							5	AU-2	206
PPT	13 1 1972	17:48:27.0	-23.60	-146.90	0	4.0 PPT							5	AU-3	207
PPT	12 3 1977	17:31:00.0	-27.10	-144.40	0	3.7 PPT							5	AU-4	208
PPT	20 3 1977	01:02:48.0	-27.10	-144.40	0	4.2 PPT							5	AU-4	209
PPT	28 8 1977	01:41:31.0	-27.10	-144.40	0	4.5 PPT							5	AU-4	210
PPT	20 11 1979	06:45:04.4	-26.57	-138.84	0	5.3 PPT							5	AU-6	211
PPT	06 10 1982	08:29:44.0	-23.56	-140.11	0	4.6 PPT							5	AU-7	212
PPT	18 05 1987	18:33:17.4	-23.50	-149.03	12	4.0 PPT							5	AU-8	213
PPT	02 10 1988	23:41:14.0	-9.47	-140.07	0	4.4 PPT							5	MQ-1	214
PPT	14 5 1975	11:49:42.3	-17.43	-136.05	0	5.0 mb							5	GB-1	215
PPT	01 3 1974	02:31:27.0	-17.00	-135.10	0	3.3 PPT							5	GB-2	216
PPT	27 3 1970	22:25:25.0	-18.10	-133.70	0	3.1 PPT							5	GB-3	217
PPT	06 9 1971	22:00:56.0	-18.10	-133.70	0	3.5 PPT							5	GB-3	218
	06 3 1965	11:10:53.1	-18.40	-132.90	0	5.5 mb	-18.40	-132.85	10	11:10:52.2			3	GB-4	219
	18 9 1966	06:40:35.5	-18.48	-132.81	0	5.0 mb	-18.40	-132.86	10	06:40:35.8			3	GB-4	220
PPT	01 5 1968	08:50:03.0	-18.40	-132.80	0	4.5 PPT							5	GB-4	221
PPT	18 8 1968	05:41:28.0	-18.40	-132.80	0	4.7 PPT							5	GB-4	222
PPT	07 8 1971	14:47:59.0	-18.40	-132.80	0	4.2 PPT							5	GB-4	223
PPT	13 5 1972	11:24:49.0	-18.40	-132.80	0	3.3 PPT							5	GB-4	224
PPT	15 5 1975	02:09:35.0	-18.40	-132.90	0	3.1 PPT							5	GB-4	225
GS	25 5 1975	14:16:31.3	-18.46	-132.99	19	5.0 mb	-18.40	-132.92	10	14:16:32.8			3	GB-4	226
PPT	13 9 1975	18:17:01.0	-18.40	-132.90	0	3.6 PPT							5	GB-4	227
PPT	15 5 1976	08:02:12.0	-18.40	-132.90	0	3.3 PPT							5	GB-4	228
PPT	22 9 1977	00:02:51.0	-18.40	-132.90	0	2.7 PPT							5	GB-4	229
PPT	31 5 1979	01:15:49.0	-18.40	-132.90	0	3.3 PPT							5	GB-4	230
PPT	30 1 1978	18:34:19.6	-16.23	-126.94	0	5.0 mb							5	GB-6	231
PPT	06 11 1978	09:05:54.0	-22.00	-132.00	0	4.5 PPT							5	GB-7	232
PPT	05 2 1986	04:04:36.0	-21.18	-135.10	12	3.9 PPT							5	GB-10	233
ISC	09 5 1974	09:52:14.7	-5.20	-129.20	33		-5.20	-129.20	33	09:52:14.7			2	SP-3	234
ISC	16 11 1983	12:31:21.8	-11.70	-126.10	10	4.8 mb							3	SP-4	235
ISC	08 11 1969	17:05:13.0	-12.00	-140.30	33	4.3 mb	-7.40	-148.00	10	17:05:17.0			6	LI-2	236

Table 1 (continued)

Sorted Dataset for Polynesia

Initial Location							Relocation						Code	Site	Index
Sce	Date D M Y	Time (GMT)	Lat. °N	Long. °E	Depth (km)	Mag.	Lat. °N	Long. °E	Depth (km)	Time (GMT)	Ns	σ (s)			
							Casualties								
WEL	27 9 1973	02:07:28.0	-16.00	-160.00	33		-23.36	179.58	646	02:07:32.6	4	0.00	7		237
ISS	21 6 1918	03:59:05.0	-22.00	-141.00	0								11		238
ISS	17 4 1927	09:05:42.0	-6.50	-126.00	160		-6.50	126.00	160				14		239
CGS	12 1 1942	16:07:18.0	-8.00	-156.50	0		-8.00	156.50					14		240
CGS	24 8 1968	18:29:58.9	-22.21	-138.81	0	5.0 mb							15		241
CGS	08 9 1968	18:59:59.3	-21.78	-139.16	0	4.7 mb							15		242
CGS	30 5 1970	17:59:58.5	-22.24	-138.79	0	4.7 mb							15		243
CGS	03 7 1970	18:29:59.1	-21.80	-139.19	0	4.8 mb							15		244
ERL	14 8 1971	18:59:59.2	-21.88	-138.95	0	4.7 mb							15		245
GS	11 7 1976	00:29:54.8	-22.67	-138.61	0	5.0 mb							15		246
GS	19 2 1977	23:29:57.9	-22.10	-138.76	0	5.3 mb							15		247
GS	19 3 1977	23:00:58.2	-21.93	-138.96	0	5.9 mb							15		248
GS	24 11 1977	16:59:58.5	-21.89	-138.95	0	6.0 mb							15		249
GS	22 3 1978	17:29:57.2	-22.10	-138.56	0	4.8 mb							15		250
GS	30 11 1978	17:31:58.4	-21.90	-138.97	0	5.9 mb							15		251
GS	19 12 1978	16:57:00.1	-21.73	-139.04	0	4.9 mb							15		252
GS	24 3 1979	16:27:58.8	-21.82	-139.06	0	4.9 mb							15		253
GS	18 6 1979	23:26:58.4	-22.04	-138.62	0	5.0 mb							15		254
GS	29 6 1979	18:55:57.9	-21.99	-138.88	0	5.3 mb							15		255
GS	25 7 1979	17:56:58.3	-21.89	-138.99	0	6.0 mb							15		256
GS	28 7 1979	19:55:59.2	-21.71	-138.90	0	4.4 mb							15		257
GS	23 3 1980	19:36:58.4	-21.87	-139.02	0	5.7 mb							15		258
GS	01 4 1980	19:30:58.6	-21.83	-138.84	0	5.1 mb							15		259
GS	16 6 1980	18:26:57.8	-22.02	-138.87	0	5.5 mb							15		260
GS	19 7 1980	23:46:58.2	-21.89	-139.02	0	5.9 mb							15		261
GS	03 12 1980	17:32:58.2	-21.94	-138.96	0	5.6 mb							15		262
GS	08 7 1981	22:22:57.9	-22.01	-138.90	0	5.3 mb							15		263
GS	03 8 1981	18:32:57.5	-22.07	-138.78	0	5.3 mb							15		264
GS	11 11 1981	17:06:58.3	-21.92	-138.99	0	4.5 mb							15		265
GS	05 12 1981	16:57:58.4	-22.03	-138.60	0	4.6 mb							15		266
GS	08 12 1981	16:46:58.4	-21.91	-138.89	0	5.2 mb							15		267
GS	20 3 1982	17:02:57.9	-21.99	-138.94	0	5.0 mb							15		268
GS	01 7 1982	17:01:58.8	-21.76	-139.05	0	5.2 mb							15		269
GS	25 7 1982	18:01:58.1	-21.86	-138.94	0	5.6 mb							15		270
GS	19 4 1983	18:52:58.4	-21.84	-138.90	0	5.6 mb							15		271
GS	25 5 1983	17:30:58.2	-21.89	-138.92	0	5.9 mb							15		272
GS	28 6 1983	17:45:58.6	-21.74	-138.92	0	5.4 mb							15		273
GS	04 8 1983	17:13:58.2	-21.83	-138.92	0	5.2 mb							15		274
PDE	12 5 1984	17:30:58.3	-21.85	-138.96	0	5.7 mb							15		275
PDE	16 6 1984	17:43:57.9	-21.93	-138.99	0	5.3 mb							15		276
PDE	02 11 1984	20:44:58.5	-21.88	-138.99	0	5.7 mb							15		277
PDE	06 12 1984	17:28:58.6	-21.85	-138.91	0	5.6 mb							15		278
PDE	30 4 1985	17:28:57.9	-22.07	-138.90	0	4.5 mb							15		279
PDE	08 5 1985	20:27:58.8	-21.82	-139.05	0	5.7 mb							15		280
PDE	03 6 1985	17:29:58.0	-22.05	-138.86	0	5.2 mb							15		281
PDE	26 10 1985	16:34:58.3	-21.85	-138.97	0	5.4 mb							15		282
PDE	24 11 1985	16:00:58.5	-21.86	-138.76	0	4.7 mb							15		283
PDE	26 11 1985	17:41:58.4	-21.86	-138.93	0	5.8 mb							15		284
GS	26 4 1986	17:01:56.7	-22.15	-139.11	0	4.8 mb							15		285
GS	30 5 1986	17:24:58.3	-21.90	-139.03	0	5.7 mb							15		286
GS	12 11 1986	17:01:58.3	-21.91	-139.08	0	5.3 mb							15		287
GS	10 12 1986	17:14:58.3	-21.92	-138.92	0	5.2 mb							15		288
GS	05 5 1987	16:57:57.7	-21.90	-139.10	0	4.9 mb							15		289
GS	20 5 1987	17:04:58.3	-21.89	-138.96	0	5.6 mb							15		290
GS	06 6 1987	17:59:59.3	-21.75	-138.89	0	4.7 mb							15		291
GS	21 6 1987	17:54:57.9	-22.05	-138.71	0	5.1 mb							15		292
GS	23 10 1987	16:49:58.8	-21.82	-139.03	0	5.5 mb							15		293
GS	05 11 1987	17:29:59.1	-21.79	-139.00	0	5.8 mb							15		294
GS	19 11 1987	16:30:58.3	-21.91	-139.01	0	5.9 mb							15		295
GS	11 5 1988	16:59:58.4	-21.87	-139.07	0	5.5 mb							15		296
GS	25 5 1988	17:00:58.4	-21.90	-139.01	0	5.6 mb							15		297
GS	23 6 1988	17:30:58.6	-21.91	-139.02	0	5.3 mb							15		298
GS	05 11 1988	16:29:58.4	-21.88	-139.04	0	5.4 mb							15		299
GS	23 11 1988	17:00:58.0	-21.99	-138.90	0	5.4 mb							15		300
GS	30 11 1988	17:54:58.0	-22.24	-138.83	0	5.5 mb							15		301

Table 2

Sorted Dataset for Southcentral Pacific (Except Polynesia)

Initial Location							Relocation						Code	Site	Index
Sce	Date D M Y	Time (GMT)	Lat. °N	Long. °E	Depth (km)	Mag.	Lat. °N	Long. °E	Depth (km)	Time (GMT)	Ns	σ (s)			
Intraplate Events															
CGS	05 1 1945	06:18:23.0	-2.00	-107.00	0		-2.54	-108.25	10	06:18:21.6	14	1.66	1	SP-1	401
ISS	21 4 1960	02:16:32.0	-2.60	-109.40	0		-2.57	-109.53	10	02:16:35.2	60	1.87	1	SP-1	402
ISC	22 7 1972	11:11:09.8	-2.40	-116.30	0	4.8 mb	-2.40	-116.30	0	11:11:09.8			2	SP-2	403
GS	30 9 1981	23:03:47.5	-4.80	-112.01	10	5.9 mb							3	IP-1	404
GS	04 10 1981	17:10:22.8	-4.67	-111.86	10	5.1 mb							3	IP-1	405
ISC	30 1 1980	00:31:14.0	-5.30	-116.00	10	5.3 mb							3	IP-2	406
GS	23 1 1988	22:01:57.3	-15.25	-116.19	10	5.1 mb							3	SP-5	407
CGS	22 11 1955	03:24:00.0	-24.50	-123.00	0	6.75PAS	-24.27	-122.77	10	03:24:05.0	19	1.48	1	IP-4	408
ISS	29 9 1951	18:15:00.0	-26.60	-122.00	0	5.9 mb	-26.55	-121.95	10	18:15:00.0	12	0.50	1	IP-5	409
CGS	03 8 1951	19:20:15.0	-28.00	-121.00	0		-26.92	-121.42	10	19:19:59.8	13	0.70	1	IP-6	410
ISC	17 1 1976	05:44:14.2	-26.00	-126.00	33		-26.00	-126.00	33	05:44:14.2			2	SP-6	411
CGS	10 11 1968	08:29:44.6	-29.73	-116.94	33	4.3 mb	-29.73	-116.94	33	08:29:44.6			2	SP-7	412
ERL	09 9 1971	03:25:47.8	-33.28	-115.14	33	4.8 mb							3	SP-8	413
CGS	14 9 1963	16:16:51.8	-33.60	-126.70	33	4.9 mb	-33.60	-126.70	33	16:16:51.8			2	IP-7	414
ISC	29 3 1975	15:02:29.6	-37.80	-138.90	0	5.0 mb							3	IP-9	415
GS	21 6 1988	19:07:20.2	-37.80	-148.80	10	4.6 mb	-37.80	-148.80	10	19:07:20.2			2	SP-9	416
ISS	22 3 1921	11:54:27.0	-38.80	-146.00	0		-40.67	-142.99	10	11:54:18.4	4	4.44	1	SP-10	417
ERL	28 9 1972	06:57:35.2	-47.79	-119.70	33	5.1 mb							3	IP-10	418
BCI	14 7 1951	06:21:14.0	-52.00	-128.00	0	5.5 Ms	-52.94	-126.57	10	06:21:19.7	8	1.32	1	IP-11	419
G	05 9 1938	14:42:32.0	-55.00	-152.00	0	6.0 PAS	-53.98	-147.85	10	14:42:36.6	16	1.78	1	IP-12	420
G-R	15 12 1947	19:20:26.0	-59.50	-160.00	60	7.2 PAS	-58.76	-159.20	10	19:20:26.3	14	1.79	1	IP-13	421
CGS	10 4 1950	06:06:46.0	-58.00	-160.00	0	6.4 Ms	-58.70	-159.11	10	06:06:43.7	6	0.97	1	IP-13	422
ISS	17 10 1959	08:35:00.0	-57.30	-161.00	0	5.5 Ms	-57.36	-161.00	10	08:35:02.5	13	1.28	1	IP-15	423
ISC	21 10 1976	03:56:28.1	-57.40	-161.10	39	5.4 mb	-57.40	-161.10	39	03:56:28.1			2	IP-15	424
GS	21 10 1988	13:45:46.9	-46.52	-153.37	10	5.0 mb	-46.52	-153.37	10	13:45:46.9			2	SP-11	425
Casualties															
ISS	02 2 1922	02:51:30.0	-49.00	-132.00	0		-41.88	-134.19	10	02:51:31.8	4	1.95	8		426
ISS	12 12 1924	08:47:30.0	-40.00	-120.00	0		-37.31	-120.85	10	08:47:39.8	4	1.41	8		427
ISS	15 6 1930	21:08:11.0	-44.00	-118.00	0		-47.03	-116.24	10	21:08:08.8	8	2.86	8		428
CGS	20 1 1940	09:58:06.0	-52.50	-134.50	0	6.75PAS	-54.23	-135.78	10	09:58:13.0	11	1.10	8		429
CGS	14 11 1944	00:30:24.0	-33.00	-115.00	0		-30.64	-113.20	10	00:30:39.6	6	0.56	8		430
CGS	17 9 1949	22:46:25.0	-35.00	-154.00	0		-64.44	-164.30	10	22:46:25.5	7	2.60	8		431
CGS	11 11 1949	10:57:36.0	-9.00	-119.00	0		-8.61	-109.03	10	10:57:40.2	10	1.75	8	IP-3	432
BCI	16 6 1954	15:53:24.0	-37.50	-114.00	0		-36.70	-112.51	10	15:53:34.7	7	1.18	8		433
CGS	26 7 1958	08:35:10.0	-60.50	-168.50	0		-63.38	-163.75	10	08:35:44.2	6	0.99	8	IP-16	434
BCI	30 7 1958	15:10:12.0	-48.00	-120.00	0		-49.83	-114.35	10	15:10:24.1	10	1.38	8		435
BCI	17 8 1959	06:28:12.0	-38.00	-115.00	0		-34.51	-109.38	10	06:28:57.8	9	0.52	8		436
BCI	17 10 1959	01:23:00.0	-54.00	-165.00	0		-64.07	-169.40	10	01:23:23.3	4	0.34	8	IP-14	437
ISS	03 4 1963	14:47:58.0	-52.10	-131.50	0		-55.08	-128.28	10	14:47:54.7	34	3.15	8		438
CGS	27 1 1964	10:32:13.4	-19.90	-115.40	33	4.2 mb	-19.90	-115.40	33				10		439
CGS	09 10 1964	00:14:22.3	-35.00	-115.00	33	4.5 mb	-35.00	-113.80	33	00:14:22.2	10	1.81	9		440
ISC	09 2 1968	08:36:24.0	-20.00	-114.00	33	4.1 mb	-20.00	-114.00	33				10		441
ISC	26 7 1969	05:21:40.0	-27.00	-120.00	33	4.5 mb	-23.14	-117.25	10	05:22:04.2	6	0.93	8		442
ISC	02 12 1975	05:23:09.7	-49.40	-120.10	33		-49.16	-120.11	10	05:23:09.2	6	1.28	8		443
GS	23 7 1976	17:44:26.8	-29.97	-114.43	33	5.1 mb	-29.70	-114.20	33	17:44:29.0	32	2.58	9		444
ISC	31 7 1976	05:11:20.7	-38.70	-123.00	34	4.3 mb	-22.53	-113.45	10	05:12:58.2	8	0.43	8	IP-8	445
ISC	15 2 1975	22:00:58.5	-3.50	-108.80	33	4.4 mb	-3.43	-108.77	10	22:00:57.3	6	1.66	8		446
ISS	26 3 1922	13:25:32.0	-41.00	-135.00	0								11		447
ISS	25 9 1924	04:01:15.0	-48.50	-160.50	0								11		448
ISS	04 11 1924	03:02:45.0	-49.00	-132.00	0		-63.32	-126.26	10	03:02:57.1	3	0.00	11		449
ISS	19 2 1920	19:54:00.0	-48.50	-160.50	0								12		450
ISS	20 7 1920	00:21:35.0	-50.00	-127.00	0						4		12		451
CGS	13 1 1938	03:15:18.0	-31.00	-155.00	0		-26.65	-170.22	10	03:14:43.7	7	0.53	12	IP-19	452

Table 3

Sorted Dataset for Campbell – New Zealand – Kermadec

Initial Location							Relocation							Code	Site	Index
Sce	Date D M Y	Time (GMT)	Lat. °N	Long. °E	Depth (km)	Mag.	Lat. °N	Long. °E	Depth (km)	Time (GMT)	Ns	σ (s)				
							Intraplate Events									
ISC	21 4 1974	06:54:27.9	-55.28	164.30	33	5.1 mb	-55.28	164.30	33	06:54:28.3	15	1.93	2		501
WEL	26 3 1982	19:45:30.5	-50.10	172.80	33	4.4 mb	-51.19	168.30	10	19:45:29.5	5	1.75	1		502
ISC	26 6 1971	22:02:18.2	-51.35	167.60	12	5.6 Ms	-51.17	167.69	11	22:02:20.0	40	1.67	2		503
ISC	11 3 1984	16:42:38.0	-48.80	174.30	33	4.0 WEL	-49.00	172.63	10	16:42:47.6	8	3.34	1		504
ISC	10 2 1980	22:59:55.1	-49.00	173.10	33	4.1 mb	-49.00	173.10	33	22:59:55.1			2		505
ISC	03 6 1983	05:44:37.6	-50.20	174.50	10	5.2 mb							3		506
WEL	01 8 1953	13:36:28.0	-44.25	-179.00	0		-44.24	-175.45	10	13:36:28.1	11	2.49	1	IP-17	507
ISC	09 4 1965	13:18:57.0	-43.60	-176.00	33	4.5 WEL	-43.25	-177.60	10	13:19:08.2	9	1.78	1		508
ISC	26 7 1975	11:36:55.5	-44.90	-175.00	69	4.6 mb	-44.90	-175.00	69	11:36:55.5			2		509
WEL	25 08 1964	02:37:12.0	-42.10	178.40	0	4.0 WEL	-42.10	178.40	0	02:37:12.0	5	0.51	2		510
WEL	04 4 1971	08:56:11.2	-44.00	177.97	12	3.8 WEL	-44.00	177.97	12	08:56:11.2	6	1.48	2		511
WEL	11 01 1974	03:07:22.1	-42.13	178.10	33	4.1 WEL	-42.13	178.10	33	03:07:22.1	25	1.61	2		512
WEL	15 2 1974	07:15:01.9	-43.11	176.90	33	4.0 WEL	-43.11	176.90	33	07:15:01.9	15	2.31	2		513
WEL	22 3 1974	22:16:20.5	-43.28	177.16	33	4.0 WEL	-43.28	177.16	33	22:16:20.5	13	2.16	2		514
WEL	26 4 1976	16:06:08.2	-42.51	177.82	33	3.9 WEL	-42.51	177.82	33	16:06:08.2	15	2.11	2		515
WEL	09 12 1976	03:54:40.0	-43.42	179.04	33	4.3 WEL	-43.42	179.04	33	03:54:40.0	23	1.91	2		516
WEL	25 12 1977	04:35:54.8	-42.05	178.27	33	4.5 WEL	-42.05	178.27	33	04:35:54.8	15	1.29	2		517
WEL	20 7 1978	14:56:42.2	-42.74	177.40	12	4.1 WEL	-42.74	177.40	12	14:56:42.2	20	1.12	2		518
WEL	28 2 1979	23:36:34.0	-43.85	176.62	33	4.2 WEL	-43.85	176.62	33	23:36:34.0	16	2.09	2		519
WEL	2 5 1979	08:32:03.8	-44.56	177.10	33	4.1 WEL	-44.56	177.10	33	08:32:03.8	25	1.93	2		520
WEL	25 4 1980	09:20:12.1	-42.82	176.87	33	4.0 WEL	-42.82	176.87	33	09:20:12.1	21	1.66	2		521
WEL	03 6 1982	08:32:46.9	-41.99	178.03	33	4.0 WEL	-41.99	178.03	33	08:32:46.9	18	1.30	2		522
WEL	02 2 1983	15:38:59.8	-42.84	177.12	33	4.3 WEL	-42.84	177.12	33	15:38:59.8	20	0.94	2		523
WEL	08 10 1985	06:23:06.1	-42.25	178.10	12	3.9 WEL							3		524
CGS	24 9 1960	11:06:39.2	-41.80	-179.30	43		-40.93	-178.72	10	11:06:33.9	16	1.56	1		525
WEL	14 7 1964	01:11:02.0	-40.40	179.70	0	4.5 WEL	-40.40	179.70	0	01:11:02.0	12	1.37	2		526
ISC	27 7 1971	14:03:05.7	-41.00	-179.30	33	4.5 mb	-41.00	-179.30	33	14:03:05.7			2		527
ISC	07 4 1972	00:53:07.9	-40.40	-179.90	33	4.7 mb	-40.40	-179.90	33	00:53:07.9			2		528
ISC	24 4 1972	09:29:17.1	-40.60	-179.40	33	4.4 mb	-40.60	-179.40	33	09:29:17.1			2		529
GS	01 11 1974	20:44:31.2	-39.06	-179.78	26	5.1 mb	-39.06	-179.78	26	20:44:31.2			2		530
ISC	13 5 1982	18:04:13.1	-40.90	180.00	12	3.7 mb	-40.90	180.00	12	18:04:13.1			2		531
ISC	02 4 1984	18:45:08.6	-40.10	-179.80	33								3		532
ISC	11 4 1984	11:10:14.3	-40.70	180.00	33	3.9 WEL							3		533
ISC	13 4 1984	09:33:54.6	-40.10	-179.90	33	3.7 WEL							3		534
ISC	23 9 1984	03:57:53.2	-40.10	-179.30	33	3.8 WEL							3		535
WEL	31 5 1985	08:16:26.5	-40.10	-179.20	33	4.1 mb	-40.08	-179.53	10	08:16:27.2	9	1.78	1		536
ISC	28 3 1976	06:48:26.2	-41.40	-171.40	33		-38.63	-170.67	10	06:48:25.5	4	0.24	1		537
ISS	10 5 1924	02:48:40.0	-36.30	-169.00	0		-35.21	-169.56	10	02:48:47.8	5	1.61	1		538
ISS	10 8 1926	21:16:20.0	-28.00	-163.50	0		-41.99	-161.25	10	21:14:57.2	4	9.31	1		539
CGS	04 1 1940	01:10:18.0	-34.00	-162.00	0	5.9 Ms	-33.84	-162.47	10	01:10:21.4		1.30	1	IP-20	540
ISS	01 8 1925	02:25:40.0	-28.00	-163.50	0		-29.38	-164.34	10	02:26:03.8	4	0.53	1		541
							Casualties									
ISS	15 4 1921	21:06:10.0	-33.30	-173.70	0		-34.88	179.96	10	21:07:20.3	5	1.19	7		542
ISS	26 12 1924	23:32:43.0	-32.00	-173.00	0		-29.66	-174.22	10	23:32:34.1	4	2.42	7		543
ISS	17 2 1925	14:13:18.0	-51.70	173.80	0		-49.83	170.04	10	14:14:29.3	4	19.63	7		544
ISS	04 1 1926	04:01:36.0	-48.00	170.00	0		-45.83	173.29	10	04:01:45.0	5	1.96	7		545
ISS	23 5 1936	15:32:07.0	-41.00	-179.50	223		-40.46	178.36	249	15:32:14.1	9	2.64	7		546
ISS	09 7 1936	10:20:45.0	-40.70	-179.40	0		-39.75	179.45	231	10:20:42.8	10	1.12	7		547
CGS	02 10 1940	10:24:00.0	-30.50	-172.00	0		-25.12	179.25	10	10:23:56.3	10	0.71	7		548
ISS	01 2 1947	13:28:56.0	-29.00	-162.00	0		-19.90	-174.23	10	13:28:56.4	14	0.81	7		549
BCI	21 4 1959	15:24:42.0	-62.50	-172.50	0		-62.19	164.48	10	15:25:02.3	4	0.98	8		550
CGS	24 8 1963	12:50:13.0	-37.30	-178.20	36		-37.47	-178.66	10	12:50:15.4	6	0.47	7		551
ISC	07 2 1964	14:45:05.5	-32.10	-174.00	33		-32.73	-179.86	10	14:45:50.6	6	1.14	7		552
ISC	01 10 1964	20:38:06.0	-35.50	-170.50	0		-32.92	-178.76	10	20:39:00.3	6	0.71	7		553
ISC	17 5 1966	04:27:24.0	-40.66	179.70	33	4.1 WEL	-40.47	178.89	33	04:27:33.0	11	1.92	9		554
LAO	10 1 1968	00:37:45.0	-35.0	-174.0	33	4.9 LAO	-18.99	-167.31	10	00:38:59.6	4	0.34	7		555
ISC	10 9 1974	15:44:23.0	-38.70	-176.50	33	3.9 WEL	-39.49	178.02	33	15:45:28.3	8	2.47	9		556
ISC	27 7 1977	15:26:45.7	-52.16	165.60	33	4.9 WEL	-51.69	164.25	33	14:07:43.9			9		557
ISC	07 11 1979	01:00:01.0	-38.1	-177.3	33	3.8 WEL	-38.97	179.30	33	01:00:41.8	11	1.83	9		558
ISC	27 5 1982	10:12:17.2	-47.30	-178.70	33	4.1 mb	-49.77	164.70	60	10:13:34.3	9	3.46	7		559
ISC	26 7 1982	10:20:18.0	-41.76	179.05	33	4.2 WEL	-41.43	178.25	33	10:20:27.7	29	1.54	9		560
PDE	30 3 1984	16:38:38.2	-30.41	-174.76	33	4.7 mb	-30.57	-176.70	33	16:38:53.0	26	1.84	9		561
WEL	04 3 1985	18:44:04.0	-40.50	-178.70	33	4.1 mb	-39.98	179.60	10	18:44:28.7	4	1.30	7		562
PDE	22 5 1985	06:55:58.2	-38.90	-178.35	33	4.7 mb	-37.95	-179.80	33	06:56:10.0	26	1.33	9		563
ISC	23 11 1985	02:44:16.0	-41.90	178.60	33	4.0 WEL	-41.66	178.14	33	02:44:23.2	7	0.81	9		564
ISC	28 2 1986	14:05:54.0	-41.1	179.80	33	3.7 WEL	-40.42	178.59	33	14:06:07.8	11	1.58	9		565
ISS	09 5 1920	08:00:04.0	-51.70	173.80	0								11		566

Table 3 (continued)

Sorted Dataset for Campbell – New Zealand – Kermadec

	Initial Location						Relocation						Code	Site	Index
Sce	Date D M Y	Time (GMT)	Lat. °N	Long. °E	Depth (km)	Mag.	Lat. °N	Long. °E	Depth (km)	Time (GMT)	Ns	σ (s)			
ISS	04 7 1923	22:54:55.0	-28.00	-163.50	0		-30.79	-160.55	10	22:55:01.9	3	0.00	11		567
ISS	25 2 1927	11:25:12.0	-28.00	-163.50	0		-6.64	-163.46	10	11:24:45.8	3	0.00	11		568
ISS	01 6 1927	10:09:36.0	-45.00	180.00	0		-45.07	178.05	10	10:09:55.2	3	0.00	11		569
WEL	06 8 1964	08:34:00.0	-38.50	-176.00	33	2.9 WEL							11		570
WEL	25 5 1984	01:04:42.0	-41.19	179.87	12	3.8 WEL	-41.19	179.80	10	01:04:42.1	4	0.18	11		571
ISS	06 8 1924	00:22:00.0	-28.00	-163.50	0		-26.50	-163.66	10	00:22:31.0	4	0.47	12		572
ISS	17 12 1925	05:41:45.0	-48.00	170.00	0		-45.77	169.05	10	05:42:13.2	3	0.00	12		573
ISC	29 11 1974	22:14:43.6	-42.60	180.00	12	3.8 mb							12		574
WEL	30 6 1985	11:19:53.4	-49.10	174.60	33	4.3 mb							12		575
ISS	15 10 1957	05:55:33.0	-30.24	-170.94	244		-30.24	-179.04					14		576

Table 4

Sorted Dataset for Off Tonga and Samoa

	Initial Location						Relocation						Code	Site	Index
Sce	Date D M Y	Time (GMT)	Lat. °N	Long. °E	Depth (km)	Mag.	Lat. °N	Long. °E	Depth (km)	Time (GMT)	Ns	σ (s)			
							Intraplate Events								
ISS	24 12 1929	04:29:18.0	-3.00	-172.00	0		-2.00	-171.15	10	04:29:10.0	5	1.90	1		651
ISS	15 6 1930	07:33:03.0	-13.00	-162.80	0		-12.68	-162.90	10	07:33:01.0	5	2.66	1		652
ISS	16 6 1932	23:13:47.0	-13.00	-167.00	0		-13.19	-166.69	10	23:13:46.4	6	0.88	1		653
ISS	20 2 1922	07:43:50.0	-17.00	-168.00	0		-15.31	-166.43	10	07:43:45.9	5	1.36	1		654
ISC	04 7 1983	17:10:30.7	-20.50	-166.80	33		-20.50	-166.80	33	17:10:30.7			2		655
CGS	04 10 1937	07:40:30.0	-26.80	-163.10	0	6.2 Ms	-22.01	-166.99	10	07:40:34.8		1.20	1	IP-18	656
							Casualties								
ISS	20 12 1914	14:08:27.0	-17.00	-168.00	0		-15.72	-173.97	10	14:09:00.5	12	1.77	7		657
ISS	23 1 1925	17:01:00.0	-11.00	-170.00	0		-8.60	-164.05	10	17:01:04.9	4	22.19	7		658
ISS	22 2 1928	12:57:20.0	-23.00	-163.00	0		-23.94	-174.20	10	12:59:28.2	5	4.13	7		659
ISS	14 2 1933	05:22:50.0	-24.60	-170.30	0		-20.18	-174.88	571	05:23:53.3	7	0.44	7		660
CGS	29 6 1938	18:44:54.0	-16.00	-168.00	0		-21.00	-174.00	0	18:44:08.0			9		661
CGS	15 5 1939	06:09:00.0	-13.00	-168.00	0		-15.43	-174.55	235	06:09:35.6	9	0.78	7		662
CGS	31 3 1954	08:30:04.0	-12.00	-171.50	0		-15.12	-174.79	10	08:29:44.7	11	0.41	7		663
ISC	23 5 1967	12:03:14.0	-8.00	-170.00	33	4.4 mb	-15.67	-173.36	10	12:02:30.3	8	0.27	7		664
ISC	12 11 1967	15:28:24.0	-25.60	-169.90	33	4.3 mb	-26.76	178.96	600	15:28:53.0	6	2.30	7		665
ISC	07 2 1974	20:10:50.7	-19.10	-167.30	33		-23.70	-179.29	10	20:12:21.5	5	1.13	7		666
GS	28 5 1974	16:58:04.1	-24.48	-173.29	33		-26.12	-175.00	191	16:58:34.2	7	1.83	9		667
ISC	01 7 1974	06:21:49.7	-13.40	-167.40	33		-15.81	-169.56	10	06:22:09.8	8	0.71	7		668
ISC	15 8 1974	07:15:10.4	-14.80	-167.30	0	3.9 mb	-17.40	-174.52	199	07:15:13.0	7	1.14	7		669
ISC	17 3 1975	08:41:06.6	-17.00	-168.20	33		-17.06	-168.16	10	08:41:05.2	5	1.30	7		670
GS	05 3 1976	08:20:09.3	-21.78	-171.55	33	5.3 mb	-21.56	-173.05	10	08:20:19.5	8	1.28	7		671
ISC	23 9 1976	09:39:04.7	-11.70	-172.00	33		-16.74	-175.48	362	09:40:19.5	8	0.30	7		672
ISC	23 10 1976	21:31:05.4	-16.80	-168.90	33		-14.59	-170.20	10	21:30:55.0	11	0.53	7		673
ISC	14 4 1979	09:21:31.5	-11.50	-166.10	33		-17.73	-175.25	550	09:23:37.5	7	0.93	7		674
ISC	09 11 1979	14:26:27.8	-11.00	-162.60	33	3.9 mb	-16.35	-172.82	100	14:28:01.3	9	1.41	7		675
ISC	01 3 1980	07:15:16.8	-21.90	-166.20	33	4.9 mb	-20.26	-177.07	502	07:17:18.3	6	0.15	7		676
ISC	06 6 1980	08:57:58.4	-19.40	-167.60	33	4.2 mb	-22.40	-174.17	200	08:59:11.0	5	0.33	7		677
ISC	25 10 1980	22:21:46.8	-13.60	-165.60	33	5.4 mb	-17.60	-177.70	552	22:24:08.7	8	0.70	7		678
PDE	24 5 1984	01:22:10.5	-15.83	-167.27	33	5.2 mb	-19.80	-177.67	448	01:24:11.6	10	1.09	9		679
PDE	30 11 1984	06:42:40.1	-26.27	-173.36	33	4.7 mb	-26.33	-173.68	10	06:42:42.0	5	0.66	7		680
GS	26 9 1986	10:36:17.0	-21.84	-171.65	33	5.1 mb	-22.60	-176.20	162	10:37:04.0	11	0.72	9		681
ISS	18 5 1917	19:05:00.0	-11.00	-170.00	0								11		682
ISS	26 3 1927	02:26:40.0	-25.00	-167.00	0		-24.12	-167.59	10	02:26:58.0	3	0.00	12		683
WEL	11 1 1965	22:13:28.1	-18.10	-166.90	33								12		684
NGD	30 6 1905	17:07:00.0	-1.00	-168.00	60	7.6							13		685
BCI	17 7 1955	07:06:03.0	-17.50	-170.00	0		-17.35	169.21	10	07:06:04.1	9	2.33	14		686
BCI	28 10 1958	19:07:48.0	-13.50	-167.00	0		-13.37	166.76	10	19:07:46.0	4	0.14	14		687
CGS	01 7 1961	03:48:36.9	-13.90	-166.10	33		-14.00	165.70	33	03:48:33.1			14		688

Table 5

Sorted Dataset for Samoa to Gilbert

Initial Location							Relocation						Code	Site	Index
Sce	Date D M Y	Time (GMT)	Lat. °N	Long. °E	Depth (km)	Mag.	Lat. °N	Long. °E	Depth (km)	Time (GMT)	Ns	σ (s)			
							Intraplate Events								
G	24 4 1937	04:58:35.0	-12.00	-178.00	200	6.25PAS	-10.14	-176.00	10	04:58:30.0		1.64	1	IP-21	751
CGS	26 6 1956	11:23:09.0	-10.00	-173.50	0		-10.26	-173.65	10	11:23:14.2	21	1.24	1		752
BCI	03 10 1957	13:44:30.0	-10.00	-179.00	0		-10.58	-179.49	10	13:44:32.8	5	1.94	1		753
ISS	30 4 1939	14:02:34.0	-5.60	163.80	0		-6.36	163.22	10	14:02:35.9	10	0.77	1		754
ISS	15 5 1931	07:41:55.0	-8.00	173.00	0		-8.35	172.82	22	07:41:57.2	11	1.53	1		755
CGS	05 3 1964	05:50:15.2	-6.10	-172.50	33	4.3 mb	-5.77	-173.82	10	05:50:22.0	4	1.48	1		756
ISC	03 6 1981	22:15:14.1	-5.30	-175.20	33	5.3 mb							3		757
ISS	10 2 1921	19:42:16.0	-3.00	177.50	0		-0.79	177.90	10	19:42:14.5	5	1.18	1		758
W,E	19 9 1967	06:26:10.9	-0.50	169.00	0								4		759
WIA	28 5 1983	23:21:26.4	-1.00	170.50	0								4		760
WIA	29 6 1983	16:15:01.5	0.00	170.00	0								4		761
WIA	19 9 1983	10:12:48.0	0.50	169.50	0								4		762
NGD	19 11 1986	08:28:33.0	0.30	169.70	33	5.3 mb							3		763
ISC	17 2 1982	14:23:43.9	-6.10	179.00	33	4.2 mb	-3.61	177.81	10	14:23:49.7	8	1.37	6		764
ISC	02 5 1982	23:13:57.0	-1.10	175.70	33	4.4 mb	-3.22	177.24	10	23:13:51.7	9	0.43	6		765
							Casualties								
ISS	06 2 1918	03:10:30.0	-11.00	-176.00	0		-12.48	-174.80	10	03:10:57.5	4	3.64	7		766
ISS	01 8 1918	11:42:00.0	-11.00	-176.00	0		-12.36	-175.31	10	11:42:21.4	4	0.27	7		767
ISS	20 1 1922	06:50:54.0	-6.50	166.50	0		-5.54	164.95	10	06:51:19.4	4	6.67	7		768
ISS	01 12 1924	22:56:48.0	-12.00	-177.00	0		-10.34	-174.72	10	22:56:42.4	4	3.78	7		769
ISS	19 11 1925	19:10:35.0	-10.00	176.00	0		-15.61	-179.65	10	19:11:49.2	4	13.13	7		770
ISS	05 2 1928	22:45:20.0	-10.00	176.00	0		-12.32	177.93	10	22:45:55.0	4	3.35	7		771
ISS	08 6 1928	14:39:10.0	-12.00	-177.00	0		-14.82	-175.60	10	14:39:10.6	7	1.39	7		772
ISS	02 2 1932	06:59:30.0	-11.00	-176.00	0		-13.86	-176.30	162	06:59:40.0	7	1.02	7		773
ISS	23 1 1933	18:14:05.0	-5.80	175.00	0		-12.12	180.82	432	18:14:58.3	9	3.03	7		774
ISS	11 9 1933	11:20:09.0	-10.80	178.50	0		-14.17	-179.54	284	11:20:40.0	10	2.91	7		775
ISS	12 9 1935	16:01:20.0	-8.60	179.80	128		-16.99	180.14	484	16:01:31.1	18	1.25	7		776
CGS	23 7 1936	06:20:48.0	-10.00	-173.00	0		-20.20	-174.20	0	06:20:13.0			9		777
ISS	02 4 1937	05:30:10.0	-8.00	180.00	0		-21.22	-178.40	494	05:30:20.7	13	2.41	7		778
ISS	10 1 1939	11:07:30.0	-12.00	-176.00	0		-12.64	-176.13	10	11:07:35.7	5	2.91	7		779
CGS	19 1 1940	13:53:06.0	-11.00	-173.50	0		-16.49	-173.00	108	13:53:06.9	7	0.12	7		780
CGS	25 4 1940	10:18:42.0	-8.50	-176.50	0		-17.51	-175.72	398	10:18:57.3	7	0.33	7		781
CGS	12 9 1940	09:21:30.0	-12.00	-176.50	200		-16.63	-176.24	220	09:21:32.8	9	0.31	7		782
CGS	18 7 1949	08:27:21.0	-11.50	171.00	0		-13.00	171.00	0	08:28:20.0			9		783
CGS	10 12 1954	00:31:40.0	-12.00	-172.50	0		-14.56	-174.17	24	00:31:32.7	16	0.67	7		784
BCI	25 1 1959	05:14:38.0	-3.75	158.75	0		-8.75	158.13	10	05:14:43.9	7	1.62	7		785
BCI	14 2 1959	07:29:59.0	-5.50	162.50	0		-10.70	162.78	10	07:30:02.1	6	1.28	7		786
BCI	04 1 1960	04:06:18.0	-8.00	170.00	0		-16.83	-178.60	10	04:05:45.8	8	1.08	7		787
ISC	10 1 1968	17:46:54.0	-10.40	179.80	33	4.4 mb	-15.41	-178.27	353	17:47:25.1	7	0.66	7		788
ISC	19 7 1969	20:51:14.0	-8.30	-174.60	33	4.3 mb	-8.16	-174.63	10	20:51:13.7	8	0.46	7		789
ISC	11 10 1969	11:02:42.0	-12.00	-178.50	33	4.7 mb	-15.92	-176.41	281	11:03:04.1	5	0.04	7		790
ISC	29 10 1969	07:02:05.0	-9.00	-177.00	33	3.8 mb	-14.23	-174.01	10	07:01:52.2	4	0.48	7		791
ISC	01 1 1970	07:25:25.2	-9.90	178.30	33	4.2 mb	-16.64	-179.09	475	07:26:03.5	6	0.41	7		792
ISC	02 3 1972	02:17:29.6	-7.50	175.10	0	4.3 mb	-23.28	-176.43	10	02:17:04.4	5	0.60	7		793
ISC	20 4 1972	12:11:30.4	-11.20	-177.60	0	4.3 mb	-15.92	-174.99	260	12:12:01.3	10	0.96	7		794
ISC	08 4 1973	03:59:56.8	-11.10	-179.70	0	4.1 mb	-15.88	-177.27	358	04:00:31.6	8	1.06	7		795
ISC	15 4 1973	12:05:05.7	-11.70	-177.70	0	4.3 mb	-15.11	-175.69	225	12:05:33.1	6	0.72	7		796
ISC	30 7 1973	00:30:33.3	-11.70	-178.60	0	4.2 mb	-14.85	-176.73	272	00:31:02.7	5	0.30	7		797
ISC	02 5 1974	20:39:46.8	-8.70	178.10	0	5.0 mb	-17.69	-178.75	512	20:40:33.7	7	0.13	7		798
ISC	10 6 1974	03:35:13.4	-11.70	-177.70	0	4.7 mb	-14.72	-175.97	251	03:35:42.0	9	0.29	7		799
ISC	18 9 1974	18:30:04.1	-11.40	-177.30	33		-16.01	-177.85	443	18:30:35.2	5	0.25	7		800
ISC	10 11 1974	21:38:11.1	-11.40	177.20	33	4.8 mb	-17.39	-178.75	482	21:38:57.4	11	0.52	7		801
ISC	31 12 1974	18:26:59.9	-11.50	-177.20	0	4.4 mb	-16.28	-174.85	241	18:27:27.4	5	2.25	7		802
PDE	27 2 1985	06:46:48.3	-6.79	163.24	33	4.8 mb	-8.00	162.2	130	06:47:13.0	7	2.33	9		803
ISS	06 2 1918	14:43:42.0	-11.00	-176.00	0								11		804
ISS	20 9 1921	18:51:30.0	-11.00	-176.00	0								11		805
ISS	22 6 1926	04:51:30.0	-12.00	-177.00	0								11		806
ISS	23 3 1927	07:37:25.0	-12.00	-177.00	0								11		807
ISS	04 5 1921	21:12:25.0	-11.00	-176.00	0						3		12		808
ISS	01 6 1926	22:17:36.0	-10.00	176.00	0		-8.13	169.90	10	22:18:31.6	4	6.59	12		809
ISS	16 12 1926	00:24:08.0	-10.50	-174.50	0		-9.50	-174.11	10	00:24:00.5	5	2.05	12		810
ISS	28 11 1927	10:12:08.0	-3.00	177.50	0		-6.76	179.80	10	10:13:09.2	4	0.59	12		811
ISS	21 10 1928	15:17:06.0	-7.00	178.00	0		-7.83	179.40	10	15:17:39.5	4	2.35	12		812

Table 6

Sorted Dataset for Micronesia and Marshall Islands

Initial Location							Relocation						Code	Site	Index
Sce	Date D M Y	Time (GMT)	Lat. °N	Long. °E	Depth (km)	Mag.	Lat. °N	Long. °E	Depth (km)	Time (GMT)	Ns	σ (s)			
							Intraplate Events								
ISS	29 9 1926	05:16:30.0	9.00	155.00	0		5.84	-170.43	10	05:15:01.7	5	4.71	1		876
NGD	03 5 1969	08:22:14.8	8.30	-175.60	33	5.2 mb							3		877
ISC	08 5 1976	23:11:35.4	13.50	-176.20	33		13.50	-176.20	33	23:11:35.4			2		878
NGD	27 1 1965	01:44:35.8	18.90	176.60	33	4.4 mb	18.90	176.60	33	01:44:35.8			2		879
WIA	26 8 1983	01:17:34.0	22.50	171.00	0								4		880
WIA	02 11 1984	17:17:20.5	26.00	162.00	0								4		881
ISC	16 1 1976	19:08:39.8	26.60	163.00	33		26.56	162.92	10	19:08:38.9	8	1.41	1		882
ISC	16 3 1976	08:05:50.4	28.90	157.00	33		28.90	157.00	33	08:05:50.4			2		883
WIA	08 7 1983	14:39:33.6	7.50	176.00	0								4		884
NGD	22 3 1982	06:04:10.7	6.60	175.10	33	5.6 mb							3		885
OBS	27 8 1981	04:04:08.0	9.00	167.00	0								4		886
OBS	13 8 1981	18:49:19.7	10.00	166.00	0								4		887
W,E	21 8 1965	18:44:34.5	15.00	167.50	0								4		888
W,E	23 5 1969	01:13:35.0	14.00	166.00	0								4		889
W,E	12 12 1963	10:03:41.6	18.00	163.00	0								4		890
W,E	18 12 1965	02:44:11.9	16.00	159.00	0								4		891
WIA	24 3 1983	00:24:08.2	19.00	154.00	0								4		892
WIA	04 7 1985	08:18:33.3	19.50	160.50	0								4		893
W,E	17 7 1963	19:28:46.8	21.00	159.00	0								4		894
W,E	20 8 1963	23:38:25.2	21.50	157.00	0								4		895
W,E	15 8 1963	17:40:22.6	23.50	154.00	0								4		896
BCI	21 7 1960	09:51:36.0	25.00	147.00	0		25.30	148.34	10	09:51:43.4	6	1.25	1		897
WIA	10 1 1985	10:13:01.4	5.50	162.50	0								4		898
WIA	05 11 1982	16:26:07.9	5.50	162.50	0								4		899
ISC	05 11 1975	01:56:38.0	6.50	159.80	33		6.50	159.80	33	01:56:38.0			2		900
ISC	02 6 1977	17:49:16.3	6.50	160.50	33		6.50	160.50	33	17:49:16.3			2		901
NGD	18 4 1981	03:00:25.6	6.90	159.80	25	5.0 mb							3		902
E	26 2 1967	06:10:54.6	10.00	159.00	0								4		903
W,E	27 3 1963	13:17:53.1	9.00	157.00	0								4		904
ISS	05 5 1924	15:56:45.0	12.50	158.00	0		11.30	156.8	10	15:57:15.8	4	0.16	1		905
W,E	28 1 1965	07:36:20.2	11.50	156.00	0								4		906
E	01 4 1964	19:56:57.9	7.00	157.00	0								4		907
NGD	16 5 1925	10:27:50.0	9.00	155.00	0		8.53	154.47	10	10:28:07.7	6	2.43	1		908
W,E	21 7 1969	04:58:55.8	12.00	151.00	0								4		909
WIA	21 9 1984	21:20:29.7	4.00	157.50	0								4		910
ISC	08 7 1969	04:09:03.1	5.50	154.70	33		5.50	154.70	33	04:09:03.1			2		911
E	07 12 1964	05:34:31.7	6.00	154.00	0								4		912
W,E	30 3 1964	08:47:34.4	7.00	151.00	0								4		913
NGD	12 3 1974	15:11:05.5	8.80	151.00	33	5.5 mb	8.80	151.00	33	15:11:05.5			2		914
ISC	14 3 1974	23:22:12.8	8.70	151.10	0	4.8	8.70	151.10	0	23:22:12.8			2		915
ISC	10 8 1985	17:02:11.9	8.77	148.20	33	5.0 mb							3		916
ISC	22 3 1966	07:52:51.0	10.13	147.90	68	4.7 mb							3		917
ISC	20 11 1964	00:56:21.6	0.60	156.30	0	4.2 mb	0.60	156.30	0	00:56:21.6			2		918
ISC	09 11 1970	02:40:06.0	2.80	150.40	33		2.80	150.40	33	02:40:06.0			2		919
							Casualties								
NGD	30 11 1918	01:33:30.0	22.00	151.00	0		22.08	151.47	10	01:33:37.1	5	13.90	7		920
ISS	19 9 1923	08:22:30.0	12.50	168.00	0		22.42	143.81	10	08:26:42.6	4	3.33	7		921
ISS	18 11 1926	16:31:18.0	29.70	147.00	0		29.51	150.29	10	16:31:14.3	5	0.47	7		922
ISS	24 11 1926	17:40:54.0	29.70	147.00	0		28.91	144.05	10	17:41:10.3	4	2.10	7		923
NGD	18 12 1926	09:38:45.0	22.00	151.00	0		17.96	145.23	10		6	1.77	7		924
ISS	30 6 1928	22:21:45.0	25.00	150.00	0		48.48	147.38	10	22:24:00.3	10	2.04	7		925
ISS	06 8 1931	15:21:15.0	0.00	151.00	0		-1.62	151.65	10	15:21:04.7	5	1.54	7		926
ISS	09 2 1933	15:34:40.0	0.00	151.00	0		-3.55	148.70	10	15:34:21.2	7	1.41	7		927
ISS	21 5 1933	21:54:05.0	27.00	146.50	0		22.58	146.00	19	21:53:51.3	13	1.52	7		928
CGS	02 5 1939	06:15:12.0	0.00	150.00	0		54.03	-162.42	10	06:20:47.5	5	0.37	7		929
NGD	15 7 1951	06:05:22.0	21.00	150.50	0		20.34	150.97	10	06:05:25.8	8	0.67	7		930
ISC	18 5 1974	17:39:38.9	1.70	153.70	33		-5.15	150.10	314	17:41:11.4	7	0.16	7		931
ISC	16 1 1976	15:34:05.5	27.60	158.10	33	4.5 mb	44.03	149.60	10	15:35:34.3	12	0.78	7		932
ISC	20 2 1976	19:26:39.3	23.70	154.20	33	4.8 mb	43.07	147.35	10	19:28:31.1	9	0.34	7		933
ISS	14 3 1918	09:29:15.0	1.00	143.50	0								11		934
ISS	21 5 1918	11:15:10.0	11.70	176.00	0								11		935
ISS	29 9 1926	05:43:30.0	9.00	155.00	0								11		936
ISS	14 5 1923	07:02:32.0	16.00	153.50	0		15.41	155.65	10	07:02:34.0	3	0.00	12		937
ISS	03 3 1928	17:15:10.0	9.00	155.00	0		9.27	157.22	10	17:15:06.9	4	3.44	12		938
ISS	24 8 1930	09:08:40.0	8.00	157.00	0		-8.00	157.00					14		939
ISS	28 4 1951	21:19:41.0	5.60	150.50	0		-5.6	150.50					14		940
BCI	04 11 1953	08:47:19.0	12.50	165.50	60		-12.50	165.50	60				14		941
CGS	17 10 1955	01:08:07.0	6.00	154.00	0		-5.53	154.17	10	01:08:12.8	16	1.22	14		942

Table 6 (continued)

Sorted Dataset for Micronesia and Marshall Islands

Initial Location							Relocation						Code	Site	Index
Sce	Date D M Y	Time (GMT)	Lat. °N	Long. °E	Depth (km)	Mag.	Lat. °N	Long. °E	Depth (km)	Time (GMT)	Ns	σ (s)			
ISS	14 7 1957	02:27:03.0	14.11	151.39	80		46.11	151.39					14		943
CGS	15 10 1960	12:12:06.7	7.40	157.20	416		-7.40	157.20					14		944
BCI	08 7 1956	18:06:01.0	11.75	163.00	0		11.65	162.10	10	18:06:02.0	10	1.11	15		945
CGS	12 5 1958	18:29:58.0	12.00	162.00	0								15		946
CGS	16 5 1958	01:30:00.0	12.50	161.00	0								15		947
CGS	14 6 1958	18:29:59.0	12.00	161.50	0								15		948
CGS	28 6 1958	19:29:58.0	12.00	162.00	0								15		949
CGS	12 7 1958	03:29:58.0	12.00	165.00	0								15		950
CGS	26 7 1958	20:29:59.0	12.00	161.50	0								15		951

Table 7

Sorted Dataset for East of Japan and Kuriles

Initial Location							Relocation						Code	Site	Index
Sce	Date D M Y	Time (GMT)	Lat. °N	Long. °E	Depth (km)	Mag.	Lat. °N	Long. °E	Depth (km)	Time (GMT)	Ns	σ (s)			
Intraplate Events															
ISC	14 2 1975	08:33:01.6	34.40	147.90	0	3.7 mb	34.40	147.90	0	08:33:01.6			2		1001
ISC	14 2 1975	08:35:33.6	34.50	147.80	0	4.4 mb	34.50	147.80	0	08:35:33.6			2		1002
ISC	05 5 1976	20:02:32.6	35.20	156.80	33		35.74	156.09	10	20:02:30.8	5	1.74	1		1003
ISC	06 5 1976	14:42:25.8	36.80	158.00	39	5.1 mb	36.80	158.00	39	14:42:25.8			2		1004
ISC	21 8 1985	06:49:10.7	37.70	149.50	20	4.2 mb	37.70	149.50	20	06:49:10.7			2		1005
ISS	11 11 1936	00:41:57.0	41.00	155.00	0		41.04	154.72	10	00:41:54.7	9	1.06	1		1006
GS	07 3 1988	15:21:06.8	41.67	152.22	10	5.9 mb							3		1007
Casualties															
ISS	06 2 1916	10:51:13.0	41.00	156.50	0		47.51	150.81	10	10:52:10.1	14	1.64	7		1008
ISS	31 10 1916	15:30:33.0	46.50	160.00	0		49.67	157.90	10	15:31:02.3	20	3.31	7		1009
ISS	31 5 1917	06:50:22.0	32.00	147.50	0		33.44	143.37	10	06:06:00.4	4	0.27	7		1010
ISS	06 9 1924	02:36:55.0	46.50	160.00	0		42.35	148.04	10	02:37:01.5	5	1.60	7		1011
ISS	28 1 1925	18:15:06.0	39.00	155.00	0		53.51	153.90	10	18:16:36.4	4	0.09	7		1012
ISS	04 10 1925	07:28:42.0	41.00	156.50	0		42.39	155.64	10	07:29:00.3	4	1.21	7		1013
ISS	28 12 1925	21:56:10.0	39.00	155.00	0		35.14	147.18	10	21:56:23.2	4	0.19	7		1014
ISS	04 3 1928	20:58:12.0	41.50	153.00	0		44.77	151.31	10	20:58:35.6	4	0.19	7		1015
ISS	20 8 1928	01:56:03.0	39.50	157.00	0		47.44	149.77	10	01:57:07.7	11	1.08	7		1016
ISS	16 2 1929	09:13:45.0	41.50	153.00	0		41.64	152.80	10	09:13:50.8	6	2.09	7		1017
ISS	25 7 1929	15:07:24.0	42.00	158.00	0		45.51	154.26	10	15:07:56.8	11	1.50	7		1018
ISS	24 2 1931	14:07:50.0	42.00	158.00	0		44.61	151.82	10	14:08:24.4	9	2.38	7		1019
ISS	02 8 1931	23:29:32.0	40.50	159.00	0		35.65	157.74	10	23:29:41.1	7	1.32	7		1020
ISS	26 4 1932	13:31:32.0	41.30	157.60	0		47.38	153.10	10	13:31:35.1	8	1.80	7		1021
ISS	30 8 1932	16:18:50.0	39.50	157.00	0		47.86	150.01	10	16:19:52.4	5	0.67	7		1022
CGS	28 6 1936	08:10:24.0	32.50	145.50	0		30.60	141.80	0	08:10:23.0			9		1023
ISC	19 12 1966	07:56:43.0	33.40	148.10	33	4.4 mb	34.18	143.38	385	07:57:20.9	9	2.71	7		1024
ISC	18 1 1967	11:17:10.0	40.00	153.00	33	4.3 mb	51.24	156.66	60	11:18:11.9	8	0.38	7		1025
ISC	29 1 1968	14:58:43.0	40.20	149.80	30		40.30	149.68	10	14:58:43.3	5	0.14	7		1026
ISC	12 8 1969	01:17:55.0	38.30	148.00	0		43.84	147.77	10	01:18:29.0	7	0.54	7		1027
ISC	18 8 1969	12:04:40.0	41.70	151.80	0		43.07	148.21	10	12:05:05.2	9	0.48	7		1028
ISC	27 8 1969	03:26:36.0	40.60	148.20	45		42.80	145.92	10	03:26:52.7	8	0.55	7		1029
ISC	04 2 1972	00:16:38.3	36.80	148.60	0	4.5 mb	26.04	145.55	10	00:15:50.1	9	1.48	7		1030
ISC	17 12 1972	09:38:35.2	39.20	148.50	0	3.8 mb	51.02	154.11	10	09:39:40.9	4	0.24	7		1031
ISC	01 5 1973	04:00:36.1	35.50	147.30	0	3.7 mb	36.50	146.70	10	04:00:45.5	5	2.74	7		1032
ISC	27 9 1974	06:08:03.8	39.80	147.70	0	4.2 mb	43.78	146.69	10	06:08:30.9	5	2.33	7		1033
ISC	10 6 1975	15:38:10.5	39.50	147.00	0	4.6 mb	44.00	148.13	10	15:38:39.2	9	0.85	7		1034
ISC	10 6 1975	20:40:59.9	39.30	148.70	33	4.3 mb	43.67	147.56	10	20:41:22.9	8	1.20	7		1035
ISC	11 6 1975	19:11:10.8	41.00	147.80	0	3.6 mb	43.68	146.88	10	19:11:30.4	6	2.11	7		1036
ISC	21 1 1976	23:49:04.9	41.00	151.60	33	4.5 mb	43.92	149.95	10	23:49:23.8	8	0.89	7		1037
ISC	07 2 1976	06:50:20.8	41.60	150.50	109	4.3 mb	44.00	149.57	10	06:50:28.0	8	0.70	7		1038
ISC	24 3 1978	21:49:26.7	41.50	151.50	33	5.4 mb	44.42	149.41	10	21:49:43.2	23	2.02	7		1039
ISC	25 3 1978	23:20:44.0	41.90	150.90	33	4.7 mb	44.19	150.75	10	23:21:00.3	8	0.20	7		1040
ISC	21 4 1978	19:07:00.3	40.80	151.20	40	4.1 mb	44.42	148.54	10	19:07:24.9	5	0.21	7		1041
ISS	05 8 1931	07:26:11.0	36.00	149.50	0		34.49	146.95	10	07:26:22.7	5	2.74	12		1042
NGD	17 2 1905	11:39:26.0	33.00	152.00	60	7.3							13		1043

Table 8

Sorted Dataset for Northern Boundary

Initial Location							Relocation						Code	Site	Index
Sce	Date D M Y	Time (GMT)	Lat. °N	Long. °E	Depth (km)	Mag.	Lat. °N	Long. °E	Depth (km)	Time (GMT)	Ns	σ (s)			
Intraplate Events															
ISC	28 4 1968	04:18:15.5	44.80	174.60	36	5.5 mb							3		1101
ISC	28 4 1968	06:23:02.0	44.90	174.70	33	4.4 mb							3		1102
ISC	18 1 1976	05:17:15.8	43.20	-179.90	33		43.11	178.89	10	05:17:14.1	5	2.79	1		1103
ISC	05 3 1985	14:01:02.6	45.70	178.80	33	5.2 mb							3		1104
CGS	21 11 1938	21:34:42.0	45.00	-178.00	0		46.68	-164.96	10	21:35:57.0	7	2.04	1		1105
ISC	14 8 1980	10:35:58.3	45.20	-161.60	0	4.4 mb	45.09	-162.40	10	10:35:58.2	4	0.25	1		1106
ISC	11 11 1975	11:53:57.9	51.20	-153.80	33		51.20	-153.80	33	11:53:57.9			2		1107
GS	27 3 1986	22:42:36.6	53.78	-148.48	33	4.5 mb	53.78	-148.48	33	22:42:36.6			2		1108
ISC	04 2 1979	21:25:41.9	42.40	-149.20	10	5.1 mb							3		1109
ISC	14 1 1975	21:56:33.6	45.00	-147.60	33		45.00	-147.60	33	21:56:33.6			2		1110
GS	04 11 1978	18:22:56.7	53.96	-139.84	10	4.4 mb	53.96	-139.84	10	18:22:56.7			2		1111
ISS	20 3 1940	00:35:40.0	46.90	-134.80	0		46.93	-134.79	10	00:35:44.6	9	1.84	1		1112
ISS	20 3 1940	02:45:27.0	46.90	-134.80	0		47.12	-134.06	10	02:45:35.0	14	2.21	1		1113
ISS	05 11 1936	20:46:20.0	40.00	-133.00	0		40.04	-132.46	10	20:46:19.3	8	1.44	1		1114
ISC	21 1 1979	05:46:13.6	32.90	-131.80	33	3.5 mb	32.90	-131.80	33	05:46:13.6			2		1115
CGS	20 5 1949	22:35:31.0	33.00	-126.00	0	4.8 PAS	33.03	-125.83	10	22:35:30.8	21	1.48	1		1116
GS	15 10 1982	10:58:39.1	32.84	-125.82	5	5.1 mb							3		1117
GS	27 10 1982	13:33:44.0	32.68	-126.02	10	4.0 mb							3		1118
GS	21 1 1981	20:49:04.7	31.15	-123.16	15	4.3 mb							3		1119
GS	05 6 1988	20:55:18.9	31.26	-126.04	10		31.26	-126.04	10	20:55:18.9			2		1120
Casualties															
ISS	29 4 1913	23:28:59.0	50.00	171.00	0		55.35	171.09	10	23:29:34.7	13	1.65	7		1121
ISS	23 11 1913	21:17:33.0	49.50	165.50	0		51.88	159.55	10	21:18:06.5	8	2.94	7		1122
ISS	06 10 1921	15:59:36.0	43.00	170.00	0		49.27	149.74	10	15:00:45.2	13	2.65	7		1123
ISS	02 2 1923	01:06:15.0	50.50	164.00	0		53.40	162.19	10	01:06:40.9	20	1.46	7		1124
ISS	02 2 1923	05:07:15.0	50.50	164.00	0	7.4 PAS	53.38	161.26	10	05:07:42.4	93	6.68	7		1125
ISS	05 2 1923	22:23:10.0	50.50	164.00	0		53.50	162.37	10	22:23:32.0	8	2.13	7		1126
ISS	03 2 1926	19:30:16.0	50.00	171.00	0		49.20	175.40	10	19:30:04.0	4	0.09	7		1127
ISS	27 8 1927	12:13:15.0	40.50	160.50	0		47.42	154.27	10	12:14:08.3	5	4.58	7		1128
ISS	24 9 1927	17:41:00.0	47.50	-169.00	0		49.14	-168.81	10	17:41:18.0	10	2.32	7		1129
ISS	28 1 1928	23:59:00.0	47.40	176.70	0		49.18	179.44	10	23:59:12.9	7	2.04	7		1130
ISS	21 4 1930	21:56:57.0	40.50	160.50	0		44.87	151.96	10	21:57:40.1	4	2.17	7		1131
ISS	09 6 1931	12:14:06.0	50.50	164.00	0		52.37	160.48	10	12:14:19.9	24	2.29	7		1132
ISS	31 1 1932	09:22:09.0	40.00	-140.00	0		40.55	-130.01	10	09:23:37.0	9	1.54	7		1133
CGS	11 8 1932	09:42:06.0	49.00	-166.00	0		51.98	-169.41	10	09:41:47.0	12	1.82	7		1134
ISS	21 7 1944	12:24:35.0	42.00	-130.50	0		42.51	-131.06	10	12:24:29.0	17	1.61	8		1135
CGS	14 6 1949	05:49:00.0	52.00	-160.00	0		48.34	-174.28	10	05:48:45.8	6	0.46	7		1136
CGS	15 7 1954	13:24:35.0	54.00	-138.00	0		53.63	-133.26	10	13:24:36.3	13	1.23	8		1137
BCI	12 12 1960	11:24:42.0	50.00	166.00	0		55.93	160.54	10	11:24:42.5	8	1.28	7		1138
BRK	23 7 1964	08:46:26.6	41.20	-130.80	3	4.5 BRK	40.42	-126.99	10	08:47:15.9	12	5.64	8		1139
ISC	04 2 1965	06:42:58.1	48.70	171.50	33	5.2 mb	51.90	174.30	10	06:43:16.1	8	0.55	7		1140
ISC	04 2 1965	17:35:20.0	50.00	171.00	33	4.0 mb	51.34	175.04	10	17:35:43.6	5	0.77	7		1141
ISC	08 2 1965	21:59:57.4	49.80	171.80	33	4.5 mb	49.96	172.07	10	21:59:58.5	9	1.22	7		1142
CGS	22 2 1965	08:49:32.8	49.00	168.00	30	4.4 mb	52.83	-164.37	10	08:51:55.6	8	2.32	7		1143
ISC	30 3 1965	03:15:34.0	49.00	172.00	33	4.6 mb	51.82	173.26	10	03:15:44.9	9	0.36	7		1144
ISC	28 12 1967	07:30:26.0	44.80	-135.60	33	4.2 mb	44.32	-130.04	10	07:31:12.9	16	2.24	8		1145
ISC	06 9 1969	10:54:40.0	47.00	-169.00	33		53.28	-168.54	10	10:54:55.8	4	0.07	7		1146
ISC	20 11 1969	07:47:43.0	48.40	173.00	33	4.2 mb	51.27	179.05	10	07:48:21.4	6	0.59	7		1147
ISC	01 4 1972	13:02:33.1	45.40	170.30	0	3.8 mb	52.08	-171.70	10	13:04:22.2	6	0.79	7		1148
LAO	17 8 1974	09:25:25.1	47.40	172.80	0	4.1 mb	47.16	172.83	10	09:25:28.8	4	1.18	7		1149
ISC	02 2 1975	09:32:35.0	49.90	171.00	0	4.2 mb	49.75	171.17	10	09:32:39.2	5	1.14	7		1150
ISC	08 4 1975	18:49:02.8	49.10	168.00	0	4.6 mb	52.04	160.64	10	18:49:34.9	4	0.17	7		1151
ISC	28 10 1985	06:15:45.8	49.30	171.70	33	4.4 mb	49.34	171.83	10	06:15:46.2	5	0.24	7		1152
ISS	05 2 1923	22:58:20.0	50.50	164.00	0								11		1153
ISS	07 7 1923	06:09:54.0	52.00	-142.50	0		52.41	-144.00	10	06:09:52.0	4	4.01	12		1154
ISS	28 6 1927	17:19:25.0	40.00	168.00	0		6.43	138.87	10	17:19:27.3	4	1.00	12		1155
WEL	29 7 1958	22:21:21.0	40.50	176.30	0	5.0 WEL	-40.50	176.30					14		1156
MOS	07 6 1961	05:03:02.9	44.38	-149.20	30	4.5 MOS	45.50	150.80	61	05:03:10.7			14		1157
BSS	11 5 1962	20:00:00.0	31.23	-124.21	0								15		1158

Table 9

Sorted Dataset for West and South of Baja California

Initial Location							Relocation						Code	Site	Index
Sce	Date D M Y	Time (GMT)	Lat. °N	Long. °E	Depth (km)	Mag.	Lat. °N	Long. °E	Depth (km)	Time (GMT)	Ns	σ (s)			
Intraplate Events															
ISS	14 1 1936	00:04:08.0	23.50	-115.50	0		23.18	-115.14	10	00:04:00.8	11	1.43	1		1201
ISS	08 5 1930	22:45:02.0	17.00	-112.00	0		15.73	-114.46	10	22:44:11.5	4	1.37	1		1202
ISS	22 9 1930	05:02:27.0	16.00	-111.00	0		15.08	-112.07	10	05:01:47.0	6	3.00	1		1203
G-R	30 6 1945	05:31:18.0	17.00	-115.00	0	6.75PAS	16.60	-115.80	10	05:31:20.0	55	2.00	1		1204
ERL	07 5 1973	16:27:12.1	16.57	-116.08	33	4.8 mb	16.57	-116.08	33	16:27:12.1			2		1205
GS	27 8 1978	01:10:28.4	14.93	-113.07	33	5.0 mb	14.93	-113.07	33	01:10:28.4			2		1206
PDE	04 5 1985	12:47:09.9	16.67	-113.53	10	4.7 mb	16.67	-113.53	10	12:47:09.9			2		1207
GS	24 3 1986	19:43:23.9	18.08	-113.57	10	5.1 mb							3		1208
ISS	21 1 1936	04:08:02.0	13.50	-107.50	0		13.01	-107.87	10	04:07:58.4	7	2.43	1		1209
GS	22 12 1977	02:57:50.8	10.88	-107.43	33	4.9 mb	10.88	-107.43	33	02:57:50.8			2		1210
ISS	24 6 1924	13:48:50.0	8.00	-118.00	0		8.38	-119.09	10	13:48:47.9	5	3.06	1		1211
ISS	25 11 1927	19:52:30.0	1.00	-129.00	0		5.36	-114.18	10	19:54:40.8	5	2.93	1		1212
G-R	20 6 1938	14:02:28.0	6.00	-119.00	0	5.6 PAS	5.77	-118.96	10	14:02:27.2	9	1.03	1		1213
CGS	23 7 1961	14:37:56.9	6.80	-123.50	33		6.81	-123.67	10	14:37:53.0	20	1.50	1		1214
ISC	08 4 1977	11:06:51.6	2.50	-115.70	33	4.6 mb	2.50	-115.70	33	11:06:51.6			2		1215
ISC	11 3 1976	00:45:19.9	4.70	-112.10	33	4.9 mb	4.70	-112.10	33	00:45:19.9			2		1216
ISC	12 6 1983	18:30:06.0	4.60	-112.20	10	4.5 mb	4.60	-112.20	10	18:30:06.0			2		1217
ISS	17 6 1924	20:51:15.0	1.00	-129.00	0		0.78	-129.32	10	20:51:19.4	4	2.13	1		1218
G	10 12 1949	19:15:42.0	4.00	-129.00	0	5.75PAS	4.12	-128.85	10	19:15:45.0	17	1.70	1		1219
ISC	12 4 1972	21:42:46.3	6.20	-130.30	0	4.4 mb	6.20	-130.30	0	21:42:46.3			2		1220
ISC	25 6 1983	02:46:40.1	10.60	-130.40	33	4.6 mb							3		1221
ISC	24 9 1966	08:57:17.0	12.10	-130.80	92	4.9 mb	12.11	-130.87	31	08:57:16.7	40	0.97	1		1222
G	04 1 1933	21:10:46.0	28.00	-127.50	0	5.5 PAS	28.42	-126.99	10	21:10:45.0	17	2.20	1		1223
CGS	06 10 1963	08:48:12.2	21.90	-127.40	0	4.0 mb	21.90	-127.40	0	08:48:12.2			2		1224
ISC	23 5 1976	17:36:32.1	22.80	-125.10	33		23.46	-126.37	10	17:36:35.6	7	1.61	1		1225
Casualties															
ISS	09 7 1919	19:19:25.0	17.00	-112.00	0		19.03	-108.00	10	19:19:44.2	7	1.71	8		1226
ISS	26 10 1920	19:04:20.0	19.40	-122.20	0		17.52	-116.83	10	19:05:04.1	4	19.54	8		1227
ISS	02 4 1922	17:00:45.0	11.00	-108.00	0		15.10	-90.39	10	17:02:21.1	6	3.77	7		1228
ISS	30 8 1922	22:40:42.0	20.00	-114.00	0		18.56	-107.86	10	22:41:32.1	4	1.11	8		1229
ISS	09 9 1922	00:15:47.0	17.50	-116.50	0		14.27	-116.04	10	00:15:50.7	4	3.41	8		1230
ISS	26 3 1924	20:22:50.0	17.00	-112.00	0		17.81	-112.91	10	20:23:31.6	4	0.70	8		1231
ISS	29 6 1926	18:55:40.0	7.00	-107.00	0		16.92	-93.26	10	18:56:21.3	7	2.92	7		1232
ISS	27 11 1926	14:40:00.0	15.00	-117.00	0		16.57	-108.45	10	14:40:49.3	4	3.86	7		1233
ISS	30 7 1928	02:41:10.0	9.00	-115.50	0		11.54	-87.62	10	02:43:52.0	8	2.62	7		1234
ISS	17 1 1930	16:54:30.0	8.00	-106.30	0		8.08	-103.37	10	16:54:44.5	10	2.99	8		1235
ISS	18 4 1931	13:05:02.0	9.50	-107.00	0		8.32	-106.44	10	13:04:50.4	6	2.29	8		1236
CGS	21 1 1936	04:54:18.0	7.50	-108.00	0		10.15	-104.40	10	04:54:27.7	9	2.09	8		1237
ISS	03 3 1937	09:21:12.0	11.00	-118.50	0		25.22	-110.87	10	09:23:38.0	7	1.45	8		1238
CGS	12 12 1938	22:02:42.0	5.50	-110.00	0		6.50	-78.00	0	22:02:46.0			9		1239
CGS	11 1 1939	21:13:54.0	12.70	-119.50	0		14.82	-114.91	10	21:14:25.0	5	1.09	8		1240
CGS	01 10 1940	20:43:12.0	22.00	-129.00	0		35.53	-115.55	10	20:45:54.4	4	0.61	8		1241
ISS	25 4 1941	12:11:39.0	26.10	-116.60	0		27.73	-115.14	10	12:12:00.6	20	1.82	8		1242
CGS	05 2 1943	03:52:18.0	20.00	-115.50	0		29.93	-114.97	10	03:52:22.0	7	1.36	8		1243
TAC	17 5 1954	22:42:07.0	16.15	-112.92	0		22.65	-109.60	10	22:46:14.1	5	1.55	8		1244
TAC	08 12 1954	20:44:45.0	12.80	-117.50	0		-4.67	-107.33	10	20:41:57.0	10	1.38	8		1245
TAC	09 5 1955	11:06:49.0	13.33	-111.00	0		19.27	-107.95	10	11:07:37.9	14	0.91	8		1246
BCI	06 6 1958	22:46:18.0	20.00	-111.00	0		8.00	-84.30		22:44:07.0			9		1247
CGS	20 3 1962	01:00:25.7	25.30	-117.90	33		29.47	-114.90	10	01:01:26.7	5	0.80	8		1248
ISS	14 11 1919	06:38:35.0	11.00	-108.00	0								11		1249
ISS	20 6 1922	09:43:06.0	13.00	-120.00	0		36.39	-100.70	10	09:42:53.6	6	25.25	12		1250
ISS	09 8 1927	01:19:00.0	12.50	-109.70	0		11.06	-111.16	10	01:19:07.2	5	4.02	12		1251
ISS	22 9 1931	01:25:46.0	15.50	-122.50	0		15.50	122.50					14		1252
USE	19 2 1933	20:36:00.0	14.20	-122.70	0		14.20	122.70					14		1253
USE	06 6 1933	18:29:00.0	14.30	-121.60	0		14.30	121.60					14		1254
USE	21 8 1933	05:46:00.0	13.60	-124.80	0		13.60	124.80					14		1255
USE	03 12 1933	00:45:00.0	20.30	-121.90	0		20.30	121.90					14		1256
USE	14 2 1934	20:00:00.0	17.33	-119.42	0		17.33	119.42					14		1257
USE	27 11 1934	04:10:00.0	14.17	-120.12	0		14.17	120.12					14		1258
USE	27 11 1934	23:48:00.0	11.08	-125.08	0		11.08	125.08					14		1259
USE	08 2 1935	09:30:00.0	12.67	-121.83	60		12.67	121.83					14		1260
USE	24 5 1935	21:37:00.0	11.25	-126.08	0		11.25	126.08					14		1261
USE	02 8 1935	06:07:00.0	10.50	-126.42	0		10.50	126.42					14		1262
USE	20 8 1937	19:59:00.0	14.17	-122.08	0		14.20	122.10		11:59:00.0			14		1263
USE	05 2 1941	06:05:00.0	10.42	-126.55	200		10.42	126.55					14		1264
USE	18 2 1941	10:06:00.0	15.28	-120.05	75		15.28	120.05					14		1265
USE	29 9 1941	01:58:00.0	14.66	-119.66	0		14.66	119.66					14		1266
USE	18 7 1957	15:24:20.0	0.00	-110.50	0		40.00	-110.50					14		1267
PAS	22 6 1971	09:53:59.2	4.45	-118.33	1	2.5 ML	34.45	-118.33	1				14		1268
ISS	14 5 1955	20:00:01.0	28.90	-126.20	0		28.87	-126.02	10	20:00:05.8	52	1.56	15		1269

Table 10

Sorted Dataset for Northcentral Pacific Basin

Initial Location							Relocation						Code	Site	Index
Sce	Date D M Y	Time (GMT)	Lat. °N	Long. °E	Depth (km)	Mag.	Lat. °N	Long. °E	Depth (km)	Time (GMT)	Ns	σ (s)			
Intraplate Events															
ISC	05 5 1976	21:41:59.3	37.50	175.10	33		37.50	175.10	33	21:41:59.3			2		1301
GS	22 9 1988	22:28:44.6	23.81	-167.20	20	5.5 mb							3		1302
ISC	30 6 1972	10:04:59.4	29.50	-163.70	0	3.0 mb	29.50	-163.70	0	10:04:59.4			2		1303
ISC	14 2 1984	07:10:03.0	30.70	-157.10	10	4.9 mb							3		1304
ISC	02 5 1975	07:15:44.0	8.10	-156.10	33	4.5 mb	8.41	-155.72	10	07:15:46.6	9	1.20	1		1305
Casualties															
ISC	14 5 1976	06:21:11.3	3.80	-167.60	33	4.8 mb	-24.78	177.23	475	06:19:16.3	10	1.46	7		1306
ISS	11 10 1928	23:32:28.0	26.80	172.00	0		47.54	151.60	10	23:35:14.4	6	1.15	7		1307
ISS	17 6 1917	08:34:30.0	34.00	-162.00	0								11		1308
USE	17 9 1932	13:03:00.0	26.25	-148.60	0								11		1309
ISS	01 10 1918	00:20:15.0	30.00	-174.00	0								12		1310
ISS	11 10 1928	23:44:16.0	26.80	172.00	0		43.35	172.29	10	23:45:46.1	6	1.24	12		1311
ISC	17 3 1976	18:47:20.7	12.70	-171.80	33		12.70	-171.80	10	18:47:27.0			12		1312
CGS	24 7 1938	03:05:00.0	32.00	-162.00	0		32.45	-115.86	10	03:05:06.8	7	2.13	14		1313
CGS	21 7 1945	21:57:57.0	29.00	-176.00	0		-19.82	179.32	10	21:58:11.2	7	1.26	14		1314
ISS	21 9 1951	09:41:20.0	39.20	171.50	0		39.20	71.50					14		1315
JMA	01 9 1953	14:14:53.0	34.00	-135.70	70		34.00	135.70					14		1316
WEL	30 9 1958	18:38:49.0	38.40	176.40	160		-38.40	176.40					14		1317
BCI	04 12 1959	18:09:10.0	36.00	-179.50	0		-35.18	-179.38	10	18:09:08.7	5	1.41	14		1318
CGS	08 10 1960	17:34:00.7	36.10	176.90	176		-36.10	176.90					14		1319
ISC	09 4 1967	17:52:10.0	39.00	163.00	33		-7.02	129.66	118	17:41:55.0			14		1320

Table 11

Sorted Dataset for Cocos Plate

Initial Location							Relocation						Code	Site	Index
Sce	Date D M Y	Time (GMT)	Lat. °N	Long. °E	Depth (km)	Mag.	Lat. °N	Long. °E	Depth (km)	Time (GMT)	Ns	σ (s)			
Intraplate Events															
G-R	24 8 1937	20:13:23.0	5.00	-89.00	0	6.0 PAS	4.98	-89.09	11	20:13:27.3	27	1.72	1	CO-1	1351
ISS	03 12 1928	12:26:10.0	4.20	-85.00	0		3.47	-87.62	10	12:26:20.8	7	2.11	1	CO-2	1352
CGS	18 1 1955	08:42:03.0	5.00	-87.50	0		5.04	-87.54	10	08:42:05.8	24	1.72	1	CO-2	1353
CGS	31 3 1968	04:16:01.0	5.20	-87.30	33	4.2 mb	5.04	-87.33	10	04:15:59.0	18	1.45	1	CO-2	1354
CGS	17 12 1969	03:11:46.5	4.34	-88.04	33	4.4 mb	4.46	-87.95	10	03:11:47.0	15	1.64	1	CO-2	1355
ERL	20 6 1973	03:53:18.1	4.03	-87.79	33	4.3 mb	3.91	-87.72	10	03:53:18.2	13	2.62	1	CO-2	1356
GS	25 6 1975	06:53:24.2	5.94	-87.37	33	4.4 mb	5.48	-87.59	10	06:53:20.7	19	2.26	1	CO-2	1357
GS	09 8 1976	12:55:39.7	4.32	-87.52	33	4.9 mb	4.32	-87.52	33	12:55:39.7			2	CO-2	1358
GS	12 8 1976	03:53:50.9	4.14	-87.48	33	5.0 mb	4.14	-87.48	33	03:53:50.9			2	CO-2	1359
ISC	11 6 1977	00:16:19.8	5.00	-88.30	33		4.74	-87.60	10	00:16:19.8	6	1.15	1	CO-2	1360
CGS	03 11 1968	19:53:22.9	7.91	-85.92	25	4.7 mb	7.79	-86.09	10	19:53:23.2	44	2.63	1	CO-3	1361
NEI	03 1 1987	18:14:41.3	5.30	-94.30	10	4.8 mb	5.36	-94.30	10	18:14:43.1	14	1.59	1	CO-4	1362
NEI	03 1 1987	18:19:35.9	5.60	-93.70	10	4.5 mb	5.75	-93.68	10	18:19:38.7	10	0.82	1	CO-4	1363
NEI	05 1 1987	15:25:33.8	5.80	-93.20	10	4.2 mb	5.55	-93.64	10	15:25:35.0	9	1.04	1	CO-4	1364
ISC	12 9 1974	15:38:14.3	8.00	-91.90	0	4.3 mb	8.12	-91.92	10	15:38:18.7	5	0.95	1	CO-5	1365
ISC	06 6 1975	14:43:30.5	8.30	-91.30	0	3.9 mb	8.41	-91.31	10	14:43:35.3	4	2.78	1	CO-5	1366
ISC	11 10 1975	07:32:02.4	8.00	-90.90	127	4.2 TUL	7.45	-91.69	10	07:31:51.0	5	1.59	1	CO-5	1367
GS	12 7 1978	01:33:35.1	10.34	-91.75	33	3.9 mb	10.65	-91.59	10	01:33:37.7	10	1.82	1	CO-6	1368
G	30 8 1931	07:34:34.0	6.00	-99.00	0	5.6 mb	5.85	-99.97	10	07:34:33.8	10	1.83	1	CO-7	1369
ISC	08 7 1978	07:57:42.3	8.60	-95.80	33	4.0 mb	8.54	-95.62	10	07:57:42.1	5	1.37	1	CO-8	1370
PDE	22 11 1984	07:48:35.4	10.17	-95.54	33	4.2 mb	10.49	-95.85	10	07:48:38.3	10	1.70	1	CO-9	1371
ISS	15 11 1932	10:30:19.0	11.90	-99.50	0		11.49	-99.26	10	10:30:12.3	10	1.00	1	CO-10	1372
Casualties															
ISS	23 9 1916	05:41:54.0	10.00	-97.00	0		12.12	-83.49	10	05:43:09.1	8	1.63	7		1373
ISS	25 1 1918	01:20:30.0	12.00	-95.50	0		14.77	-91.29	10	01:20:54.8	10	1.54	7		1374
ISS	05 11 1918	22:39:00.0	12.00	-95.50	0		13.27	-88.12	10	22:39:59.6	4	2.31	7		1375
ISS	30 8 1928	21:58:51.0	12.00	-95.50	0		12.56	-95.23	10	21:59:08.3	7	2.58	7		1376
G	26 12 1928	21:32:52.0	6.00	-99.00	0	6.0 PAS	5.83	-101.44	10		16	1.94	8		1377
ISS	07 4 1929	19:31:45.0	12.00	-95.50	0		14.37	-94.10	10	19:32:16.9	30	3.24	7		1378
CGS	17 10 1933	13:33:30.0	11.00	-95.00	0		10.57	-93.90	10	13:33:19.5	11	1.33	7		1379
ISS	24 7 1934	02:47:24.0	8.20	-87.00	0		9.00	-84.82	10	02:47:34.0	11	4.05	7		1380
CGS	09 11 1934	16:11:42.0	7.00	-89.00	0		7.21	-79.46	10	16:11:38.8	8	1.34	7		1381
CGS	14 10 1935	17:36:30.0	5.00	-86.00	0		4.74	-82.52	10	17:36:50.4	10	0.73	8		1382
CGS	29 12 1936	13:58:42.0	5.00	-90.00	0		13.50	-92.50	10	13:59:58.0			9		1383

Table 11 (continued)

Sorted Dataset for Cocos Plate

Initial Location							Relocation						Code	Site	Index
Sce	Date D M Y	Time (GMT)	Lat. °N	Long. °E	Depth (km)	Mag.	Lat. °N	Long. °E	Depth (km)	Time (GMT)	Ns	σ (s)			
BCI	12 4 1951	04:10:30.0	8.00	-86.00	0		11.56	-78.34	10	04:11:24.7	5	4.14	7		1384
CGS	10 3 1955	04:55:10.0	10.00	-90.50	0		11.29	-90.11	10	04:55:22.1	14	1.61	7		1385
TAC	20 4 1955	10:16:59.0	7.50	-99.00	0		7.87	-103.89	10	10:16:53.8	11	0.49	8		1386
CGS	26 4 1961	12:18:32.0	8.80	-91.10	33		15.62	-89.91	10	12:19:16.0	6	1.57	7		1387
CGS	21 2 1962	23:46:49.4	3.00	-86.50	25		3.79	-83.47	10	23:46:44.4	6	0.84	8		1388
TAC	14 3 1966	15:09:11.5	11.42	-96.67	0		11.15	-95.71	10	15:09:12.8	4	0.69	7		1389
CGS	20 8 1967	16:43:29.8	7.20	-85.10	33	4.2 mb	7.41	-84.80	10	16:43:30.5	21	2.21	9		1390
ISC	01 5 1969	16:27:40.0	10.00	-92.40	33	4.2 mb	18.08	-94.52	10	16:28:58.8	10	2.13	7		1391
ISC	19 9 1969	22:21:50.0	10.90	-96.90	33		13.78	-96.33	33	22:22:22.8			9		1392
ISC	09 1 1970	12:05:23.0	11.60	-93.30	33	4.2 mb	15.71	-93.45	88	12:06:06.6	11	1.26	7		1393
ISC	29 4 1970	16:01:17.0	11.10	-94.20	33	4.7 mb	12.30	-94.20	33	16:01:31.8	10	1.60	7		1394
ISC	22 5 1970	03:08:16.0	11.50	-94.50	33	4.3 mb	17.59	-93.10	45	03:09:05.2	8	2.80	7		1395
ISC	09 5 1973	14:20:31.0	12.00	-97.00	0	4.3 mb	12.87	-97.56	10	14:20:39.0	4	0.55	7		1396
ISC	18 10 1973	21:58:24.9	9.50	-90.60	0	4.3 mb	12.74	-91.47	10	21:58:53.3	8	3.11	7		1397
ISC	11 12 1974	20:49:44.1	7.20	-91.30	0	3.4 mb	13.52	-87.39	10	20:50:33.1	6	0.29	7		1398
ISC	24 4 1975	18:12:41.0	12.80	-99.30	50	4.5 mb	16.30	-98.70	33	18:13:07.9	16	0.80	9		1399
GS	26 2 1976	23:25:25.5	8.35	-87.46	33	4.6 mb	11.60	-87.68	188	23:26:05.7	19	0.99	9		1400
ISC	29 9 1977	05:28:36.1	4.20	-95.00	0		2.41	-95.61	10	05:28:27.9	10	0.74	8		1401
ISC	08 3 1978	23:42:07.0	10.00	-93.90	33	4.4 mb	13.50	-91.10	194	23:42:36.8			9		1402
ISC	24 4 1978	05:42:00.0	7.30	-89.10	146	2.5 mb	10.68	-85.12	146	05:42:54.0			9		1403
ISC	02 7 1980	23:56:40.0	11.90	-96.90	33		3.09	-90.03	10	23:55:05.3	10	1.29	8		1404
ISS	04 1 1918	04:30:05.0	10.50	-91.00	0								11		1405
ISS	04 1 1918	04:32:25.0	10.50	-91.00	0								11		1406
ISS	16 11 1918	05:56:30.0	12.00	-95.50	0		15.80	-93.66	10	05:57:06.7	3	0.00	11		1407
CGS	07 6 1937	04:03:12.0	5.00	-92.00	0						4		12		1408
ISC	05 12 1966	02:10:00.0	7.00	-94.20	33	4.0 mb	2.92	-98.74	10	02:09:38.8	5	1.16	12		1409
ISC	13 8 1979	11:42:25.0	8.70	-88.80	33	5.0 mb							12		1410
BCI	28 3 1958	13:06:30.0	12.00	-95.50	0								13		1411
CGS	26 1 1962	18:40:23.0	10.30	-90.60	45								13		1412

Table 12

Sorted Dataset for Nazca Plate

Initial Location							Relocation						Code	Site	Index
Sce	Date D M Y	Time (GMT)	Lat. °N	Long. °E	Depth (km)	Mag.	Lat. °N	Long. °E	Depth (km)	Time (GMT)	Ns	σ (s)			
							Intraplate Events								
ISC	29 7 1968	11:48:57.0	-2.00	-90.10	33	4.3 mb	-1.96	-90.09	10	11:48:56.3	9	1.00	1	NZ-1	1501
ERL	14 8 1971	04:26:03.9	-2.62	-89.15	33	4.6 mb	-2.50	-89.21	10	04:26:03.6	20	1.53	1	NZ-1	1502
ISC	16 8 1975	09:43:48.3	-2.10	-90.33	33	4.8MB	-1.95	-90.24	10	09:43:47.6	15	1.63	1	NZ-1	1503
CGS	07 8 1951	04:08:54.0	-6.50	-85.00	0		-6.54	-84.98	10	04:08:53.8	19	1.07	1	NZ-2	1504
ISS	20 8 1959	07:18:34.0	-6.90	-85.20	0		-6.77	-85.10	10	07:18:37.9	47	1.26	1	NZ-2	1505
CGS	24 12 1963	02:40:42.6	-6.60	-85.10	33	4.3 mb	-6.48	-85.03	10	02:40:41.8	11	0.78	1	NZ-2	1506
ISC	18 6 1983	07:14:53.1	-6.10	-85.40	33	4.4 mb	-6.22	-85.40	10	07:14:50.8	7	2.44	1	NZ-2	1507
GS	02 10 1988	23:21:03.2	-7.07	-88.62	10	4.7 mb	-7.07	-88.62	10	23:21:03.2			2	NZ-3	1508
ISC	12 11 1969	06:44:51.0	-3.80	-99.50	33		-3.60	-99.55	10	06:44:51.2	7	0.49	1	NZ-4	1509
ISS	23 8 1923	05:12:45.0	-5.00	-95.00	0		-5.39	-96.91	10	05:12:48.8	4	0.87	1	NZ-4	1510
ISC	11 1 1967	13:37:51.0	-4.80	-96.60	33	4.8 mb	-4.78	-96.64	10	13:37:48.9	5	0.66	1	NZ-4	1511
ISC	07 9 1986	07:50:39.5	-8.06	-97.60	10	4.8 mb							3	NZ-4	1512
ISC	17 12 1972	16:00:33.9	-11.00	-90.20	65	4.7 mb							3	NZ-4	1513
G	05 8 1944	00:57:17.0	-13.50	-92.50	0	6.0 PAS	-12.94	-92.44	10	00:57:23.0	13	0.54	1	NZ-4	1514
G	05 8 1944	01:24:08.0	-13.50	-92.50	0	6.25PAS	-13.29	-92.62	10	01:24:12.4	16	0.75	1	NZ-4	1515
ISC	12 3 1969	07:02:25.6	-11.70	-95.20	33	4.3 mb	-11.60	-95.18	10	07:02:24.6	7	0.25	1	NZ-4	1516
CGS	22 8 1958	12:18:53.0	-11.50	-97.00	0		-12.72	-97.74	10	12:18:51.7	8	0.57	1	NZ-4	1517
ISC	15 4 1976	14:27:43.4	-14.00	-98.90	33		-13.98	-99.02	10	14:27:41.8	4	0.67	1	NZ-4	1518
ISC	25 11 1965	10:50:50.8	-17.10	-100.20	143	5.3 mb	-17.10	-100.20	13	10:50:40.0			1	NZ-4	1519
ISC	08 2 1982	15:03:07.9	-17.80	-99.00	10	4.7 mb							3	NZ-4	1520
ISC	23 1 1983	06:00:52.9	-17.90	-96.80	10	4.2 mb							3	NZ-4	1521
ISC	08 10 1967	23:43:43.1	-17.20	-106.00	33	4.4 mb	-17.17	-106.11	10	23:43:42.1	13	0.67	1	NZ-5	1522
GS	16 6 1975	05:05:24.3	-20.37	-109.12	33	4.8 mb							3	NZ-6	1523
ISC	08 12 1964	09:14:31.6	-21.30	-82.00	48	5.0 mb	-21.26	-82.06	18	09:14:30.9	30	1.18	1	NZ-7	1524
ISC	19 10 1972	20:31:54.3	-22.51	-82.94	33	4.3 mb	-22.49	-82.99	10	20:31:53.0	26	1.56	1	NZ-7	1525
ERL	20 4 1973	15:16:15.4	-28.76	-108.65	33	4.9 mb	-28.59	-108.64	10	15:16:14.7	8	0.33	1	NZ-8	1526
ISC	09 1 1986	09:05:34.9	-29.00	-106.50	10	4.8 mb	-28.83	-106.14	10	09:05:36.8	24	1.79	1	NZ-8	1527

Table 12 (continued)

Sorted Dataset for Nazca Plate

Initial Location							Relocation						Code	Site	Index
Sce	Date D M Y	Time (GMT)	Lat. °N	Long. °E	Depth (km)	Mag.	Lat. °N	Long. °E	Depth (km)	Time (GMT)	Ns	σ (s)			
PDE	11 3 1984	13:42:56.4	-26.65	-108.51	10	5.7 mb							3	NZ-8	1528
GS	06 7 1987	01:06:07.7	-27.00	-108.29	10	6.2 mb							3	NZ-8	1529
GS	08 7 1987	11:50:14.8	-26.97	-108.16	10	6.1 mb							3	NZ-8	1530
GS	02 6 1988	02:53:45.5	-26.82	-108.16	10	4.7 mb	-26.82	-108.16	10	02:53:45.5			2	NZ-8	1531
ISC	01 1 1970	04:44:42.0	-29.40	-90.60	33		-28.73	-90.00	10	04:44:38.2	5	0.57	1	NZ-9	1532
ISC	21 6 1964	07:42:55.0	-30.00	-91.50	33	4.5 mb	-29.89	-91.75	10	07:42:54.2	10	0.71	1	NZ-9	1533
ISC	25 9 1965	16:27:26.0	-30.50	-90.60	33	4.6 mb	-30.37	-90.55	10	16:27:25.6	11	1.02	1	NZ-9	1534
G	25 5 1918	19:29:20.0	-30.50	-91.50	60	7.0 PAS	-30.85	-91.88	10	19:29:19.8	11	1.75	1	NZ-9	1535
BCI	05 1 1960	02:27:36.0	-35.00	-92.00	0		-31.27	-90.34	10	02:27:56.2	8	1.20	1	NZ-9	1536
ERL	28 5 1972	08:38:51.5	-32.85	-92.18	33	5.0 mb							3	NZ-9	1537
ISS	28 1 1959	10:04:09.0	-30.70	-78.90	0		-30.65	-79.01	10	10:04:12.9	52	1.25	1	NZ-10	1538
ISC	23 2 1968	12:28:04.0	-30.00	-76.00	33		-29.41	-75.96	10	12:27:59.3	4	0.47	1	NZ-11	1539
CGS	26 1 1962	14:34:45.7	-36.90	-88.90	60		-36.81	-89.21	10	14:34:43.3	14	1.24	1	NZ-12	1540
ISC	04 6 1981	07:39:41.5	-34.20	-78.70	37	5.1 mb	-34.04	-78.86	10	07:39:39.7	60	1.57	1	NZ-13	1541
NEI	27 10 1986	08:02:52.3	-34.20	-78.90	10	5.0 mb							3	NZ-13	1542
ISC	22 1 1981	02:23:58.7	-34.40	-79.60	33	4.1 mb	-34.47	-79.74	10	02:23:56.9	8	0.91	1	NZ-13	1543
ISC	14 9 1974	17:20:17.0	-35.80	-79.60	33		-35.66	-79.65	10	17:20:16.6	5	0.18	1	NZ-13	1544
ISC	13 6 1973	15:10:38.8	-37.00	-79.30	0	4.1 mb	-36.91	-79.39	10	15:10:42.5	5	0.56	1	NZ-13	1545
Casualties															
ISS	30 1 1921	18:58:38.0	-0.50	-93.00	0		-0.36	-93.84	10	18:58:49.9	5	2.19	8		1546
ISS	06 1 1922	19:20:38.0	-19.00	-76.00	0		-16.50	-73.0					9		1547
ISS	06 6 1925	20:45:25.0	-32.00	-95.50	0		-47.77	-109.15	10	20:43:24.2	4	22.69	8		1548
ISS	05 6 1926	01:20:15.0	-17.00	-78.50	0		-15.20	-76.07	10	01:20:42.8	4	0.13	7		1549
ISS	05 8 1927	03:43:03.0	0.00	-85.00	0		-0.80	-83.23	10	03:43:35.6	7	2.19	7		1550
ISS	23 5 1928	20:24:44.0	-30.00	-77.00	0		-29.77	-79.45	10	20:24:32.1	4	3.36	7		1551
CGS	09 9 1937	05:29:00.0	-5.00	-84.00	0		12.01	-93.56	10	05:32:35.4	9	1.16	7		1552
CGS	15 11 1937	00:51:06.0	-14.60	-82.40	0		-7.38	-77.33	10	00:51:22.5	5	0.27	7		1553
CGS	28 1 1940	07:27:48.0	-12.00	-82.00	0		10.74	-85.10	10	07:30:34.4	6	0.66	7		1554
CGS	31 8 1940	17:12:42.0	-17.00	-78.00	0		-15.39	-70.63	153	17:12:37.0	12	1.92	7		1555
CGS	10 8 1941	17:02:48.0	-5.00	-88.00	0		-32.00	-70.00	0	16:59:45.0			9		1556
ISS	15 2 1942	14:20:49.0	-9.70	-85.10	0		-8.41	-84.13	10	14:20:56.1	10	1.15	7		1557
ISS	13 2 1947	00:13:21.0	-19.00	-75.00	0		-18.27	-75.09	10	00:13:27.0	13	1.55	7		1558
CGS	07 9 1949	07:26:57.0	-2.00	-93.00	0		0.79	-90.26	10	07:27:09.5	8	1.25	8		1559
CGS	16 7 1950	11:58:48.0	-2.00	-86.00	0		-1.25	-86.12	10	11:59:00.1	13	1.92	8		1560
BCI	29 12 1951	10:38:00.0	-31.00	-96.00	0		-39.24	-95.17	10	10:37:19.9	12	1.72	8		1561
BCI	24 11 1958	21:42:49.0	-10.00	-85.00	0		-10.19	-80.70	10	21:42:52.9	4	0.55	7		1562
CGS	23 5 1960	12:02:36.0	-38.00	-76.00	60		-39.04	-74.42	10	12:02:28.4	8	0.84	7		1563
CGS	19 6 1960	21:42:50.0	-36.50	-76.00	0		-36.84	-73.10	10	21:42:44.7	10	0.91	7		1564
CGS	22 10 1961	07:01:42.1	-0.20	-94.60	60		0.22	-98.39	10	07:01:53.8	11	1.61	8		1565
CGS	27 10 1963	01:30:32.1	-29.50	-101.20	33	4.6 mb	-36.07	-103.92	10	01:29:55.0	17	2.07	8		1566
CGS	05 1 1964	17:15:14.2	-29.80	-105.20	33	4.5 mb	-30.57	-105.21	10	17:15:07.8	8	1.14	8		1567
CGS	09 1 1964	21:19:38.4	-1.20	-89.90	33	4.0 mb	0.88	-90.33	10	21:19:54.3	5	0.46	8		1568
CGS	18 1 1964	07:10:21.9	-32.50	-103.70	33	4.5 mb	-31.88	-103.46	10	07:10:25.3	12	1.59	8		1569
CGS	29 8 1964	17:17:34.2	-3.20	-92.20	33	4.2 mb	1.31	-92.24	10	17:18:08.8	10	1.72	8		1570
CGS	25 3 1965	20:36:32.0	-38.10	-80.20	33	4.4 mb	-42.00	-75.17	10	20:36:05.5	12	0.97	7		1571
CGS	30 5 1965	07:21:56.2	-37.70	-89.30	27	4.2 mb	-40.65	-88.43	10	07:21:40.6	7	1.00	8		1572
CGS	23 7 1965	23:21:25.3	-39.10	-85.50	33	4.9 mb	-39.40	-85.64	10	23:21:22.9	12	0.86	8		1573
CGS	23 9 1965	15:16:58.8	-36.80	-91.70	33	4.2 mb	-36.57	-92.79	10	15:16:58.8	9	1.43	8		1574
ISC	03 5 1967	01:52:00.0	-29.00	-105.50	33	4.1 mb	-31.32	-105.99	10	01:51:43.3	8	0.95	8		1575
ISC	16 5 1967	08:25:07.0	-20.00	-100.60	33	4.4 mb	-28.78	-106.07	10	08:24:15.3	10	1.83	8		1576
ISC	15 10 1967	15:16:10.0	-30.00	-98.00	33	4.2 mb	-30.49	-98.04	10	15:16:06.7	5	2.29	8		1577
ISC	07 2 1968	07:28:30.0	-28.00	-93.70	33	4.1 mb	-32.63	-95.33	10	07:28:04.3	5	1.19	8		1578
ISC	19 3 1968	23:06:49.0	-32.00	-100.30	33	4.4 mb	-30.64	-100.07	10	23:06:53.3	6	1.73	8		1579
ISC	05 6 1968	14:07:11.0	-3.30	-98.00	33	4.3 mb	2.12	-97.04	10	14:07:48.5	9	0.49	8		1580
CGS	30 8 1969	05:43:33.2	-0.61	-89.62	33	4.2 mb	-0.64	-89.54	10	05:43:32.2	10	1.48	7		1581
ISC	20 5 1970	03:26:46.5	-30.70	-98.40	25		-34.09	-99.69	10	03:26:26.8	4	0.45	7		1582
ISC	10 9 1970	04:32:08.0	-2.00	-84.00	33		-2.25	-84.01	10	04:32:06.6	4	2.89	7		1583
ISC	12 6 1972	00:54:48.2	-18.50	-104.50	0	3.8 mb	-28.12	-112.38	10	00:53:44.7	4	1.17	8		1584
ISC	15 4 1973	13:08:42.4	-30.50	-76.10	0	3.4 mb	-30.35	-75.40	10	13:08:49.3	10	1.91	7		1585
GS	27 12 1975	02:44:00.2	-3.51	-88.62	33	4.5 mb	0.00	-90.97	10	02:44:31.9	14	0.65	8		1586
ISC	23 4 1977	14:27:11.8	-27.70	-77.10	33		-30.15	-72.89	10	14:28:09.4	11	2.52	7		1587
ISC	15 5 1977	16:46:13.9	-35.60	-85.30	33	4.6 mb	-40.03	-86.34	10	16:45:48.2	9	1.06	8		1588
ISC	01 10 1977	00:42:32.1	-37.90	-76.50	33		-37.90	-76.56	10	00:42:31.5	11	2.57	7		1589
NEI	19 7 1978	03:29:25.4	-3.10	-84.30	33		-3.44	-84.14	10	03:29:28.2	6	2.22	7		1590
ISC	04 4 1980	08:18:56.4	-10.60	-82.20	33		-11.28	-80.96	10	08:19:13.9	6	1.85	7		1591
ISC	06 5 1981	09:30:55.0	-18.30	-75.20	33		-18.26	-74.86	14	09:30:53.8	9	1.21	7		1592
ISC	27 4 1982	21:51:36.9	-23.80	-75.30	33		-23.99	-74.67	10	21:51:43.4	7	2.16	7		1593
ISC	27 10 1982	14:37:07.7	-29.40	-75.20	33		-29.49	-74.45	10	14:37:13.5	22	2.45	7		1594
ISC	04 12 1983	00:14:12.0	-34.20	-78.10	33		-32.54	-71.84	10	00:15:19.9	16	0.71	7		1595

Table 12 (continued)

Sorted Dataset for Nazca Plate

Initial Location							Relocation						Code	Site	Index
Sce	Date D M Y	Time (GMT)	Lat. °N	Long. °E	Depth (km)	Mag.	Lat. °N	Long. °E	Depth (km)	Time (GMT)	Ns	σ (s)			
NEI	30 7 1986	06:09:16.6	-30.20	-75.70	33		-30.31	-75.26	10	06:09:21.2	18	1.23	8		1596
ISS	16 2 1917	02:12:10.0	-26.00	-80.00	0								11		1597
ISS	21 2 1917	09:41:22.0	-26.00	-80.00	0								11		1598
ISS	22 2 1917	09:12:20.0	-26.00	-80.00	0								11		1599
ISS	28 9 1918	10:19:30.0	-26.00	-80.00	0								11		1600
ISS	07 9 1919	20:21:16.0	-29.00	-98.00	0								11		1601
CGS	11 11 1963	16:21:14.4	-32.80	-95.50	33	4.2 mb							11		1602
ISS	15 2 1917	00:48:09.0	-26.00	-80.00	0		-24.73	-75.80	10	00:49:02.7	4	1.80	12		1603
ISS	03 2 1918	14:41:50.0	-3.00	-88.00	0								12		1604
ISS	01 9 1920	02:45:50.0	-3.00	-88.00	0		-9.36	-96.23	10	02:45:07.7	4	5.87	12		1605
ISS	06 6 1925	03:42:25.0	-30.00	-77.00	0		-30.32	-77.69	10	03:42:23.9	4	10.46	12		1606
ISS	07 3 1926	20:32:30.0	-9.50	-84.00	0								12		1607
ISS	28 10 1947	09:39:21.0	-14.80	-106.50	0		-15.07	-107.59	10	09:39:22.5	8	1.03	12		1608
CGS	08 2 1962	08:28:26.8	-1.70	-84.60	45								12		1609
ISC	27 7 1972	15:19:21.7	-36.10	-91.70	0	3.9 mb							12		1610
ISS	28 9 1918	10:35:20.0	-26.00	-80.00	0		-29.71	-78.15	10	10:17:38.1	3	0.00	14		1611

Table 13

Sorted Dataset for Antarctic Plate

Initial Location							Relocation						Code	Site	Index
Sce	Date D M Y	Time (GMT)	Lat. °N	Long. °E	Depth (km)	Mag.	Lat. °N	Long. °E	Depth (km)	Time (GMT)	Ns	σ (s)			
Intraplate Events															
G-R	12 3 1927	18:44:32.0	-41.00	-106.00	50	6.5 PAS	-39.28	-103.91	10	18:44:41.5	7	2.33	1		1701
NOS	09 5 1971	08:25:01.7	-39.78	-104.84	33	6.2 mb							3		1702
NOS	09 5 1971	08:53:25.9	-39.74	-104.93	33	5.2 mb							3		1703
NOS	09 5 1971	18:00:59.9	-39.84	-104.89	33	5.4 mb							3		1704
NOS	09 5 1971	18:35:09.8	-39.72	-104.98	33	5.4 mb							3		1705
ISS	04 12 1956	10:07:54.0	-45.50	-106.90	0		-45.40	-107.30	10	10:07:55.7		0.90	1		1706
CGS	28 1 1961	14:06:12.6	-45.10	-106.40	25		-45.00	-106.50	10	14:06:10.5		1.30	1		1707
ISC	11 1 1976	23:22:41.2	-46.40	-101.10	33	5.3 mb	-46.40	-101.10	33	23:22:41.2			2		1708
GS	07 3 1988	08:50:44.1	-44.52	-93.26	10	4.9 mb	-44.52	-93.26	10	08:50:44.1			2		1709
ISC	29 4 1975	08:33:27.3	-45.80	-87.20	0	4.1 mb	-45.80	-87.20	0	08:33:27.3			2		1710
ISS	05 12 1927	17:49:30.0	-68.00	-90.00	0		-66.81	-102.80	10	17:49:17.2	4	2.03	1		1711
PDE	15 6 1984	04:18:57.4	-68.54	-111.73	10	5.2 mb							3		1712
CGS	06 6 1970	06:14:11.9	-62.59	-93.27	33	4.9 mb							3		1713
GS	05 2 1977	03:29:18.9	-66.45	-82.58	33	6.2 mb	-66.45	-82.58	33	03:29:18.9			1		1714
GS	07 11 1979	11:31:49.6	-62.58	-72.91	10	5.1 mb	-62.58	-72.91	10	11:31:49.6			2		1715
Casualties															
ISS	11 5 1922	00:44:32.0	-48.80	-79.00	0		-50.43	-77.54	10	00:44:39.6	5	1.97	7		1716
G	27 12 1926	08:42:55.0	-57.00	-110.00	0	6.0 PAS	-61.17	-104.58	10	08:42:50.2	4	1.19	8		1717
G	27 12 1926	09:20:30.0	-57.00	-110.00	0	6.25PAS	-61.88	-103.61	10	09:20:22.4	5	2.08	8		1718
G-R	18 5 1944	19:55:12.0	-44.00	-109.00	0	6.0 PAS	-43.84	-110.87	10	19:55:15.8	13	0.92	8		1719
ISS	18 1 1949	04:43:18.0	-44.50	-90.50	0		-42.40	-90.80	10	04:43:33.0		1.80	8		1720
ISC	16 8 1967	10:03:08.0	-55.20	-83.00	33		-55.76	-76.07	10	10:02:55.7	4	1.81	8		1721
GS	20 6 1974	09:03:20.9	-43.91	-88.58	33	4.8 mb	-43.89	-88.91	10	09:03:19.2	15	1.30	8		1722
ISC	17 1 1967	21:37:08.0	-57.00	-85.00	33	5.3 mb							11		1723
ISS	01 9 1919	19:12:25.0	-69.00	-108.00	0		-65.89	-112.57	10	19:12:33.3	4	2.21	12		1724
G-R	14 8 1929	02:16:50.0	-66.00	175.00	0	6.0 PAS							12		1725
WEL	13 9 1975	08:40:10.0	-51.00	-105.00	33								14		1726

regrouped and sorted by date. The index number reflects this particular arrangement. The numbering sequence has gaps to allow for the possible updating of the catalog in the future.

A computerized version of the whole dataset is available from the senior authors. This package comprises both the sorted dataset, arranged geographically and by relocation code, and the chronological list of all events in Tables 1–13. In addition, it also includes separate files for the swarm events described in Appendix A.

The general processing code represents the nature of the analysis performed for each earthquake supposed to be intraplate, and is a factor of the type of data available and the results of the relocation. The events can be divided into two basic categories: those we deem to be true intraplate earthquakes, and the casualties we consider are not.

Intraplate:

- Code 1 (123 events): Relocation yields a statistically significant intraplate epicenter.
- Code 2 (72): Relocation confirms the bulletin listing as intraplate, and the bulletin listing has been retained.
- Code 3 (52): Epicenter very well located by the reporting agency, with no relocation deemed necessary.
- Code 4 (28): Modern event located by a local array of either Wake Island, Enewetak Island or Ocean Bottom Seismometers, retained here without relocation (WALKER, 1989).
- Code 5 (128): Modern event located by a local array of Polynesian stations, retained without relocation (OKAL *et al.*, 1980; J. TALANDIER, pers. commun., 1989).
- Code 6 (3): Relocation makes them part of a swarm described independently in Appendix A.

Casualties:

- Code 7 (196): Earthquakes that were relocated to seismically active subduction zones.
- Code 8 (76): Events relocated to a ridge or transform fault system.
- Code 9 (30): Original location is intraplate, but a second listing from a distinct agency is interplate.
- Code 10 (2): Listing appears in WALKER'S (1989) catalog, but epicenter locates on a ridge system.
- Code 11 (32): Two few arrival times available to perform a meaningful relocation.
- Code 12 (37): Relocation was attempted but failed to converge to a stable solution.

- Code 13 (4): Events for which no arrival times could be obtained.
- Code 14 (41): Original location was blatantly wrong, as the probable result of a clerical error in reporting.
- Code 15 (70): Announced or presumed to be a nuclear explosion.

Discussion

Code 1: For an event for which a relocation was performed to be considered truly interplate, several criteria had to be satisfied. The new location had to not only be intraplate but also remain at least 2° from a plate boundary, a requirement discussed above. In addition the event had to be statistically significant, as determined through the Monte Carlo simulation, also discussed above. Otherwise the epicenter was rejected as interplate and given a code of either 7 or 8, depending on the type of plate boundary. All events initially deemed intraplate from a relocation were given a Monte Carlo test.

Code 2: In these cases a relocation and Monte Carlo test were performed but the new location did not differ significantly from that listed in the bulletin. Events with this code did not relocate more than 0.5° and had depths which, when unconstrained, did not become intermediate or deep. There are a few borderline cases, however, where the epicenter moved less than 0.5° but in such a direction that it becomes less than 2° from a plate boundary, thus giving it an interplate rating.

The depths listed by the various agencies for these events (as well as with codes 3, 4 and 5) ranged from 0 km to below 60 km, and were commonly 33 km. We now know that oceanic intraplate earthquakes are generally shallower than the latter, and therefore do not necessarily endorse these depths. If an epicenter did not move much during the relocation we kept its original depth unless it was substantially overestimated, in which case we changed the depth and adjusted the origin time (e.g., Event 1367 located by the ISC as being 127 km deep in the interior of the Cocos plate. Relocation verified it as intraplate, but a better standard residual was found with a depth of 10 km).

Code 3: If the location given by the reporting agency was considered to be very reliable, then no relocation was performed. This required a large number of travel time arrivals, very small residuals (with a standard deviation on the order of 1.0 s) and a fairly complete azimuthal coverage of stations. These events were in the middle of plates so there was little chance of relocating to plate boundaries. It was also important that other arrivals listed but not used in the agency's location, such as *S*, *PKP*, *ScS*, etc., were well fit by the location. This code is not given to any historical (pre-1963) events because all of these were relocated (when enough data was available).

Codes 4 and 5: For the 152 events located by local arrays no relocation was performed. A full description of the Polynesian array and its location algorithm can be found in OKAL *et al.* (1980). We refer to WALKER and MCCREERY (1985) regarding the Western Pacific arrays.

Code 6: These three events had original locations that were independent from any other seismicity, but their relocations yielded epicenters and origin times that were concurrent with large swarms. The fact that this occurred only three times for swarms that included a total of over 800 events reassuringly implies a great degree of accuracy in the determination of these swarms.

Codes 7 and 8: These 272 events relocated to plate boundaries—either trenches and Wadati-Benioff zones or ridge and transform systems. These earthquakes were labelled as being interplate for one of three reasons: either their hypocenters were directly on, or within 2° from, or had 95% confidence ellipses that intersected, a seismically active plate boundary. This was largely the case for events listed by WALKER (1989) near the Tonga and Japan-Kuril trenches, and events from the NEIC tape listed near the East Pacific Rise and the Nazca-Antarctica plate boundary. A large number of events relocated to interplate regions using only the arrival times used in the original location. More often, however, the events relocated to active plate boundaries after applying techniques discussed earlier: including *S* waves in the inversion, floating the depth and removing emergent arrivals.

Code 9: For these events the existence of a well determined interplate epicenter by one agency invalidated the intraplate location by another. The interplate epicenter was preferred either because it was a more thorough location with more data and/or smaller residuals, or because we relocated the event and found it agreed with the plate boundary location.

Code 10: These two events, listed as intraplate in WALKER (1989), were within 2° of the East Pacific Rise and were therefore removed from the intraplate dataset.

Code 11: A location was given for which there were three or less *P* or *S* arrival times and a relocation was not possible. Most of these events occurred before 1930, when ISS locations were occasionally done on the basis of the arrival times of surface waves. Other exclusions were for locations determined on the basis of only 3 arrivals. While an inversion for three parameters can be carried out using three arrival times, the solution is uniquely determined and yields residuals of zero for the arrival times (unless the arrival times have differences greater than a certain threshold of compatibility). We do not feel that this is a meaningful solution, and require a minimum of four arrivals to achieve some measure of reliability.

Code 12: There were two possible results of the relocation that were deemed as failing to converge to a stable solution. The first is a strict interpretation of this: The inversion, no matter how many times it was iterated did not reach a final location. Unable to find a minimum in the residual space, the least-squares regression would yield a very different location with each successive iteration. In the second case the inversion program would actually iterate to a single epicenter for any given subset of arrival times, but the addition or exclusion of one arrival time could significantly change its location (in some cases by over 10°), and there was no rationale for choosing one station over another. This was often accompanied by excessively large residuals for what was usually a small number of arrival times, indicating the inadequacy of the location. Both of these cases are representative of large errors in the available arrival times.

Code 14: There were a surprisingly large number of blatant typographical errors in the reporting bulletins, signified by Code 14 in Tables 1–13. These errors were usually in the form of a missing or improperly included negative sign or reversal of adjacent numerals either in the latitude, longitude or origin time. Most of these errors are not traceable to the original locating agency but rather seem to occur upon transcription by the cataloging agency.

A dramatic example consists of 14 USE epicenters (1253–1266) listed as occurring off the coast of Mexico during the years 1933 and 1941; these epicenters formed a very distinct curvilinear trend around (15°N, 125°W), but it did not match with any known bathymetric features in this region, and no references to these events could be found in any other bulletins. However, when the negative signs of the longitudes were removed they located precisely on top of the known seismicity of the Philippines for the same time period. The events were found in the original USE catalogs, but as small local earthquakes felt on the Philippine Islands.

Some of the errors, when corrected, merely place the epicenter at the nearest trench, but some move them far from their true origin. Another USE epicenter, Event 1267, was listed at (0.00°, 110.50°W) but was actually a local Utah earthquake at (40.00°N, 110.50°W). A 1951 ISS event (1315) was put in the Northcentral Pacific at (39.20°N, 171.50°E) but was actually a Hindu Kush earthquake at (39.20°N, 71.50°E), and four other "Northcentral Pacific" earthquakes (Events 1156, 1317, 1318, 1319) listed in the Northern Pacific near (38°N, 176°E) were actually New Zealand events at (38°S, 176°E) which were missing minus signs on the latitudes.

In the case of Event 1726, the earthquake is credited to WEL but does not appear in the Wellington (or associated) bulletins (B. FERRIS, pers. commun., 1989); it is therefore assumed that there is an error in the listing of the date (and perhaps in the location as well) and the event is for all practical purposes irretrievable.

There is one other segment of this category, though less populated, which consists of blatant errors in the original location procedure. An example is Event 1320 (April 9, 1967), which was given a preliminary determination by LASA, later located by the ISC (see Figure 7) and finally compiled into WALKER (1989). The LASA array received the arrival at 18:01:45.1 and located the event in the North Pacific at (36°N, 172°E) with an origin time of 17:51:39, giving it an epicentral distance of 59.72°. We surmise however that the earthquake never occurred because at 17:41:55 there was an event in the Banda Sea (7.02°S, 129.66°E; $h = 118$ km; $m_b = 5.3$). The distance to LASA from this event was 118.12°, and taking into a.

```
  LAO Apr  9d 17h 51m 39s, 36°N 172°E. Mag=5.0
          (611) North Pacific Ocean / (39) Pacific Basin
  318  The distances and residuals correspond to the position and time given by LAO

L A O   Lasa Centre             59.72  52 i 18 01 45.1   +2.4

  319  Apr  9d 17h 52m 10±11s, Epicentre 39°±2.7°North by 163°±1.0°East, 14 obs
       Depth= 0.0000R or 33 km, SD=6.48s on 14 obs, 1D
       (611) North Pacific Ocean / (39) Pacific Basin

T F O   Tonto Forest            66.15  64 i 18 02 40.3  -12.1  0.6
WM O    Wichita Mountains       74.54  58 i 18 03 53.6  +10.4  0.8
F A Y   Fayetteville            76.54  54 i 18 04 03.9   +9.3
S C H   Schefferville           77.05  27 e 18 04 02     +4.8
L N D   London                  79.50  42 e 18 04 18     +7.2

S I C   Seven Islands           80.76  30 e 18 04 17     -0.4
S F A   Seven Falls             81.47  34 e 18 04 20     -1.2
M R G   Morgantown              82.56  44 i 18 04 28.3D  +1.4
C BM    Caribou                 82.78  33 i 18 04 25.4   -2.5
B N H   Berlin (N.H.)           83.23  36 i 18 04 28.8   -1.4

M I M   Milo                    83.71  34 i 18 04 29.2   -3.4
E MM    East Machias            84.78  34 i 18 04 31.6   -6.5
WE S    Weston                  84.89  37 i 18 04 32.0   -6.7
K E R   Kermanshah              86.08 312 e 18 04 46     +1.3
```

b.

Times from the Banda Sea Earthquake

7.02°S 129.66°E d = 118 km O.T.= 17:41:55.0

Arrival		Distance	Residual
Station	Type	(°)	(sec)
LAO	PP	118.10	0.8
TFO	?	117.87	
WMO	SKP	127.81	0.1
SCH	SKP	130.48	-1.3
FAY	SKP	130.61	0.1
SIC	SKP	134.79	-1.0
LND	SKP	134.99	-0.6
SFA	SKP	136.30	-2.7
MRG	SKP	137.99	0.6
CBM	SKP	138.12	-2.6
BNH	SKP	138.32	0.2
MIM	SKP	138.54	0.0
EMM	SKP	139.50	-0.2
WES	SKP	140.14	-1.5
KER	S	87.84	-4.7

Figure 7

The "ghost" event of April 9, 1967 (Event 1320). (a) The LASA and ISC locations for an event that most likely never existed. (b) The residuals for the stations used in (a) if the arrivals are interpreted as *PP*, *SKP* and *S* waves from the earlier Banda Sea earthquake.

account the depth of the Banda Sea earthquake, the LASA arrival has the exact time and distance expected for a *PP* arrival from the Banda Sea event. However, since LASA located using the slowness vector across a small array, there was no way for them to distinguish between the two.

This ghost event was then located by the ISC at (39°N, 163°E) and encounters similar problems. The ISC lists 13 *P* arrivals at North American stations, mostly in

New England and Northeastern Canada, and one in Iran. Of the 13 North American stations, all except TFO are fit excellently by *SKP* arrival times from the Banda Sea earthquake, at epicentral distances of 128°–140°, a range in which P_{diff} is small but *SKP* can be a very significant arrival (CHOUDHURY, 1973). The Iranian station KER is nearly equidistant from the Banda Sea and ghost Pacific events, and the alleged *P* arrival time from the latter would fit the *S* time for the former. This case could be included in the category of events relocated to plate boundaries but unlike the cases where locations are contaminated by arrivals from other events or mislabelled phases, this earthquake never occurred.

Code 15: A large number of announced or presumed nuclear explosions took place in the Pacific Basin since 1946. Some are listed in computerized and other epicentral catalogues, but this dataset is far from homogeneous, with many events missing while officially announced as nuclear tests by the U.S. Government (ANONYMOUS, 1989). Actually, we failed to recognize a rational algorithm for the identification and/or elimination of nuclear tests (presumed or announced) on the NEIC tape. In particular, neither a threshold in yield or seismic magnitude, nor the nature of the event (atmospheric, underwater or underground) can explain it, even over periods of time as short as a few months. It is thus suggested that the policies of the various seismological agencies towards reporting nuclear tests varied over the years, or perhaps even were occasionally nonexistent or random. As a result, the dataset on the NEIC tape is confusing and could be misleading. We have chosen to compile in Tables 1, 6, 8 and 9 events listed in various seismological catalogues and known or believed to be nuclear tests. These tables are intended as a warning to the seismological user of these catalogues (primarily the NEIC tape), and do not pretend to be a complete listing of nuclear explosions in the Pacific.

Seven Bikini and Enewetak events (945–951) listed on the NEIC tape were officially announced as nuclear explosions (ANONYMOUS, 1989).

Finally, Event 1269 (May 14, 1955; 28.9°N, 126.2°W), part of WALKER'S (1989) dataset, is an announced underwater U.S. nuclear explosion (ANONYMOUS, 1989). We also include in Table 8 Event 1158 (May 11, 1962; 31.2°N, 124.2°W); because of its unusual location, this announced nuclear test could be a source of confusion.

In French Polynesia, the NEIC tape includes 61 events in the vicinity of Mururoa and Fangataufa atolls, 42 of which are flagged on the tape as presumed nuclear explosions. All 61 feature a computed origin time no more than 5.2 s away from an even minute, and all occurred during daylight hours (07:28 to 15:30 GMT-9). On the basis of these characteristics, and also for several of them of strong $m_b:M_s$ anomalies, we believe the remaining 19 are also explosions, and list all 61 as such in Table 1. Once again, the criteria for identification of events as explosions on the NEIC tape are unclear.

Conversely, the tape lists Event 126 at Polynesian site TU-10 on April 16, 1982 as an explosion, with a zero depth ("assigned by Geophysicist"). This is most unlikely, since the USGS epicenter (equivalent to the ISC's) is more than 550 km from the cluster of presumed explosions at Mururoa, and 200 km from Puka-Puka, the nearest island. Rather, this epicenter plots on the Eastern flank of the Northern Tuamotu chain, and complements the alignment (TU9-GB1-GB2-GB3-GB4) described by OKAL *et al.* (1980). We regard this event as a genuine earthquake.

5. Results: Statistics

Of the total of 894 events (not related to swarms) that we extracted from reporting agencies and examined, 406 were considered to be genuinely intraplate (including three that relocated to swarms), with the breakdown between categories given in the previous section. This represents an intraplate percentage of 45.4%. In other words, less than half of the events reported that were not associated with localized swarms were actually intraplate earthquakes. The locations of the 894 original bulletin listings are shown in Figure 1a and the 406 remaining intraplate epicenters are shown in Figure 1b.

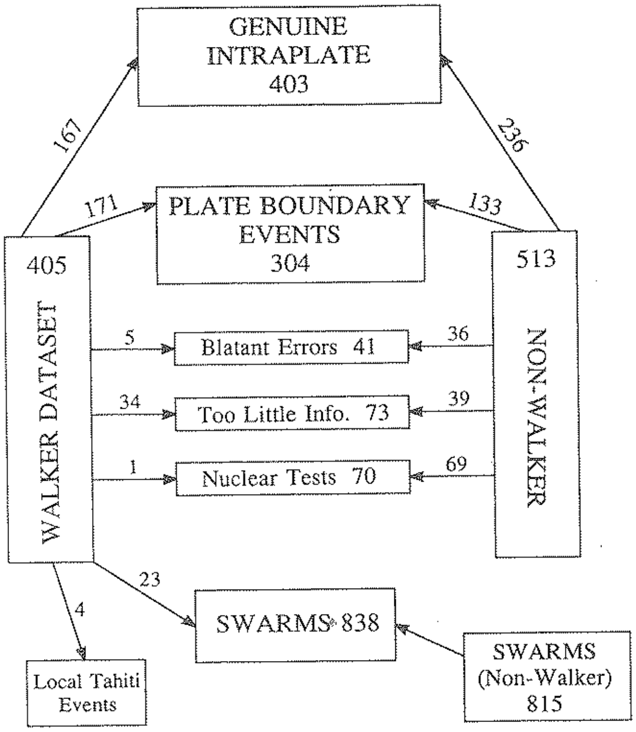


Figure 8

Chart of the repartition of the dataset between various sources (left and right), and according to the results of the processing (center).

The distribution of rate of success was fairly even amongst the reporting agencies. For example, of the 405 events available to us as part of the WALKER (1989) dataset, 194 were found to be intraplate (47.9%), though if we do not count the 24 earthquakes he includes that were only a small part of the Line Islands, Tahiti and Gilbert Islands swarms, then the WALKER (1989) set yields 170 intraplate out of 381, a percentage of 44.6% which is nearly identical to that of the total set. These results are shown schematically in Figure 8, where we show the final numbers and their sources. The sources have been divided into those events which were taken from WALKER (1989), and those that were from the NEIC tape and elsewhere. Those events that were found in both references are therefore included on the WALKER (1989) side, though as mentioned earlier, the overlap was small.

Expectedly, there was a noticeable difference between *historical* and *modern* events as to the rate of success for intraplate verification. Of the 340 historical events (before 1963), only 71 (18.5%) were actually intraplate. The majority, 105, relocated to trenches. Of the succeeding 554 modern events 60.5% were found to be intraplate.

Number of Events with Time

The results as a function of time as shown in Figure 9. Figure 9a shows the total references to Pacific intraplate earthquakes between 1913 and 1988, with actual intraplate events shown in Figure 9b and plate boundary events shown in Figure 9c. The bimodal distribution seen in Figure 9a is an interesting feature, and is an artifact of the evolving location capabilities of recording agencies since the two major peaks also appear in Figure 9c. Through the late 1920s there was an increase in the number of reported intraplate events as the increase in stations world-wide allowed for an increase in the number of total events recorded. These do not represent an increase in actual intraplate activity, however, which as is shown in Figure 9b remains constant. For the next decade the number of reported events decreases and remains low during post-war depression. This actually mirrors very well the reported world-wide seismicity, as contained in the NEIC tape, where we see seismicity increase until the mid-1930s and then decline, reaching a low in 1945 which is one-third the number from 1935. This pattern of an increase and then decrease in the number of reported intraplate events may therefore not only be a factor of the accuracies in locating Pacific events and the amount of Pacific activity but may also be simply expressing the influence of world events (principally World War II) on the activity of seismological observatories.

In the early years location accuracy significantly affected the number of reported events. In 1917 over 10% of global seismicity as listed by the NEIC, 7 out of 65 events, is placed in the Pacific Basin. The following year 17 of 431 are reported as Pacific intraplate events. Only one from both of these two years is reliably intraplate. By the 1950s only 0.5% of global seismicity was listed as being Pacific intraplate, and this continues until the 1980s when this drops to around 0.15%. It

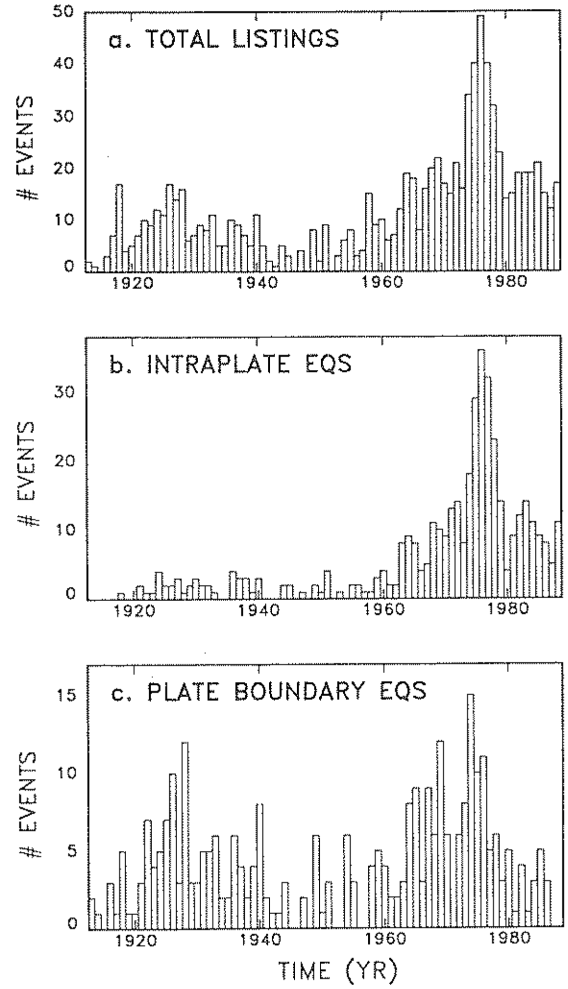


Figure 9

Histograms, by year, of the data used and analyzed. (a) Total event listed as intraplate by reporting bulletins. (b) Relocated and verified intraplate earthquakes. (c) Earthquakes that have relocated to plate boundaries. Note: the vertical scales are not the same.

is interesting to note, however, that until 1963 the number of reliably intraplate events remains nearly constant at ~1.5 per year, implying that the magnitude detection threshold is not significantly lowered during this time. After 1963, we do see an increase in intraplate seismicity due to the emplacement of Pacific arrays. The large peak that appears in Figure 9b in the mid-1970s is the increase in Polynesian seismicity made detectable through the operation there of many local stations. Excluding this large peak, since the start of the 1970s the number of actual intraplate events has averaged around 10 per year.

Residuals

Figure 10a shows a plot for each event of the standard arrival time residuals from all listed *P* and *S* arrivals. Even though this was somewhat arbitrary, as arrivals that we considered blatantly wrong were removed and this value is also a function of the number of stations used, it still gives a good indication of the quality of the data over time. A continual improvement in either picking arrivals or clock maintenance is evident, especially from the late 1920s to the early 1940s.

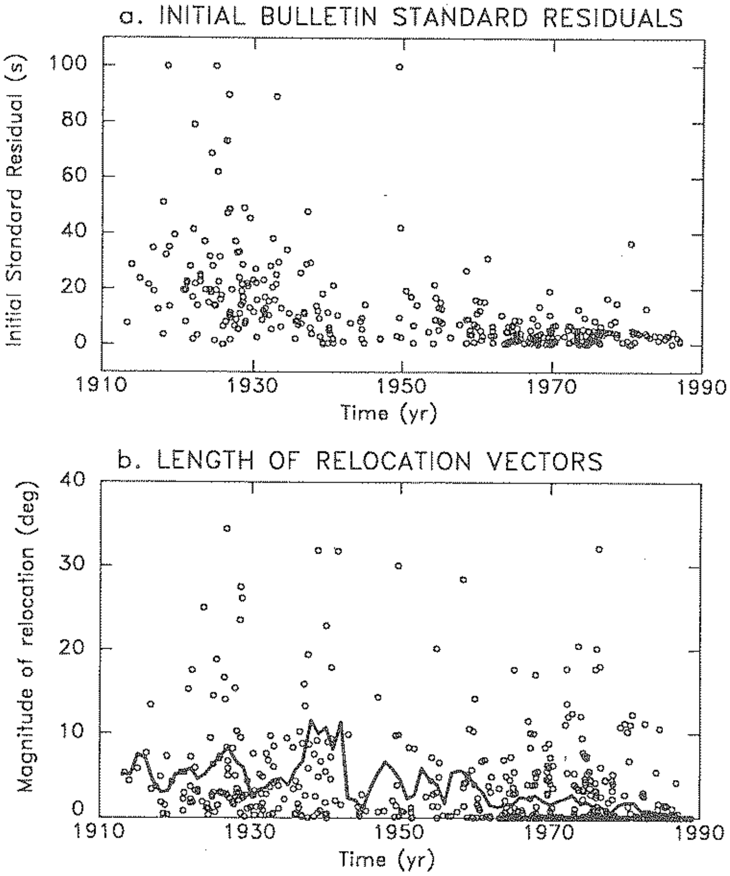


Figure 10

(a) Plot of the initial standard residuals for bulletin locations. The value is taken from all available *P* and *S* arrivals that are not blatantly in error. The quality of the data shows a steady improvement through time. (b) The length of the relocation vectors (in degrees). Open circles are individual values and the solid line is a 3-yr moving average through them. The trend of the average starts from 6° for early events and decreases to almost zero at the present. Note the significant deterioration of solutions during WWII.

Relocation Vectors

The distance that the epicenters move as a result of our relocations is shown in Figure 10b, with the open circles marking individual values and the solid line representing the average change in distance using a three-year moving window. After 1963 the averaged curve is not as meaningful because in cases where the epicenter moves less than 0.5° we have kept the reporting agencies' epicenters. Nonetheless, there is an evident quasi-linearly decreasing trend in the average distance by which the original epicenter was in error, starting at 6° before 1920 and decreasing to nearly zero by 1988. A plot of the median change in distance would be similar, starting at 6° (nearly 700 km) in 1915 but decreasing to less than 0.5° earlier, by 1970.

The relocation vectors in Figure 11 show magnitude and direction of the relocations separately for the historical and modern epicenters. Only changes of more than 0.5° are shown. Figure 11a is visually dominated by the blatant errors that were due to typographical bulletin errors, such as the cluster of Philippine events with the longitudes reversed and the New Zealand earthquakes with the latitudes flipped. Figure 11b shows an attractive force of "slab pull" in the Tonga and Japan/Kuril regions, where nearly all events listed as intraplate actually relocate to the trenches. It is remarkable that on both figures, the plate boundaries

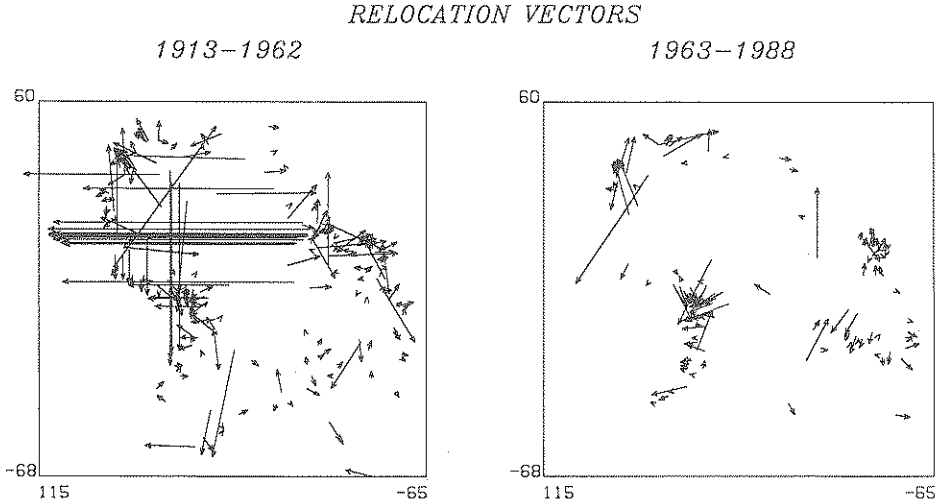


Figure 11
Relocation vectors for all earthquakes relocating more than 0.5° from their bulletin listing. The tail of each arrow is the original listing, and the head the relocated epicenter. The dataset is categorized into historical (pre-1963) and recent events. Note that the historical dataset is dominated by clerical errors affecting the sign of one coordinate. For clarity, the 1951 event relocating into the Hindu Kush is simply shown as an arrow exiting the box. The recent dataset is dominated by small earthquakes relocating to nearby subduction zones.

are well delineated even though all events were initially considered to be intraplate. This is true not only for the trenches, but also for the ridge and transform systems that separate the Cocos, Nazca, Pacific and Antarctic plates.

Focal Mechanisms

Table 14 lists all focal mechanisms available in the literature for genuine intraplate events listed in our catalogues, with orientation conventions after AKI and RICHARDS (1980). Sources are various individual studies listed in Table 14, and for more recent events, the Harvard moment tensor solutions (DZIEWONSKI *et al.*, 1983a,b,c; 1984a,b; 1987a,b,c; 1988a,b,c; 1989a,b,c).

While it is conceivable that some of the older mechanisms could be partially or fully constrained from relatively sparse datasets of old seismograms (STEIN *et al.*, 1988; JIMENEZ *et al.*, 1989), such studies are outside the scope of the present paper.

Table 14

Focal Mechanisms Available for Intraplate Events

Date	Epicenter		Index	Focal mechanism			Moment	Reference
D M Y	°N	°E		ϕ (°)	δ (°)	λ (°)	(10^{25} dyn-cm)	
			Regular Events					
30 6 1945	16.60	-115.80	1204	80	40	270	11	a
15 12 1947	-58.76	-159.20	421	350	30	90		b
22 11 1955	-24.27	-122.77	408	270	70	210		b
14 9 1963	-33.60	-126.70	414	29	67	154		b
06 3 1965	-18.40	-132.85	218	84	69	204		c
25 11 1965	-17.10	-100.20	1519	22	46	113	0.18	d
18 9 1966	-18.40	-132.86	219	103	69	206		c
28 4 1968	44.80	174.60	1101	330	65	70	0.2	e
09 5 1971	-39.78	-104.84	1702	16	60	90		f
25 5 1975	-18.40	-132.92	225	115	63	187		c
05 2 1977	-66.45	-82.58	1714	1	58	82	4.4	g
30 1 1978	-16.23	-126.94	230	187	85	169		c
07 11 1979	-62.58	-72.91	1715	353	48	121	0.036	h
20 11 1979	-26.57	-138.84	211	139	47	109	0.097	h
03 6 1981	-5.30	-175.20	757	331	44	123	0.047	i
30 9 1981	-4.80	-112.01	404	107	75	25	0.22	j
04 10 1981	-4.67	-111.86	405	302	19	71	0.05	i
22 3 1982	6.60	175.10	885	300	57	56	0.46	k
15 10 1982	32.84	-125.82	1117	282	79	17	0.09	k
03 6 1983	-50.20	-174.50	506	301	51	354	0.11	l
11 3 1984	-26.65	-108.51	1528	211	68	250	0.14	m
19 11 1986	0.30	169.70	763	118	79	146	0.10	n
06 7 1987	-27.00	-108.29	1529	38	50	249	15	o
08 7 1987	-26.97	-108.16	1530	51	42	260	5.5	o
07 3 1988	41.67	152.22	1007	350	54	72	0.22	p
22 9 1988	23.81	-167.20	1302	44	78	117	0.04	q
			Swarm Events					
29 7 1968	-7.47	-148.16	Reg. A	232	85	191		c
06 8 1969	-7.40	-148.19	Reg. A	241	75	199		c
19 1 1973 (A)	-7.36	-148.24	Reg. A	253	75	195		c
19 1 1973 (B)	-7.31	-148.27	Reg. A	265	80	211		c
05 1 1978	-20.80	-126.94	Reg. C	56	50	104	0.07	r
25 7 1978	-20.76	-126.97	Reg. C	152	90	0		c
31 7 1983	-20.13	-126.93	Reg. C	150	40	270	0.54	s
29 3 1976	3.929	-85.88	Cocos	208	77	183	11.3	t

Table 14 (continued)

Focal Mechanisms Available for Intraplate Events

Date	Epicenter		Index	Focal mechanism			Moment	Reference
D M Y	°N	°E		φ (°)	δ (°)	λ (°)	(10^{25} dyn-cm)	
12–17 6 1968	-0.25	-91.5	Galap.	335	47	247	0.6–1.2	u
24 2 1988	-0.507	-91.653	Galap.	185	43	100	0.18	p
24 2 1988	-0.427	-91.627	Galap.	16	45	117	0.04	p
20 5 1988	-0.493	-91.668	Galap.	320	38	358	0.10	v
13 12 1981	-3.45	177.55	Gilbert	167	52	129	0.05	i
7 1 1982	-3.37	177.52	Gilbert	125	60	120	0.81	w
20 1 1982	-3.36	177.38	Gilbert	351	81	172	0.22	k
15 2 1982	-3.43	177.38	Gilbert	253	86	0	1.10	w
23 2 1982	-3.39	177.37	Gilbert	78	56	26	0.20	k
16 3 1982	-3.20	177.38	Gilbert	140	60	138	0.97	w
22 3 1982	-3.35	177.53	Gilbert	12	25	158	0.12	k
27 3 1982	-3.42	177.60	Gilbert	150	37	126	0.09	k
14 4 1982	-3.40	177.52	Gilbert	277	23	51	0.05	k
18 4 1982	-3.43	177.47	Gilbert	121	16	95	0.12	k
22 4 1982	-3.46	177.61	Gilbert	133	49	122	0.09	k
28 4 1982	-3.42	177.57	Gilbert	281	38	69	0.15	k
17 5 1982	-3.46	177.54	Gilbert	277	41	47	0.08	k
23 5 1982	-3.35	177.40	Gilbert	120	54	120	0.72	w
7 7 1982	-3.25	177.47	Gilbert	281	50	26	0.08	k
11 7 1982	-3.22	177.55	Gilbert	2	49	141	0.05	k
13 7 1982	-3.28	177.55	Gilbert	300	32	95	0.10	k
15 7 1982	-3.37	177.62	Gilbert	259	25	36	0.10	k
15 7 1982	-3.39	177.54	Gilbert	142	44	132	0.09	k
5 8 1982	-3.38	177.66	Gilbert	316	33	100	0.04	k
9 9 1982	-3.27	177.57	Gilbert	261	35	44	0.07	k
13 9 1982	-3.51	177.58	Gilbert	279	48	34	0.17	k
14 9 1982	-3.47	177.70	Gilbert	93	26	80	0.10	k
16 9 1982	-3.33	177.60	Gilbert	72	53	354	0.11	k
26 9 1982	-3.44	177.66	Gilbert	106	43	101	0.03	k
3 10 1982	-3.48	177.66	Gilbert	254	48	41	0.04	k
5 10 1982	-3.49	177.69	Gilbert	272	32	38	0.07	k
9 10 1982	-3.44	177.76	Gilbert	116	43	106	0.05	k
9 10 1982	-3.47	177.70	Gilbert	60	15	56	0.06	k
8 12 1982	-3.37	177.57	Gilbert	325	41	54	0.03	k
9 12 1982	-3.48	177.62	Gilbert	124	42	114	0.16	k
31 12 1982	-3.56	177.73	Gilbert	284	32	48	0.05	k
21 1 1983	-3.53	177.67	Gilbert	163	43	144	0.12	x
31 1 1983	-3.39	177.62	Gilbert	283	38	76	0.19	x
5 2 1983	-3.37	177.67	Gilbert	130	36	95	0.19	x
8 3 1983	-3.48	177.63	Gilbert	118	27	96	0.11	x
05 10 1984	20.10	-116.01	So. Baja	60	45	290	0.14	a
02 12 1984	20.36	-115.77	So. Baja	50	55	270	4.9	a
28 5 1986	19.96	-115.88	So. Baja	40	50	280	0.28	a

References: a: Wiens and Okal (1987); b: Okal (1984); c: Okal *et al.* (1980); d: Mendiguren (1971); e: Stein (1979); f: Forsyth (1973); g: Okal (1980); h: Dziewonski *et al.* (1987*b*); i: Dziewonski *et al.* (1988*b*); j: Focal mechanism Okal (1984), Moment Dziewonski *et al.* (1988*b*); k: Dziewonski *et al.* (1983*a*); l: Dziewonski *et al.* (1983*c*); m: Dziewonski *et al.* (1984*b*); n: Dziewonski *et al.* (1987*c*); o: Dziewonski *et al.* (1988*c*); p: Dziewonski *et al.* (1989*a*); q: Jimenez *et al.* (1989); r: Dziewonski *et al.* (1987*a*); s: Wiens (1985); t: average of Wiens and Stein (1984) and Bergman and Solomon (1984); u: Kaufman and Burdick (1980) (21 events with similar mechanism); v: Dziewonski *et al.* (1989*b*); w: Lay and Okal (1983); x: Dziewonski *et al.* (1983*b*).

Magnitudes

Magnitude values reported in Tables 1–13 were compiled from the reports of various primary agencies. With regard to several available magnitudes, the largest figure was kept. Available seismic moments, principally from the Harvard CMT solutions, but also from a number of individual studies, are listed as part of the focal mechanism data, in Table 14.

In our previous study, OKAL (1984) noted an absence of magnitude 6 or larger events in that portion of the Pacific plate generated at the Old Farallon, prior to the reorientation of spreading. In contrast, other oceanic plates, and those portions which were not involved in the reorientation, feature larger intraplate earthquakes, (commonly $M = 6$ and occasionally $M = 7$). OKAL (1984) interpreted this pattern as a consequence of greater vulnerability of the plate in a geometry where stresses are oriented at an angle to the lithospheric fabric. Our present results fully uphold this observation: the only earthquakes with $M \geq 6$ in our dataset are located either at the fringes of the Pacific plate (e.g., the 1984 swarm South of Baja California), in the Southern portion of the plate (e.g., Events 408, 420, 421), or in the Cocos, Nazca and Antarctic plates (e.g., Events 1351, 1515, 1535, 1702, 1714).

6. Geographical Discussion

It has long been suggested that the state of stress in oceanic intraplate regions is controlled largely by the gravitational sliding of the lithosphere as it ages ("ridge-push") and to a lesser extent by drag forces on the lithosphere-asthenosphere boundary (FORSYTH and UYEDA, 1975; SBAR and SYKES, 1977; RICHARDSON *et al.*, 1979; OKAL, 1980). Where and how this stress is released, however, can be determined through the knowledge of the distribution of seismicity, especially if there are correlations with bathymetric features (OKAL, 1983).

SYKES (1978) discussed the possibility of intraplate seismicity occurring along pre-existing zones of weakness such as fracture zones and fossil spreading centers. This has been supported by studies of oceanic intraplate regions. BERGMAN and SOLOMON (1980) found that larger earthquakes were often associated with old fracture zones. OKAL and BERGEAL (1983) have suggested that there is increased seismicity on the boundary line of lithosphere generated at the old Farallon Ridge before it jumped and reoriented itself along the present East Pacific Ridge, and STEIN (1979) has also discussed ancient plate boundaries such as the Emperor Trough as preferential sites for seismicity. Ancient traces of hot spots have also been proposed as possible zones of weakness.

A major tectonic fabric in the Pacific is the presence and often high density of seamounts. While a correlation betwen seismicity and seamounts or islands is difficult—seamount dimensions can be smaller than the inherent uncertainties in the earthquake epicenters—its occurrence may signify the release of very local as proposed to plate-wide stress. Such seismicity may be the expression of isostatic compensation of oceanic islands or the injection of magma associated with volcanism. Indeed, seismic activity has been well documented in association with volcanism in the Polynesian Islands (TALANDIER and OKAL, 1984a, 1987).

What will follow here is a discussion, region by region, of the possible correlations between Pacific intraplate seismicity and the tectonic settings it occurred in.

The latter includes bathymetric features, such as fracture zones, fossil ridges, seamounts and hot spot traces, as well as seafloor age, determined through magnetic lineations.

In order to classify our dataset and arrange it in a manageable fashion, we proceeded with the regionalization described on Figure 6 and Tables 1–13. It must be realized, however, that while small-scale geological features, such as seamounts and short fracture zones, lend themselves well to such classifications, many large-scale bathymetric expressions transcend any attempt to regionalize the Pacific Basin. As a result, our geographical discussion of the seismicity will not strictly adhere to the chosen regionalization, but rather proceed along a very broad clockwise spiral, starting with Polynesia.

We concentrate in this section on a description of the resulting intraplate seismicity in the context of local geology. Technical details regarding the quality of the individual relocations, and a documentation of the casualty events, can be found in Appendix B. In areas where seismicity tends to cluster at identifiable sites, we have followed our earlier practice (OKAL *et al.*, 1980; OKAL, 1984) of assigning location codes to these various sites. In some areas, the level of seismicity and its scattered character do not warrant this effort, and no codes have been assigned.

Polynesia

Most of the sites in Polynesia have been described in detail by OKAL *et al.* (1980). The present discussion will emphasize the new sites, and in particular their possible relationship with features recognized earlier. OKAL *et al.*'s dataset is compiled and updated to 1988 in Table 1, with the exception of Regions A and C, whose swarms are described separately in Appendix A. Figure 12a shows the updated seismicity in the area. We keep these authors' coding scheme for the various seismic locations involved. A total of 136 genuine intraplate earthquakes were recognized, most of them located by the Polynesian network. In keeping with our exclusion of the seismicity in the immediate vicinity of Hawaii, we do not include in our dataset epicenters located in the Tahiti-Mehetia area, defined as "TM" in OKAL *et al.* (1980), and outlined on Figure 12a. This results in the elimination of 4 events selected by WALKER (1989) out of the more than 70 listed in OKAL *et al.* (1980).

It is remarkable that activity in Polynesia has been extremely low during the 1980s: Event 127 defines a new site (TU-11) in the Northeastern corner of the Tuamotu Islands. Renewed activity took place at a very low level Northwest of the Society Islands (Events 143, 145 and 146), two new epicenters were defined Northeast of the Austral Islands (AU-7 and -8, Events 212 and 213), and one North of the Gambier Islands, along the northern flank of the Marutea-Acton group (GB-10, Event 233). Finally, one event (214, on October 2, 1988) was widely felt in the Marquesas Islands, and located by PPT in the center of the archipelago. We should recall, however, that volcanoseismic activity was extremely intense during 1981–1985 in the Tahiti-Mehetia area, and at Macdonald Seamount during the whole decade.

The two new sites SC-4 and SC-5 North of the Society Islands (Events 145 and 146) define, together with SC-1 and SC-2, a cluster grossly parallel to the axis of the island chain. In the Tuamotu and North-of-Gambier regions, and as noted by OKAL (1984), the single 1982 event at TU-10 (number 126) is remarkably aligned with the lineation running from TU-9 (Event 125) to the cluster at GB-4 (Events 219–230), which can indeed be extrapolated to the swarm site GB-5, part of Region C. While the exact origin of this lineament is speculative, it also coincides with the 4000-m isobath (with the exception of Region C). It is remarkable that the two sites immediately North of the Gambier Islands (Events 232 and 233) are also in the immediate vicinity of the same isobath.

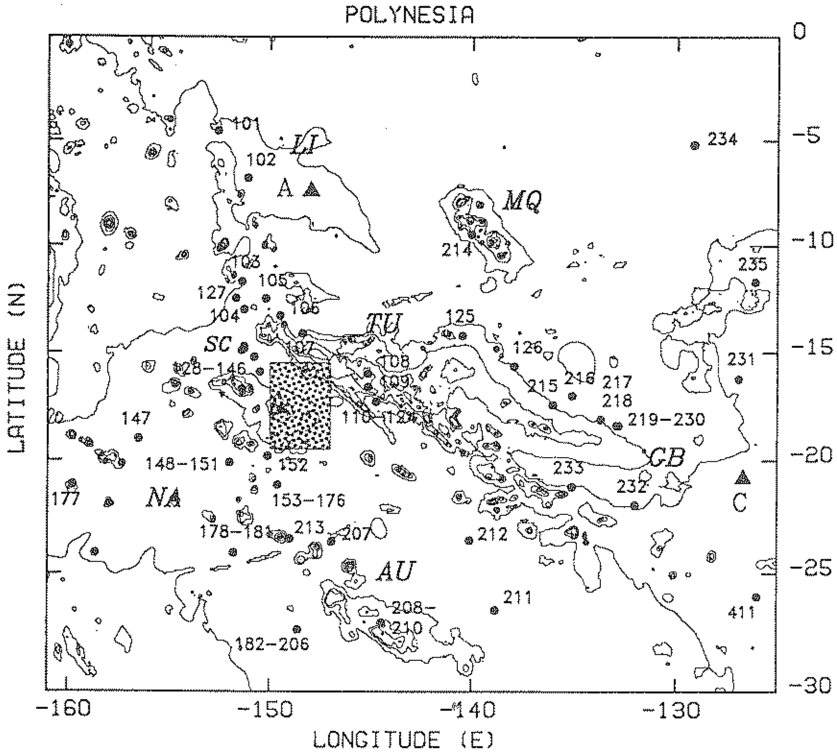


Figure 12a

Map of intraplate epicenters in Polynesia. Numbers refer to individual indices in Table 1. Triangles identify the swarm site at Regions A and C. Bathymetry is contoured at 1000 m intervals. The stippled quadrangle is the Tahiti-Mehetia area, as described by OKAL *et al.* (1980), and excluded from the present study. Two-letter codes follow the scheme of these authors.

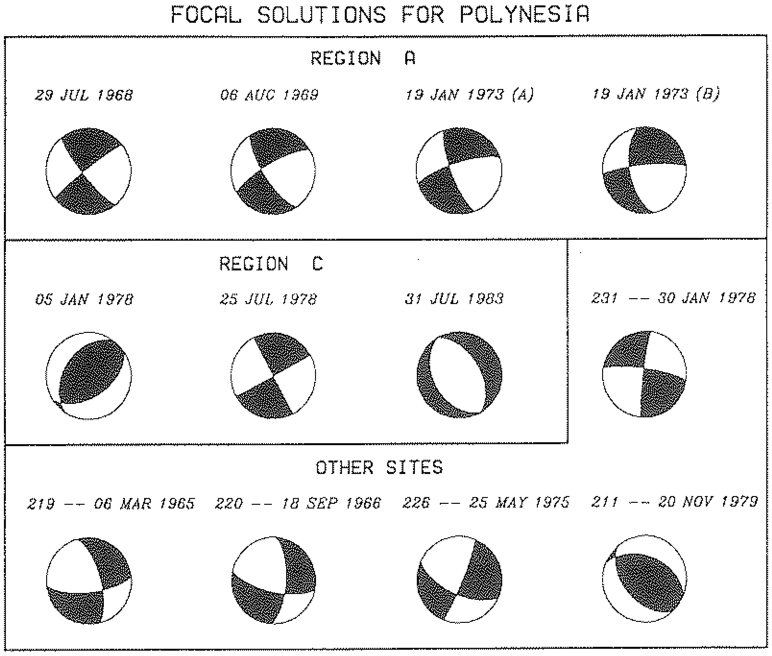


Figure 12b
Focal mechanisms available for Polynesia.

Southcentral Pacific

In the Southcentral Pacific and East of Kermadec (Figures 13 and 14) we update OKAL'S (1984) description of the active sites, by recognizing a few remarkable features:

- Four events (425, 537, 538, 539) are located at most 1.5° from the Louisville Ridge. These earthquakes could represent tectonic processes linked to prolonged activity, reactivation, or differential subsidence along this feature, generally interpreted as the wake of a hotspot presently located in the vicinity of the Eltanin transform (HAYES and EWING, 1971). A precise interpretation remains however speculative in the absence of any knowledge of lower-magnitude seismicity.
- A remarkable North-South lineament between longitudes 130 and 125°W can be followed from 34°S (Event 414) all the way into the Northern Pacific (see discussion below). The maximum distance between sites is 7°. This "130°W" seismic line, recognized by WALKER (1989), runs through the swarm site at Region C. Because of the numerous fracture zones in that part of the Pacific Basin, this North-South lineament is neither an isobath (ocean depths range from 2500 to 5500 m), nor an isochron (the various epicenters being spread out from Chron 6 (Region C) to Chron 18 (at SP-3)). Upon intersecting the Oeno-Ducie-Crough

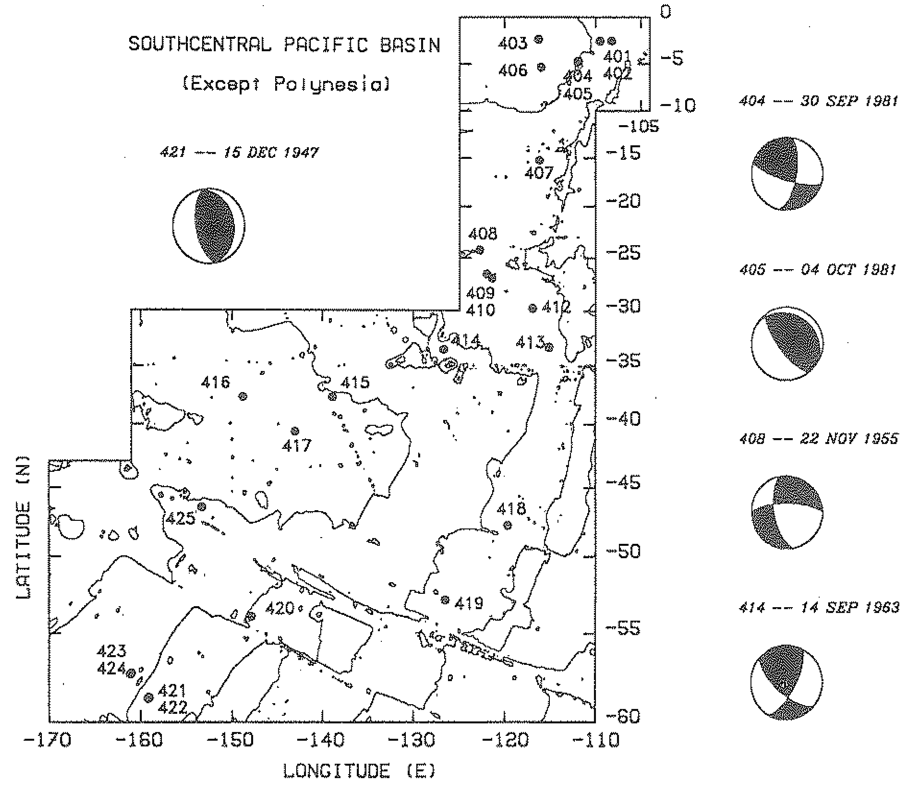


Figure 13
Map of intraplate epicenters for the Southcentral Pacific, with available focal mechanisms. Numbers refer to individual indices in Table 2. Bathymetry contoured at 1000 m intervals.

chain, the lineament branches out Eastward, the new epicenters SP-7 and SP-8 (Events 412 and 413) providing some continuity with Sites IP-4, IP-5 and IP-6 (Events 408-410), recognized by OKAL (1984).

In a previous study, OKAL and BERGEAL (1983) had suggested that seismicity might be preferentially released along a line of age discontinuity related to the Miocene jump of the Farallon ridge. This line does run between 125 and 130°W at latitudes 10–38°S, but is offset Eastwards further North. It should also be noted that three events used by OKAL and BERGEAL (1983) are proven casualties in the present study: Events 432, 445 and 1267.

Campbell Plateau to Samoa

The region east and south of New Zealand has a large amount of documented intraplate seismicity due to the complex geophysics of the region and the extensive network of local stations. Out of 76 intraplate events listed for this region, 41 were

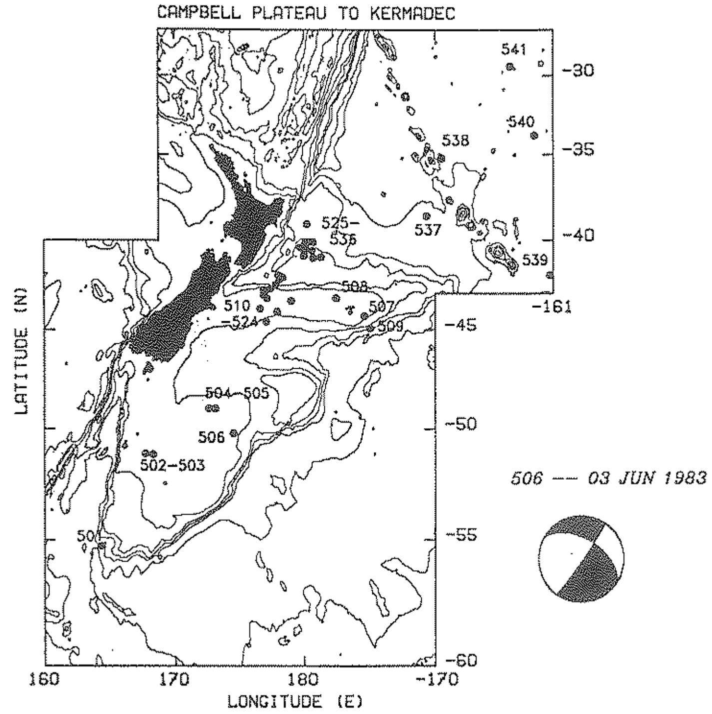


Figure 14
Same as Figure 13 for Campbell-to-Kermadec Region. See Table 3.

considered genuine, and for many of these our relocations did not differ significantly from the epicenters determined by Wellington (Figure 14; Table 3).

Much of the seismicity in this region is located on the Campbell Plateau and Chatham Rise, both of which are of continental origin and possess a complex history (FLEMING, 1970): They are thought to have been former extensions of a N-S trending Triassic geosyncline that were swung clockwise about the South Island during the Early Cretaceous, based on the continuation of geologic facies from the bottom of the South Island to the Chatham and Bounty Islands (FLEMING, 1970), and the continuation of the Stokes Magnetic Anomaly on the South Island out into the Campbell Magnetic Anomaly System (DAVEY and CHRISTOFFEL, 1978). The Campbell Plateau was then separated from and moved south relative to the Chatham Rise, with 330 km of right-lateral displacement determined by DAVEY and CHRISTOFFEL (1978) to have occurred along the Campbell Fault, which trends northeast. The seismicity correlates well with these lineations.

Two earthquakes, Events 502 and 503, occur at the same position just east of the Auckland Islands, at the junction of the southern end of the proposed Campbell Fault and the western end of a large, positive magnetic anomaly. This magnetic anomaly terminates at the Pukaki Saddle, a location where seismic data has shown a sediment-filled faulted graben (HOUTZ, 1975); this is the site of Event 506 ($m_b = 5.2$), an earthquake whose CMT focal solution is shown in Figure 14. Two other events (504–505) relocate to the same location on the northernmost Campbell Magnetic Anomaly (the equivalent of the Junction Magnetic Anomaly), which extends from northeast of the Auckland Islands to south of the Bounty Islands. There is also one earthquake (501) at the extreme southern end of the Campbell Plateau, along the Campbell Spur.

Seismicity is conspicuously absent from the Bounty Trough, but is very active along the Chatham Rise, just north of it. The North Island of New Zealand represents a transition zone from the Kermadec Trench to the South Island's Alpine Fault System, and though there has been Pacific oceanic lithosphere subducted under the North Island at the Hikurangi Trench, the entire island is displaying internal deformation and the exact location of the plate boundary is not evident (MOLNAR, 1988). We have therefore chosen our 2° buffer to extend from the current coastlines of New Zealand, and we find that the seismicity beyond this point is dominated by two large clusters.

Events 510–524, with local Wellington magnitudes of 3.8–4.5, occur at the western end of the Chatham Rise and are separated into two features. The first, containing most of the epicenters, lies just beyond our 2° buffer. Though this appears as a linear feature, extending northeast from the rise into oceanic crust, this is misleading as there is much seismicity directly to the west of here. Particularly significant is a linear northeast-trending termination to these events which defines a zone of inactivity between this cluster and the second feature, three events (511, 516 and 520) which also lie along a northeasterly trend. These three shocks also define a previously recognized fault shown on the Circum-Pacific Map of the AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS (1981). Further out on the rise, centered around the Chatham Islands, are three more events (507–509).

The second cluster, separated by about 150 km, lies directly to the northeast of the first (Events 525–536). These are slightly more energetic than the other cluster, with 4 events of $m_b \geq 4.5$. Unlike the first cluster, which is temporally continuous, these events occur in three separate groups: Events 526 (1964), 527–530 (1971–1974), and 531–536 (1982–1985). They do not correlate with an obvious bathymetric feature.

There are five more earthquakes, also listed in Table 3, which are further to the east. Three (537–539) located on or just beyond the Louisville Ridge, and are discussed earlier. The remaining two are east of the Louisville Seamounts and are both old. Event 540 (IP-20 in OKAL, (1984)) is from 1940, and Event 541 is from 1925.

The Pacific regions surrounding the Tonga Trench and Fiji Plateau were found to have very low seismicity. This was surprising, considering that most previous maps of Pacific seismicity, such as WALKER'S (1989), have displayed a very high density of seismicity in this region. Of the 100 events listed in these regions,

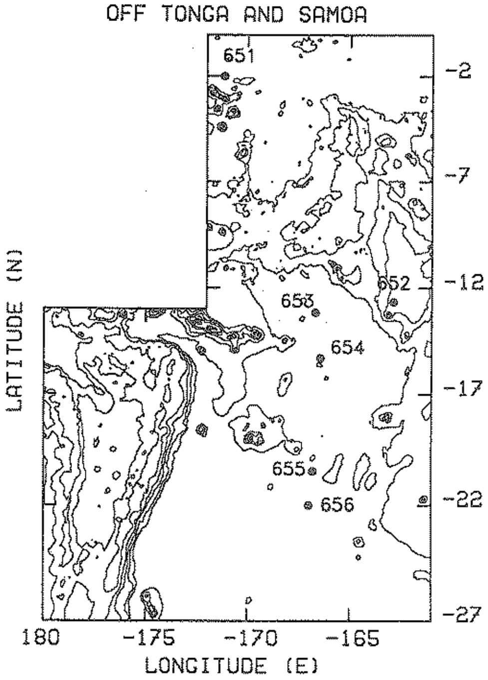


Figure 15
Same as Figure 13 for Region East of Tonga and Samoa. See Table 4.

delineated in Figures 15 and 16, only 21 were reliably intraplate. The majority (63) of reported events were relocated to the Tonga Trench.

The seismicity east of Samoa and the Tonga Trench was found to be very minimal (Figure 15). Of the five earthquakes that are retained (Events 651–656), four occurred before 1930, and therefore have larger error ellipses. Nonetheless, the best found epicenters for four of these (653–656) form a lineation that extends north-south along the 167.5° meridian. We have no simple explanation for this feature, as the distance from the trench is too great to invoke a systematic buckling of the lithosphere in the manner of CHEN and FORSYTH (1978) and CHAPPLE and FORSYTH (1979).

Finally, a single historical event (651) relocates north of Canton Island, possibly at the eastern end of the Nova Canton Trough.

Samoa to Micronesia

We concentrate here on a large region extending from Samoa to the Marianas Arc as shown in Figures 16 and 17. This region exhibits substantial scattered seismicity which was dominated by the Gilbert Islands swarm of 1981–1984 (LAY and OKAL, 1983, summarized in Appendix A). On this basis it has been suggested

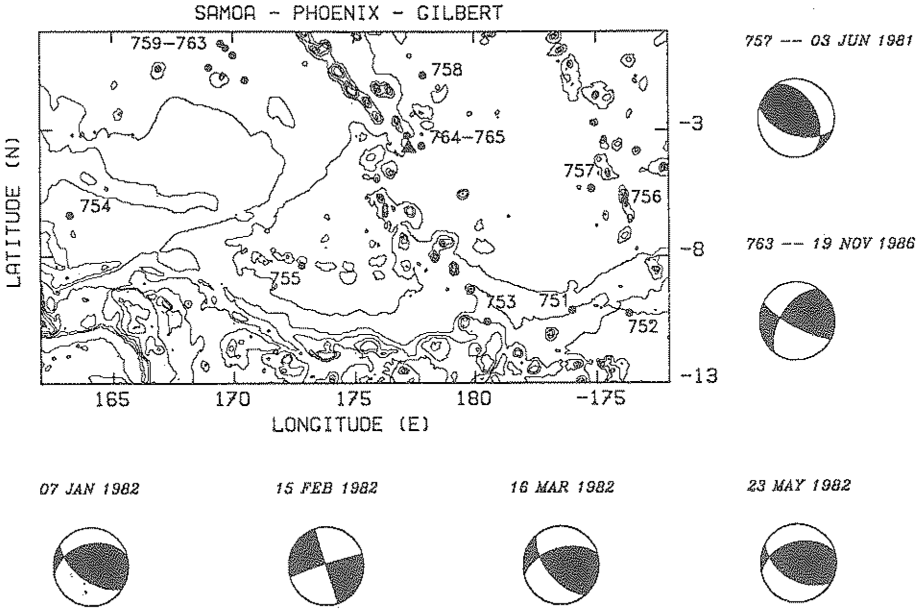


Figure 16

Same as Figure 13 for Samoa-Phoenix-Gilbert Region. The triangle identifies the Gilbert Island swarm site. See Table 5. The four bottom focal mechanisms are for those events in the swarm studied by LAY and OKAL (1983). Thirty-two additional CMT solutions are listed in Table 14.

that a process of incipient subduction is taking place. OKAL *et al.* (1986) have traced this line of activity from Samoa to the Ralik Fracture Zone, north of Ocean Island. KROENKE and WALKER (1986) have extended it all the way to the Caroline Ridge just east of the Yap Islands.

We will examine the seismicity of the region in the context of these speculative models, and in particular will show that a significant difference in the level of seismicity, as well as inconsistencies in focal mechanisms, result in a picture both fuzzier and more complex than the simple relocation of the Solomon subduction zone to the North.

Immediately to the North of Samoa were three historical events (751–753) two of which relocated to the Robbie Bank, with the third one (753) 1° east of Nurakita. Further north, in the Phoenix Islands, there are two events (756 and 757), with the latter given a CMT solution that shares the NE-SW compressional axis common to all Gilbert Islands events (Figure 16).

In the SW part of the Tuvalu Basin a single event (755) is located on a chain of seamounts that extend west from Funafuti Atoll. Further west a single historical event (754) relocates to the interior of the Ontong Java plateau.

At the Gilbert Islands swarm site two earthquakes in 1982 (764–765) became

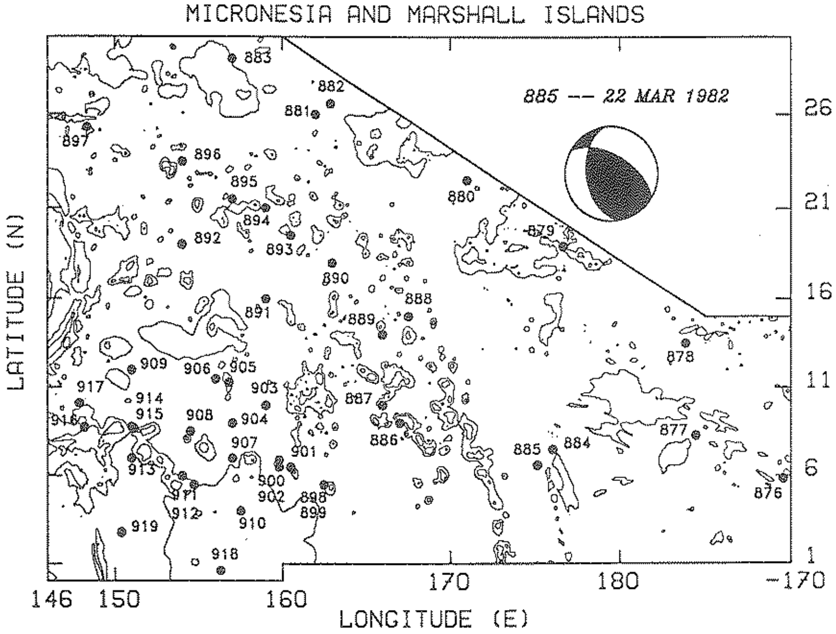


Figure 17
Same as Figure 13 for Micronesia and the Marshall Islands. On this particular figure, bathymetry is contoured at 2000 m intervals. See Table 6.

part of the swarm when relocated, and there was a third event (758) that relocated north of the site but whose error ellipse incorporates this region.

To the northwest, the Ralik FZ site underwent a new strong event since the studies of KROENKE and WALKER (1986) and OKAL *et al.* (1986). The CMT solution for this event (763; $m_b = 5.3$), however, is irreconcilable with the stress orientation at the Gilbert Islands (Figure 16).

Further north, in Micronesia and the Marshall Islands, seismicity is arranged along several linear trends oriented about 307°; we have geographically ordered the 44 intraplate events along these lineaments.

While these trends do not represent a unique way of organizing the seismicity of this region, they form very striking features. Certainly the dominant trend, the subject of the previous studies, is the one that extends from Samoa to the Caroline Ridge. Largely due to the inclusion of the Gilbert Islands swarm this line of seismicity was estimated by OKAL *et al.* (1986) to have accounted for 15–30% of the total Pacific intraplate seismic moment budget for the years 1937–1983. This line of seismicity does not indicate a localized active subduction zone as suggested by KROENKE and WALKER (1986), however, because there is no evidence for a trench (OKAL *et al.*, 1986) and because the trend is only moderately linear. As was discussed above, the seismicity at the Samoa and Ralik locations is very minimal, certainly compared to the Gilbert Islands activity, and the extension of this trend into the Micronesian region (Events 898–919) is as a zone of diffuse seismicity.

In addition, there are two other distinct features (considerably more linear) that form ESE trends, pointed out by WALKER (1989). One extends from the Ogasawara Plateau (east of the Izu-Bonin Trench) down to the Marshall Islands, following the Jurassic Magnetic Quiet Zone (Events 884–897), and the other (seen across the top of Figure 17) extends from south of the Shatsky Rise through the Mid-Pacific Mountains into the Central Pacific Basin (Events 876–883). The orientation of these trends is the same as the direction of absolute plate motion, determined relative to hot spots. The top and middle lineaments, when taken SE to NW on a Mercator projection, have azimuths relative to north of 308° and 306°, and the absolute motions of the middle of the trends are 307° and 304°, respectively (GRIPP and GORDON, 1989). The earthquakes in these regions, with the exception of Events 877 ($m_b = 5.2$) and 885 ($m_b = 5.6$, with a CMT solution shown in Figure 17), are small and usually only detected by local arrays. The presence of these three distinct belts of seismicity supports the idea that Australian-Pacific subduction is being arrested, but suggests that it has not yet found a new home.

Off the Coast of Japan and Kuriles

Compared to the Micronesian and Polynesian regions, the northern part of the Pacific Basin displays very sparse seismicity. There are two sites of active seismicity—the Hawaiian Island and the swarm at (20°N, 117°W) studied by WIENS and OKAL (1987; see Appendix A)—and otherwise there is very little. There is one large tract of oceanic lithosphere, with latitudes 0–40°N and longitudes 152–132°W, that does not boast a single recorded epicenter.

This lack of seismicity is especially remarkable near the Japan, Kuril and Aleutian Trenches, which like Tonga have many intraplate bulletin listings (WALKER, 1989). Off the coast of Japan and the Kurile Islands (Figure 18, Table 7) we retained 7 intraplate earthquakes of the 43 that were reported. The largest (Event 1007: $m_b = 5.9$), on March 7, 1988, was given a CMT thrust fault mechanism, shown in Figure 18. Though this epicenter does not correlate with any bathymetric feature, it is interesting to note that a 1936 earthquake (1006) relocates near this site.

Of the remaining 5 events in this region, two occur on the same day adjacent to an unnamed seamount (Events 1001–1002) and two locate to the western flank of the Shatsky Rise. Of the latter, the larger earthquake (Event 1004 on May 6, 1976: $m_b = 5.1$) has a reliable location on the 4000 m isobath. Occurring on the previous day, Event 1003 relocates 2.5° to the southwest of this, but it was a small event (no magnitude given) with a poor relocation, so it may very likely have occurred at the site of Event 1004.

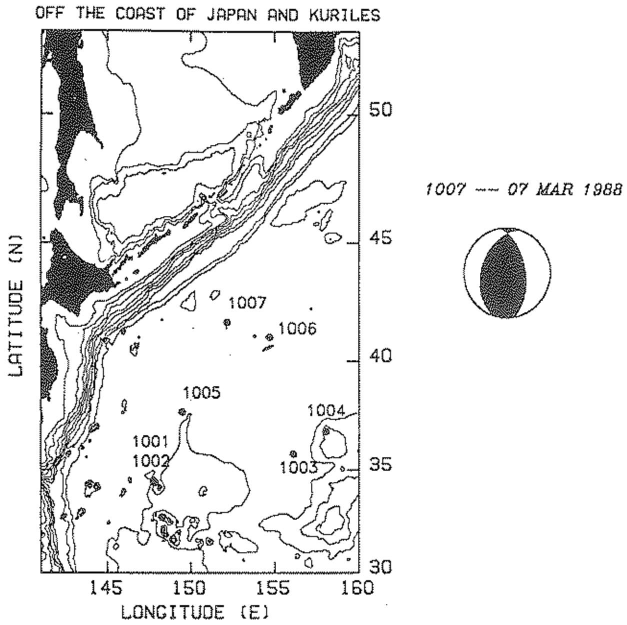


Figure 18
Same as Figure 13 for Region East of Japan and Kuriles. See Table 7.

Northern Boundary

The tectonics of the Northern Boundary (Figure 19; Table 8) are dominated by the Aleutian Trench, and as with the Japan and Kuril Trenches, most of the reported seismicity relocates into the trench. There are 20 epicenters (out of 58) that are reliably intraplate, however, and they are distributed fairly evenly throughout the region, occasionally forming small clusters that correlate with bathymetric features.

The largest event in this geographical region was an $m_b = 5.5$ shock in the Emperor Trough (Event 1101), which had a thrust mechanism (Figure 19) determined by STEIN (1979), and had one recorded aftershock (1102). Event 1108 is located on a seamount in the Seamount Province south of Kodiak Island, though the other earthquakes in the central part of the Northern Boundary (1105–1107, 1109–1110) are not associated with identifiable seafloor structures.

Particularly recognizable in this and the Japan-Kuril regions, and eliminated as casualties of the relocation process, are aftershocks of the large interplate earthquakes of February 3, 1923 in Kamchatka, February 4, 1965 in the Aleutians, August 11, 1969 and March 23–24, 1978 in the Kuriles, and June 10, 1975 at the Hokkaido corner (with moments ranging from 8×10^{26} to 1.4×10^{29} dyn-cm). Our failure to document reliable intraplate seismicity among the aftershocks of these large intraplate events means that the oceanic lithosphere at a distance of 2° from

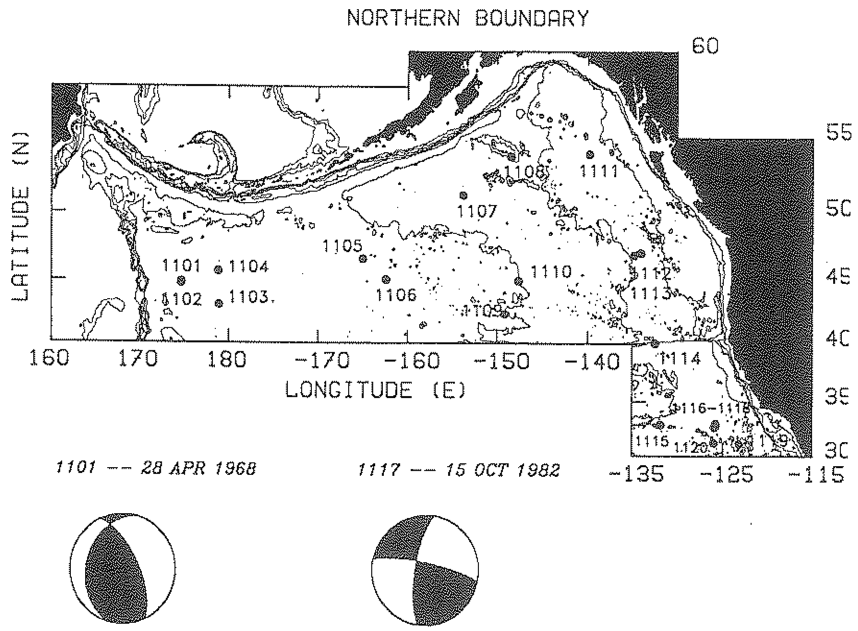


Figure 19
Same as Figure 13 for Northern Boundary Region. See Table 8.

the trench does not participate in the coseismic stress relaxation. In this respect, our study yields an interesting result, since the pattern of seismicity observed on published maps of unrelocated earthquakes would lead to the exact opposite conclusion.

Further east, one epicenter is retained from the Alaska Plain, Event 1111, which is in the far northeast corner of the Pacific, but still south of the incipient plate boundary seismicity described by LAHR *et al.* (1988).

Slightly southwest of the Eickelberg Ridge are the epicenters of two events (1112–1113), statistically identical, that occurred within hours of each other on March 20, 1940. Further to the south, there are two earthquakes that occurred on major fracture zones: Event 1114 relocated to the Mendocino, and Event 1115 occurred on the Murray.

West of Southern California there is a cluster of epicenters that occur near or on the Feiberling Tablemount. Event 1116, with a magnitude of 4.8 (PAS), occurred in 1949 at the northern edge of the Tablemount, the same location as Events 1117–1118 which happened in 1982. The CMT mechanism for the larger of these two was dominantly strike-slip (Figure 19). A 1988 earthquake (1120) was located directly on the Feiberling Tablemount, and one more occurred 3° to the east. These events may possibly be associated with volcanism, which was reported to have erupted in 1972 at a location between Events 1119 and 1120. This report was qualified as "uncertain" by SIMKIN *et al.* (1981).

West and South of Baja California

The region west of Mexico is a very complicated one (Figure 20), and appropriately there is a significant deal of seismicity that correlates with the seafloor structures. As listed in Table 9, there are 25 events of the 69 listed that are genuine intraplate earthquakes. The success rate of relocations was actually better than this would suggest, as 15 of the casualties were the mislisted USE epicenters that occurred in the Philippines.

The tectonics of the Pacific-North American-Cocos-Nazca-Rivera plate boundaries have been complex, and the fabric of the Eastcentral Pacific seafloor displays this. There are many east-west trending fracture zones, several north-south fossil spreading ridges, and countless seamounts. It is interesting, however, that the most visually striking patterns in the seismicity are two north-south lineaments that do not seem to be associated with former tectonic activity: that along the 130°W meridian, mentioned above, and along the 116°W meridian, extending into the South Pacific. The 130°W lineament starts at 31°N the Northern Boundary Region (Figure 19) with Events 1116–1120 on the Feiberling Tablemount, passes through this region as Events 1218–1225 and extends into the Southern Pacific (Figures 12a

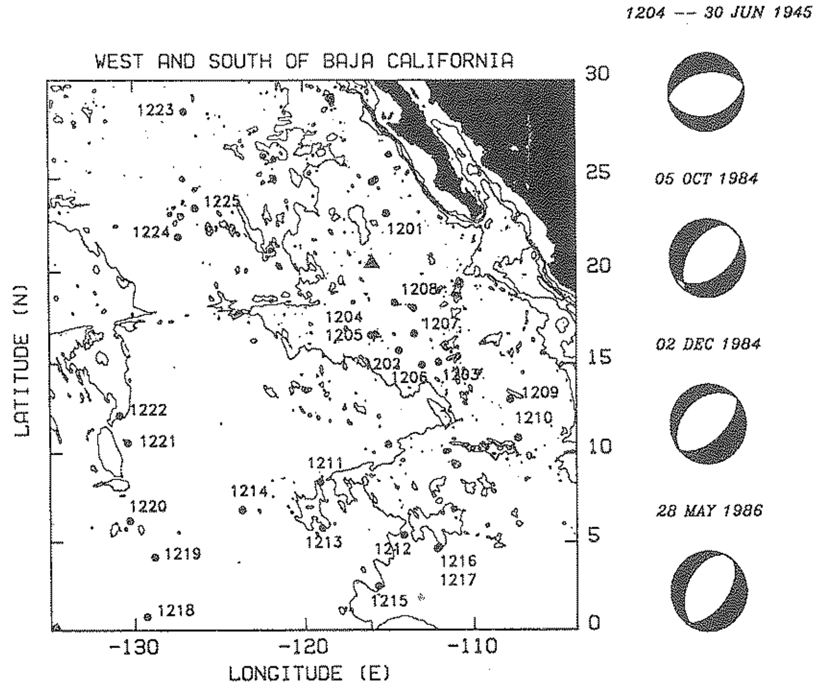


Figure 20

Same as Figure 13 for Region West and South of Baja California. Triangle identifies the site of 1984 swarm studied by WIENS and OKAL (1987). See Table 9.

and 13) as Events 230, 233, 234, Region C, all the way down to Event 414 at 34°S. This lineament is insensitive to magnitude thresholds, as the earthquakes contained within it cover a range of magnitudes, and does not seem to be an artifact of detection capabilities as similar patterns are not seen in the South Pacific areas where a gradient of detection threshold also exists. The 116°W lineament begins with Events 1212 and 1215 in this region and then passes into the Southern Pacific (Figure 13) as Events 403, 406 and 407.

Many of the earthquakes on these lineaments also correlate well with small scale or east-west features, so the lineaments may not be statistically significant. Event 1220 is one of four small earthquakes, along with 1210, 1211 and 1214 (within error bounds) that occur on the Clipperton Fracture Zone. The epicenter of Event 1219 (and also 1213) relocates to an unnamed fracture zone south of the Clipperton, Event 1215 is located on the Galapagos Fracture Zone, and the relocation of a 1927 earthquake (Event 1212, if it can be trusted) puts it on a 10 Ma fossil spreading ridge (MAMMERICKX and KLITGORD, 1982). In addition, there are two earthquakes (1216–1217) that occur seven years apart at the same place on a fracture zone just north of the Galapagos Fracture Zone.

Much of the seismicity in this region also occurs in parts of the crust that are densely populated with seamounts. Nine events (1201–1209), as well as the swarm studied by WIENS and OKAL (1987; see Appendix A), occur in an area that includes the Suitcase Seamounts to the north, the Shimada Seamounts to the west and the Mathematicians Seamounts to the east. Three more events (1223–1225) are located in the Baja California Seamount Province. This region is very young, formed by a spreading center (now the Mathematicians Ridge) that created a microplate between the Rivera, Cocos and Pacific plates (KLITGORD and MAMMERICKX, 1982). Though there is still volcanism associated with the northern part of the Mathematicians Ridge at the Revilla Gigedo Islands (SIMKIN *et al.*, 1981), none of the seismicity is associated with it. It is significant, however, that events 1202–1206 and one further to the east (1209) form a lineation that locates very well on the O'Gorman Fracture Zone, formerly a major transform in the development of this area.

Northcentral Pacific

With the exception of the Hawaiian hot spot, the region of the Pacific shown in Figure 21 is seismically very quiet, with only five earthquakes of a possible 25 located or relocated as intraplate (8 of those listed were clerical or typographical bulletin errors). Though a large amount of Pacific intraplate seismicity has been found to correlate with seamounts or seafloor ridges, it is somewhat surprising that the Hawaiian and Emperor Chains, which are very bathymetrically elevated, are mostly inactive (though their isolation would reduce detectability). The one notable exception is Event 1302 (September 22, 1988; $m_b = 5.5$). This earthquake occurred

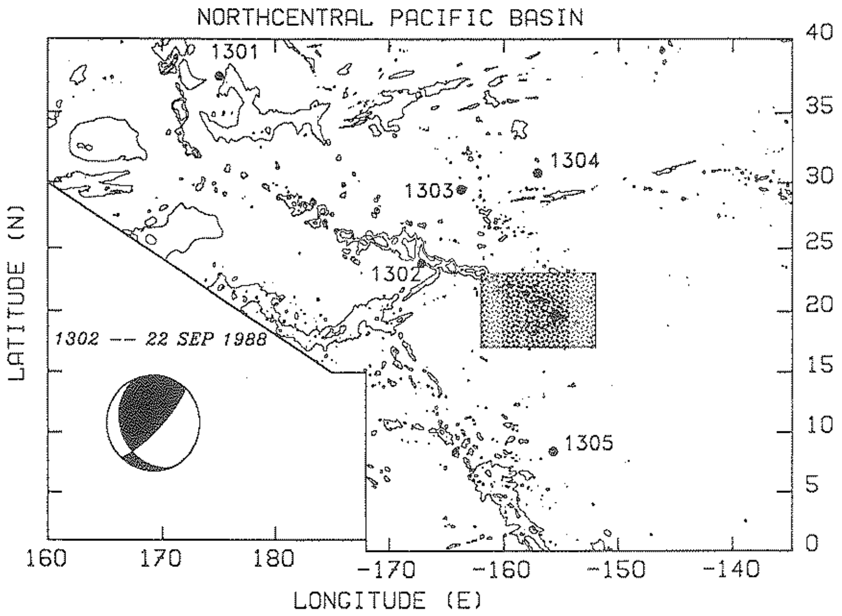


Figure 21
Same as Figure 13 for Northcentral Pacific. The stippled quadrangle is the Hawaiian area, excluded from the present study. See Table 10.

on the southern flank of the Hawaiian chain, approximately 100 km west of Tern Island, where it was felt. In this region, the chain includes a broad structure, continuous at the 1000 m depth, comprising French Frigate Shoals, and the Brooks and St. Gregatien Banks. It is limited by the Necker Ridge to the East, and separated by a deep North-South channel from the Gardner Pinnacles group to the West. Event 1302 took place directly South of the Brooks Bank. The focal mechanism of the event was given by JIMENEZ *et al.* (1989) and DZIEWONSKI *et al.* (1989c). It features nearly horizontal compressional stress release in a direction (293°) within 20° of the direction of absolute motion of the plate (311°) (GRIPP and GORDON, 1989).

The deployment (even on a temporary basis) of a seismic station at Tern Island could help shed light on the origin of Event 1302, by allowing the detection of any possible activity at lower magnitudes.

The other four shocks in this region were small, all with $m_b \leq 5.0$. One of these, Event 1301, is only 2° from the Emperor Seamounts and is located on the 4000 m contour of the Hess Rise. Events 1303 and 1304 are north of Hawaii, with the former occurring in the Musician Seamounts and the latter farther to the east, just north of the Murray Fracture Zone, Event 1305 relocates directly south of Hawaii, east of the Christmas Ridge.

To the east of these events is the Northeast Pacific Basin, a region of smooth bathymetric contours, mostly devoid of significant seamounts and disturbed only by the major fracture zones: Murray, Molokai, Clarion and Clipperton. It is significant that until we reach the line of seismicity at 130°W we do not have any intraplate earthquakes in this region, even though it is close enough to the coast of North America for an $m_b = 5.0$ earthquake to be well detected.

Cocos Plate

There were 22 events of 62 that were listed in bulletins that relocated as reliably intraplate in the Cocos plate (shown in Figure 22). The location capabilities for both Cocos and Nazca events are greater than for many other parts of the Pacific Basin due to the presence of local Central and South American stations, but the added coverage also lowers the magnitude detection threshold, and it is the unreliability of the smaller events that causes this low intraplate percentage.

The Cocos plate is the product of the East Pacific, Farallon and Galapagos Rifts, and is therefore younger to the west and south, but the seismicity is scattered across the plate and does not bear any obvious correlation with age. There is a strong correlation, however, with the location of the Cocos Ridge, the northeast-southwest trending fossil trace of the Galapagos hot spot (Hey, 1977). Eleven events (1351–1361) occur on the ridge, with ten relocating to the middle and one

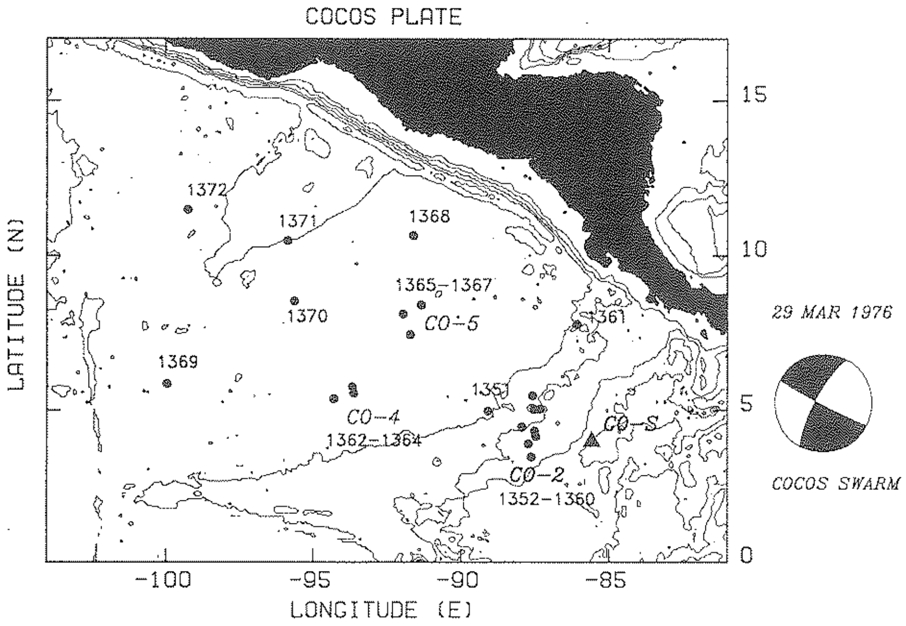


Figure 22
Same as Figure 13 for Cocos plate. The triangle identifies the site of the 1976 East of Cocos swarm. See Table 11.

to the north. In the middle there is a spatial cluster of nine events (Site CO-2) which is temporally spread out between 1928 and 1976, with an isolated event slightly to the west (Site CO-1). They are well separated from Event 1361 which is located further up the ridge at Site CO-3. In addition, there occurred in 1976 a swarm of 28 earthquakes at a location on the east flank of the Cocos Ridge (see Appendix A). The age of the ridge at Site CO-2 is approximately 10 Ma, but there has been rejuvenescent volcanism along the Cocos Ridge (CASTILLO, 1987) so the seismicity in this region may be due either to attempts to isostatically compensate the ridge or to recent magma migrations.

There are two sites to the west of the Cocos Ridge that involve small clusters of events. Site CO-4 consists of three events (1362–1364) that occurred on January 3–5, 1987, and Site CO-5 also contains three events (1365–1367) which took place during 1974–1975. These earthquakes and the five others that are scattered to the west, however, do not suggest any spatial trends and do not correlate with any recognizable bathymetric features.

Nazca Plate

Within the Nazca plate seismicity seems to correlate very well with known bathymetric features, as can be seen in Figure 23. Outside of the very active Galapagos swarms, there are 45 earthquakes that we consider to be reliably intraplate (of the 111 originally listed here), of which fully 90% locate on or near seamounts, islands, or other bathymetric features. The especially strong correlation with extinct ridges is a striking feature of the Nazca seismicity.

The seismic activity at the northern part of the plate is dominated by the Galapagos hot spot. The Galapagos Islands are active volcanically, and there is much seismicity connected with this (see Appendix A). The Carnegie Ridge is the ancient trace of the hot spot, but unlike its symmetrical counterpart, the Cocos Ridge, which is still seismically active, the Carnegie Ridge seems to be quiet. There are three events (1501–1503), however, which lie on its southern flank, and it is uncertain whether or not they are of volcanic origin. Two of these are 0.5° from the islands Floreana and Española, which are certainly of volcanic origin but do not seem to be currently active. It was thought that eruptions occurred on these islands in 1813 and 1958, respectively, but these reports have since been discredited (SIMKIN *et al.*, 1981).

There is one other site of seismicity in the Nazca plate, Site NZ-13 near the Juan Fernandez Islands, that may be associated with volcanic activity. Submarine volcanism occurred in 1835 just north of the main island at (33.62°S, 78.78°W), and possibly in 1839 at (33.62°S, 76.83°W) as well (SIMKIN *et al.*, 1981). There are five earthquakes (1541–1545) that occur at this site, three on the south flank of the islands, about 40 km from the eruption sites, and two further south.

South of the Carnegie Ridge lies the Grijalva Ridge and two bathymetric highs

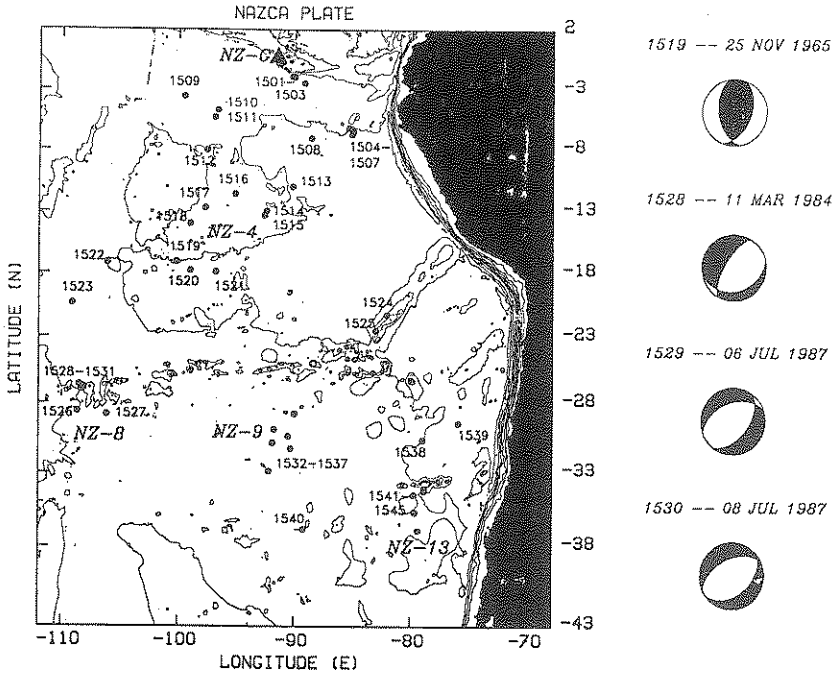


Figure 23
Same as Figure 13 for Nazca plate. The triangle identifies the site of the Galápagos swarm activity, 1968–1998. See Table 12.

that are south of and parallel to it, the southern being the Sarmiento Ridge. These features have complicated histories in which they began as fracture zones between the Pacific and Farallon plates, but became involved with the early spreading between the Cocos and Nazca plates. The Grijalva Ridge seems to have been the southern scarp of the Cocos-Nazca spreading center when it initiated 25 Ma b.p. (HEY, 1977), though the scarps south of that may also have been involved with the spreading. All five of the events occurring here locate on the sharp bathymetric scarp between the Grijalva and Sarmiento Ridges, with 4 (Events 1504–1507) clustering at 85°W and one (1508) further west at 88.6°W.

There is also an association between seismicity and the bathymetric lineament that forms the Quebrada Fracture Zone (Site NZ-3, Events 1509–1511). Of the three events here, one locates just north of the fracture zone and two relocate to its eastern terminus. One other earthquake located on a fracture zone, that being Event 1540 on the Challenger Fracture Zone.

Lithosphere forming the present Nazca plate was involved in the reorientation and jump of the old Farallon Ridge and concurrent break up of the Farallon plate starting in Late Oligocene (HERRON, 1972; MAMMERICKX *et al.*, 1980). As a result, a set of extinct spreading centers, in three distinct segments trending north-south, divide the plate in half. These fossil remnants of the Farallon Ridge are the Galapagos Rise to the north, the Mendoza Rise in the center and the Roggeveen Rise in the southern end of the plate. Though these spreading centers have been extinct for some time, their active seismicity suggests that they constitute zones of tectonic weakness.

Ten events (1512–1521) locate in the region of the Galapagos Rise, as defined by the 400 m isobath. This spreading center was active until 6.5 Ma ago, as described by MAMMERICKX *et al.* (1980), when Pacific-Nazca motion was fully taken up by the East Pacific Rise. This area (Site NZ-4) has several ridge segments that extend from just south of the Quebrada Fracture Zone down to the Mendaña Fracture Zone, and the 10 earthquakes are evenly distributed throughout. This includes Event 1519, quoted by the ISC as having a depth of 143 km but which was relocated to 13 km by MENDIGUREN (1971), who also showed that its mechanism (see Figure 23) is compatible with ridge-push stresses.

The Mendoza Rise is seismically quiet, but the Roggeveen Rise (Site NZ-9) is very active, with six events (1532–1537) clustering on the fossil ridge. The 3500 m isobath defines this feature as having two parallel north-south bathymetric highs, and the earthquakes occur along these prongs, three on a side. Event 1535 on the western prong is tentatively one of the largest events in our dataset ($M_{PAS} = 7.0$).

There is also seismicity connected with the hot spot trace that extends across the plate, the Sala y Gomez Ridge and the Nazca Ridge. There are six events located at Site NZ-8, at the Western end of the Sala y Gomez. Four of these earthquakes are very recent and cluster 1° due east of Easter Island (1528–1531). Though Easter Island is the most recent expression of the hot spot, there has not been any known Holocene volcanic activity there. There are two adjacent events that relocate to site NZ-7 along the 2500 m isobath of the Nazca Ridge, though the rest of the Sala y Gomez Ridge between here and Easter Island is seismically quiet.

In conclusion, the Nazca plate is remarkable in that only 4 events (1522, 1523, 1538, 1539) do not seem to be associated with prominent bathymetric features.

Antarctic Plate

There have been 15 intraplate earthquakes in the region of the Antarctic plate that is part of the Pacific Basin, shown in Figure 24. The seismicity is in two parts, a northern set that is in relatively young lithosphere and a southern segment that is older.

The seismicity of this region is sparse (there were no confirmed earthquakes west of 115°W) and does not match significantly with bathymetric features, though there are two locations of recurrent seismicity. One involves the earthquake of May 9, 1971 ($m_b = 6.2$, studies by FORSYTH (1973)) and its three aftershocks (1702–1705), as well as an older event (1701 on March 12, 1927) at approximately the same site. The recurrence of seismicity at this location is an interesting feature.

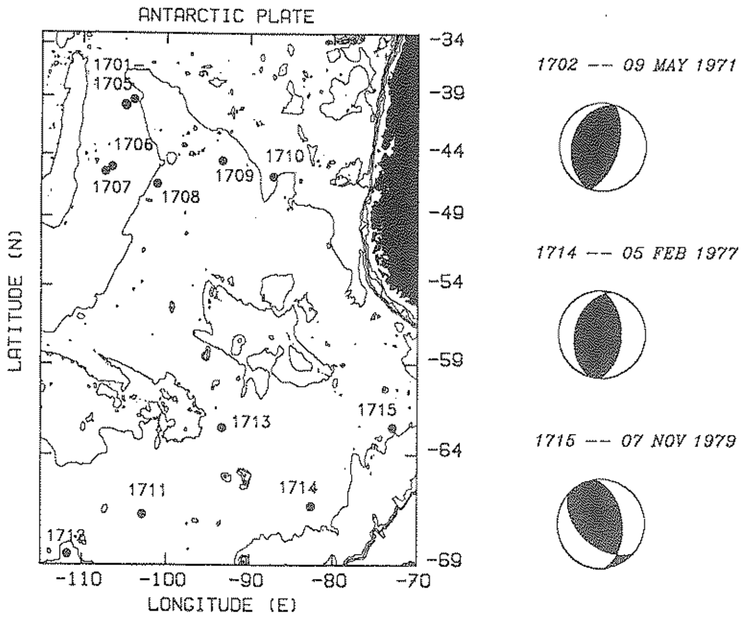


Figure 24
Same as Figure 13 for the Antartic plate. See Table 13.

The second site is situated to the south of the first and consists of two shocks (1706–1707) relocated by OKAL (1981) that occur at nearly the same location in 1956 and 1961. Both of these sites are on very young lithosphere near the Pacific-Antarctic spreading center. The first site is between the 5 and 5a magnetic lineaments, implying an age of 10 Ma, and the second is even younger, with an age of no more than 6 Ma.

The two events (1709–1710) at the eastern side of the northern seismicity both occur on fracture zones of the Chile Rift. Event 1710 relocates to the Guafo Fracture Zone, and the other locates on the unnamed fracture zone directly north of it.

The five earthquakes (1711–1715) that are further to the south form a quasilinear trend and occur in much older lithosphere adjacent to Antarctica—the three western events are in Cretaceous lithosphere. The two events to the east are both within 4° of the South Shetland trench, which is an active subduction zone south of the diffuse plate boundary with the Scotia plate (PELAYO and WIENS, 1989).

7. *Conclusions*

The principal aspects of our study can be summarized as follows:

1. The measurable level of intraplate seismicity of the Pacfic Basin is very low, considering its size, and even less so than previously assumed. Our relocations

have revealed 403 intraplate events (not counting localized swarms), which is only 48% of the amount reported from previously published bulletins.

2. The majority of earthquakes occur as parts of a small number of spatial and temporal swarms. Some of these, like the Galapagos Islands swarms and Hawaiian seismicity, are clearly connected with hot spot volcanism, while others, like the Line Islands swarms, do not have any recognizable tectonic or volcanic origins. Nothing is known at lower magnitudes and the exploration of swarm locations like the Gilbert Islands, Regions A and C, and South of Baja is long overdue.
3. A very large number of earthquakes, 304, relocated to seismically active plate boundaries, in particular the Tonga, Japan and Central American trenches. Errors in the original locations can be rectified through a more careful and critical use of a least-squares linear regression routine. Many events located in Pacific intraplate regions are small, poorly located aftershocks of larger plate boundary earthquakes.
4. The correlations between seismicity and bathymetry in the intraplate regions of the Pacific are inconclusive. In some regions, like the Nazca plate or Eastcentral Pacific, nearly all of the seismicity is highly correlated with identified bathymetric features. These include former plate boundaries (like fracture zones and fossil spreading ridges), seamounts and hot spot traces. In other regions, like Region A, the seismicity does not correlate well with bathymetric features, and often the release of large amounts of seismic energy is not understood in the context of local tectonics.
5. The seismicity also takes the form of distinct lineaments in several regions of the Pacific. Some, such as those along the northeastern flank of the Tuamotus and the three lineations through Micronesia and the Marshall Islands, follow the direction of plate motions. Others, like the spectacular 130°W lineament, neither follow plate motions nor correlate with bathymetry.
6. The high amount of seismicity in the Western Pacific may represent the onset of a relocation of the choking Solomon trench further to the north. There is obviously considerable activity in the eastern part of the region, with the Gilbert Islands seismicity as the biggest contributor and some level of consistent activity in the Phoenix Islands. But in the west the mechanism at the Ralik site is incompatible with the Gilbert Islands mechanisms, and seismicity further west is much more diffuse. A simple linear model for the creation of a new trench is therefore certainly an oversimplification, especially west of 170°E.
7. Maps of global seismicity often show many earthquakes surrounding subduction zones and extending for hundreds of km into the oceanic plate. Most of these events, especially around the Tonga, Japan, Kurils and Aleutian trenches, are mislocated plate boundary events. This suggests that coseismic stresses from trenches are not transmitted into the approaching oceanic plate beyond 2° in a manner that can be released as teleseismic earthquakes.

8. Databases of intraplate events contain many erroneous listings. Most of those are blatant clerical errors that have occurred either by the locating agency or in the transcription to a reporting bulletin, and many involved switched negative signs in the latitudes or longitudes. There are many nuclear tests that are listed, but as they are only a percentage of the full number, the criteria for their identification in published bulletins is unclear.
9. Pacific intraplate events tend to be small, with a paucity having reliable magnitudes of $m_b \geq 6.0$. In regions where there is a good distribution of local stations, like Polynesia and New Zealand, the magnitude detection threshold is lowered and considerably more events are recorded. This detectability is not available for many isolated regions of the Pacific, and the numbers of reliable epicenters there is extremely small. The small magnitudes and large teleseismic distances for these events make the determination of focal mechanisms difficult, and there are surprisingly few available.

Appendix A

Swarms

In addition to events isolated in space and time, considerable seismic activity takes place in the Pacific Basin in the form of swarms. In order to avoid cluttering our datasets, we have removed such events from Tables 1–13. In this appendix, we present a rapid review of the main swarms known in the Pacific Basin. Individual listings of all 838 events involved have been prepared and are available as part of our computerized datasets.

Gilbert Islands, 1981–1984

Probably the most remarkable swarm to take place in the Pacific Basin, the Gilbert Islands activity lasted from December, 1981 to April, 1983, with two isolated events continuing into 1984. A total of 225 earthquakes were detected teleseismically, at a minimum magnitude threshold of $m_b = 3.9$ (see Figure A-1). Two more (Events 764 and 765) were relocated into the swarm from a different bulletin location. In the absence of a local network, nothing is known of the probable activity at lower magnitudes. The major events in the swarm have been studied in detail by LAY and OKAL (1983), and their conclusions have been confirmed by 36 available moment tensor solutions listed in Table 14. Using cluster relocation techniques, SVERDRUP and OKAL (1987) have estimated the spatial extent of the main events in the swarm to be 40 by 30 km. Despite its high b-value, LAY and OKAL have indicated that the swarm is unlikely to have a volcanic origin;

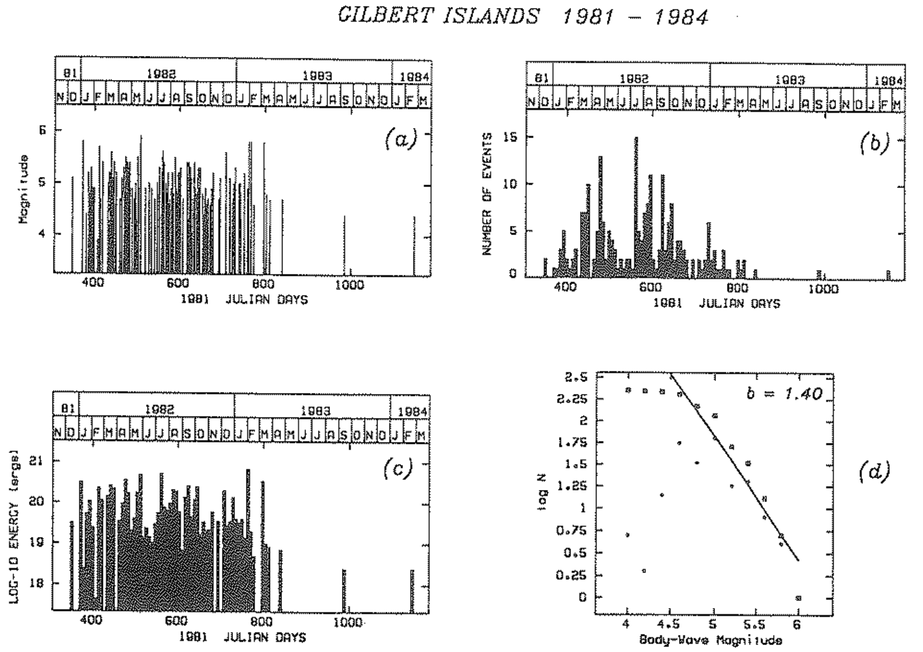


Figure A-1
Gilbert Island swarm, 1981–1984. (a) History of individual events, with magnitude, as a function of time. (b) Histogram of number of earthquakes per 7-day window; (c) Histogram of energy release per 7-day window; (d) Frequency-magnitude analysis: dots are incremental values, squares cumulative ones. The straight line shows a best-fit regression of the cumulative values.

interpretation of the orientation of released stress has been given by OKAL *et al.* (1986), in the general, although at this stage somewhat speculative, framework of the incipient development of a new "Micronesian" subduction zone (KROENKE and WALKER, 1986). The occurrence, in 1921, of an event about 200 km to the North, with a confidence ellipse encompassing the swarm site, suggests a pattern of recurrence of seismicity at the site. It is clear that this location should be earmarked for a small-scale marine geophysical study including OBS deployments.

South of Baja California, 1984–86

As studied in more detail by WIENS and OKAL (1987), this swarm involved 69 teleseismically detected earthquakes ($m_b \geq 3.5$). It started abruptly in September, 1984, culminated with the main shock on December 2 ($M_s = 6.2$), and died off very quickly with sporadic activity until July, 1985, followed by two isolated aftershocks in April and May, 1986. No new activity had been reported at the site as of June 6, 1990. Figure A-2 shows a b-value comparable to world-wide averages. The available focal solutions shown on Figure 23 point out to normal faulting; WIENS

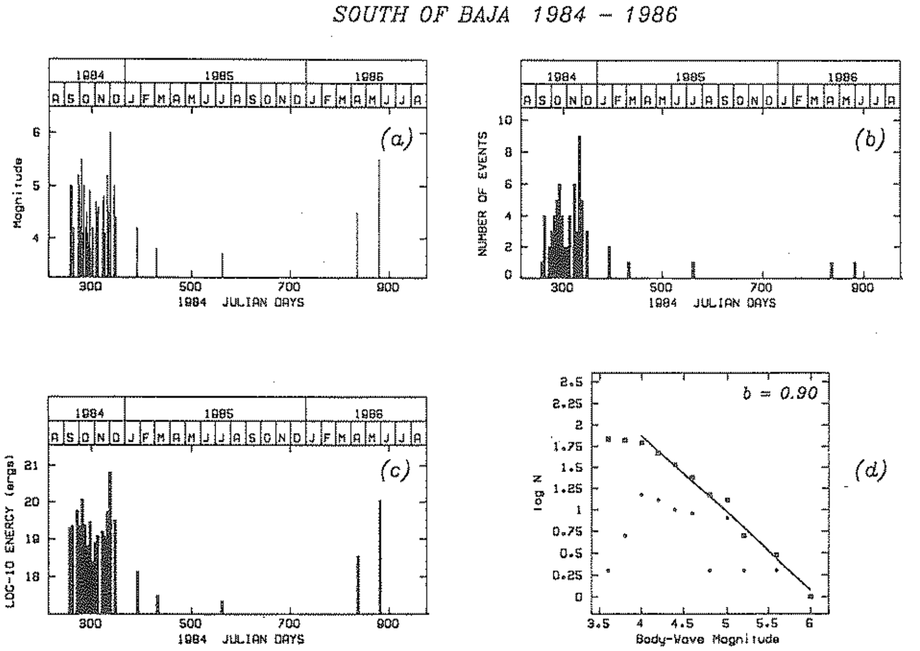


Figure A-2
Same as Figure A-1 for the 1984–86 swarm South of Baja California, studied by Wiens and Okal (1987). Time windows in (b) and (c) are 5 days.

and Okal (1987) have indicated that they are compatible with the release of thermoelastic stresses, as suggested by Turcotte (1974) and Bratt *et al.* (1985), but if so, the question of the spatial concentration of this activity, and of its magnitude, remains unclear.

Galápagos Islands

We discuss here seismic activity in the immediate vicinity of the Galápagos Islands, despite its location within 2° of the Nazca-Cocos spreading center. Its characteristics, evaluated within the framework of documented volcanic activity, shed precious light on the nature of other swarms, notably underwater ones, for which no such evidence is accessible.

Activity in the Galápagos Islands is presented on Figure A-3. About 250 earthquakes ($3.8 \leq m_b \leq 5.4$) were recorded teleseismicaly during the collapse of the Fernandina caldera, in June, 1968. We refer to Filson *et al.* (1973) for a detailed analysis of this seismicity, and of a myriad of events of smaller magnitude detected either by the local station GIE, or by distant high-gain observatories (including Pacific Basin hydrophones). Focal mechanisms are available for the largest event

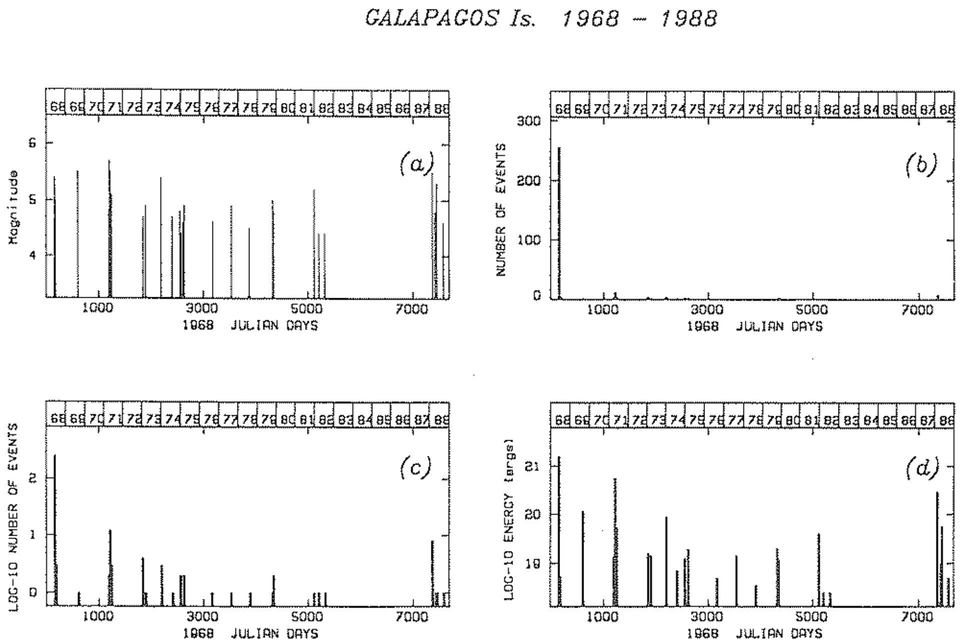

GALAPAGOS Is. 1968 – 1988

Figure A-3
Activity at the Galápagos site, 1968–1988. (a) History of individual events; (b) Histogram of number of earthquakes per 30-day time window; note that the 1968 swarm dominates all activity; (c) Same as (b) plotted on a logarithmic scale; (d) Energy release per 30-day window. A comparison of (c) and (d) illustrates the difference in nature between the 1968 caldera collapse, and the relatively more energetic swarms in the subsequent years.

(June 14, 1968, 22:27 GMT) and KAUFMAN and BURDICK (1980) have shown that at least 20 events of smaller magnitude have exactly similar geometries.

In the present study, we have limited ourselves to a compilation of Galápagos events reported on the NEIC tape (Figure A-4). A frequency-magnitude analysis of our dataset yields a high b-value (1.95) comparable to FILSON *et al.*'s (1973) result for the high-end of their magnitude range ($b = 1.91$).

Additional activity in the Galápagos Islands featured a short-lived swarm of 17 teleseismically detected events in the Spring of 1971, sporadic activity through the 1970s and 1980s, and a burst of 11 teleseismically detected earthquakes in 1988, eight of them on February 24. Of the total 51 events recorded posterior to the 1968 swarm, only the latest earthquake (September 14, 1988) is listed as associated with volcanism. Our b-value investigations of the 1971 and 1988 episodes, as well as of the whole post-1968 activity, yield values typical of world-wide averages (0.97, 1.00 and 1.05, respectively), suggesting that these events were not directly controlled by magmatic processes (Figure A-5). Furthermore, CMT solutions available for two events on February 24, 1988 feature thrust faulting (see Figure A-6), and a larger earthquake on May 20 is predominantly strike-slip on a dipping fault.

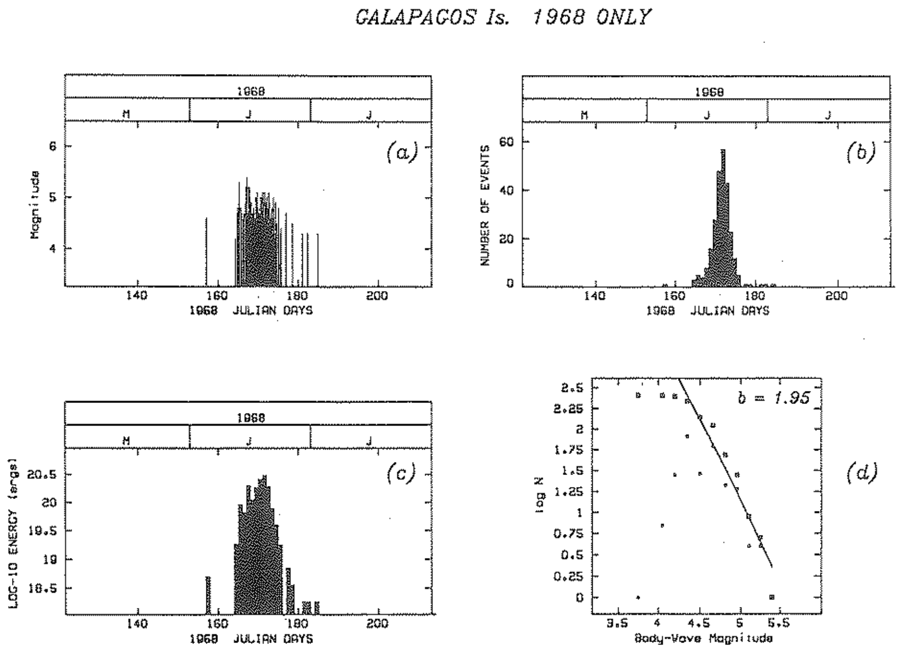


Figure A-4
Same as Figure A-1 for the 1968 swarm during the collapse of Fernandina. Time windows in (b) and (c) are 1 day.

East Flank of Cocos Ridge, 1976

The Eastern Flank of the Cocos Ridge, in the vicinity of 4°N, 87.5°W, was the site of a swarm of 28 teleseismically located events, during a period of 70 days in the first half of 1976. The ISC reprinted a rather long description of the main event (March 29, 1976; 05:39, $m_b = 5.9$; $M_s = 6.5$) by the Smithsonian Institution's Center for Short-lived Phenomena, as representing interplate motion along the Cocos-Nazca boundary. However, it is now clear that the plate boundary in this region runs along the Panama Fracture Zone, about 300 km to the East, and this swarm is actually intraplate.

The history of the activity of the swarm and a frequency-magnitude plot ($b = 0.99$) are shown on Figure A-7. A focal mechanism for the main event is given on Figure 22 (BERGMAN and SOLOMON, 1984; WIENS and STEIN, 1984; WIENS, 1987). It is characterized by strike-slip motion with one of the fault planes striking at an azimuth of 28°, identical to the direction of absolute motion of the plate, 28.6° (GRIPP and GORDON, 1989), which is of course also the trend of the Cocos chain.

The Cocos Ridge has been described as the wake of the Galápagos hotspot on the Cocos plate (HOLDEN and DIETZ, 1972; HEY, 1977). Significant volcanic edifices postdating the formation of the ridge itself have been recognized on its

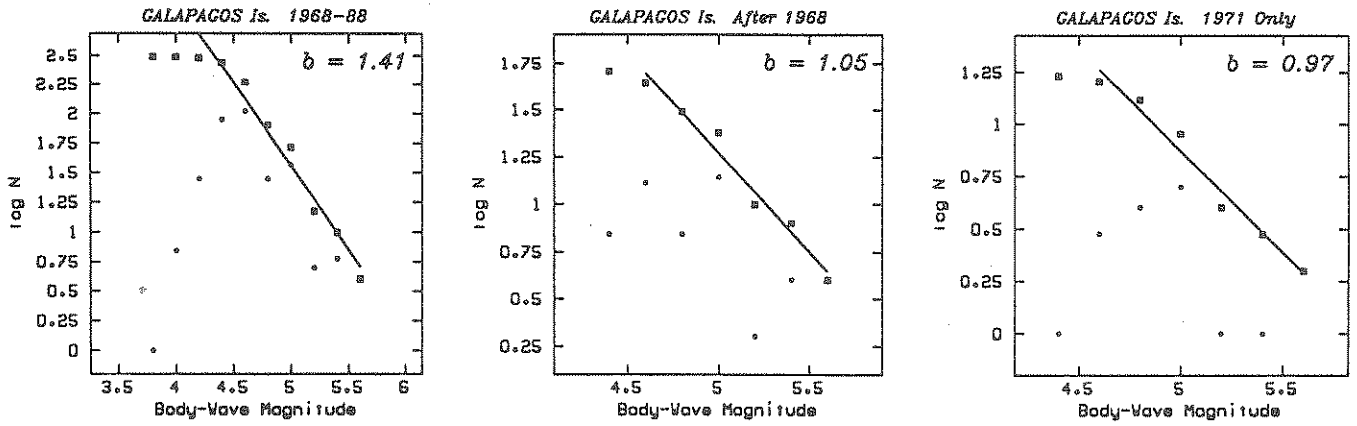


Figure A-5
Frequency-magnitude analyses of Galápagos activity for various time windows: *Left*: Full dataset; *Center*: Since caldera collapse: *Right*: 1971 swarm only.

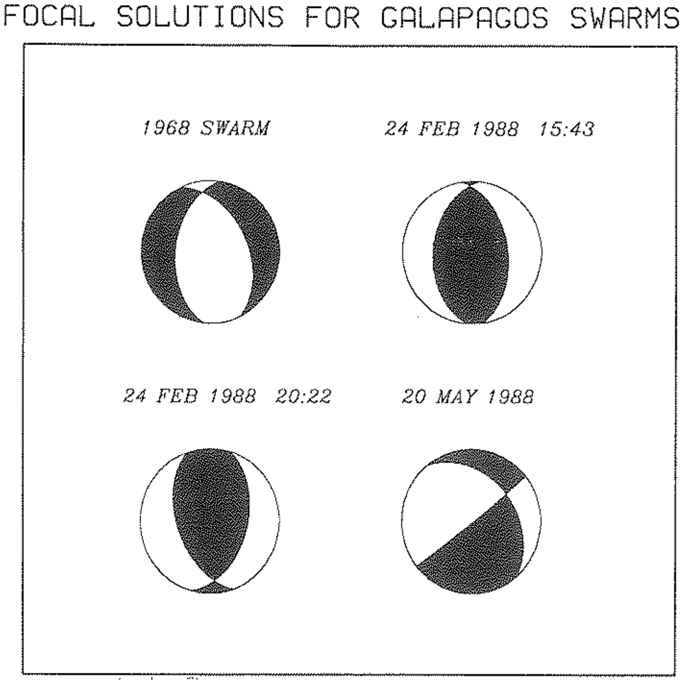


Figure A-6
Focal mechanisms available for Galápagos swarm events. Sources are listed in Table 14. For the 1968 swarm, this mechanism is common to at least 21 events (KAUFMAN and BURDICK, 1980).

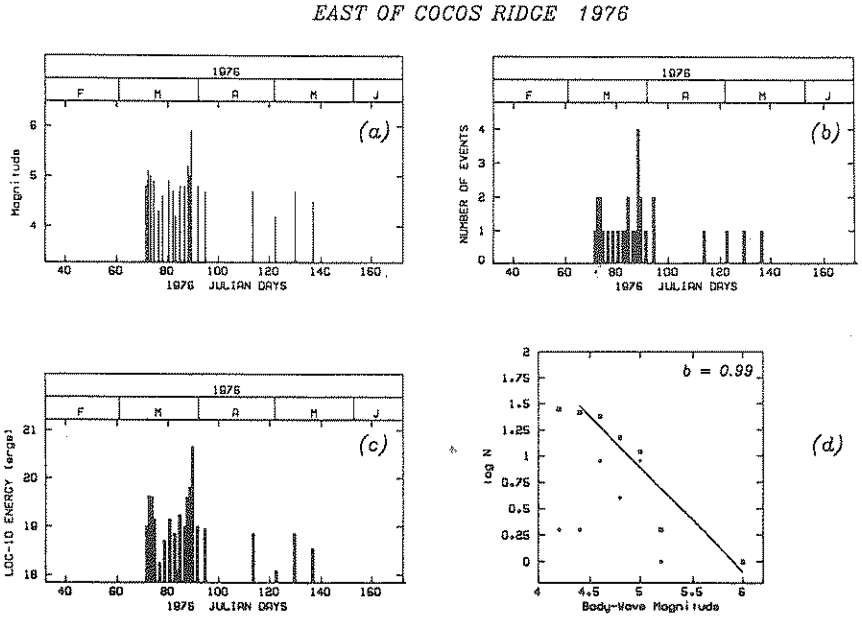


Figure A-7
Same as Figure A-1 for the 1976 swarm East of Cocos. Time windows in (a) and (b) are 1 day.

summit and its flanks, the most prominent being Cocos Island (Castillo, 1987). The site of the 1976 swarm is on the East flank of Cocos Ridge, approximately aligned with Tortuga and West Cocos seamounts. The occurrence of a swarm at this site is suggestive of volcanic activity. However, the strike-slip geometry of the main shock, together with the *b*-value of 0.99, suggest that the seismicity was not directly controlled by active magmatism. It is clear that a more detailed investigation of the site is warranted.

Region A, Line Islands

Okal *et al.* (1980) reported 90 events, 10 of which detected teleseismically, at a location ("Region A") East of the Line Islands, approximately 7.5°S and 148°W (see Figure 12a). A major swarm took place during 1968–70, followed by sporadic energy release continuing until the end of 1976. The site was then quiet for 9 years, until a short burst of new activity took place in 1985 at an epicenter undistinguishable from Region A. Six events were detected teleseismically and 8 more recorded at the French Polynesia array, bringing the total to 104 events at the site since 1968. The history of activity at Region A is presented on Figure A-8.

Jordan and Sverdrup's (1981) cluster relocations showed that the 4 main events were spread over approximately 25 km. Available focal mechanisms (Okal *et al.*, 1980) are all strike-slip, compatible with the release of ridge-push stresses.

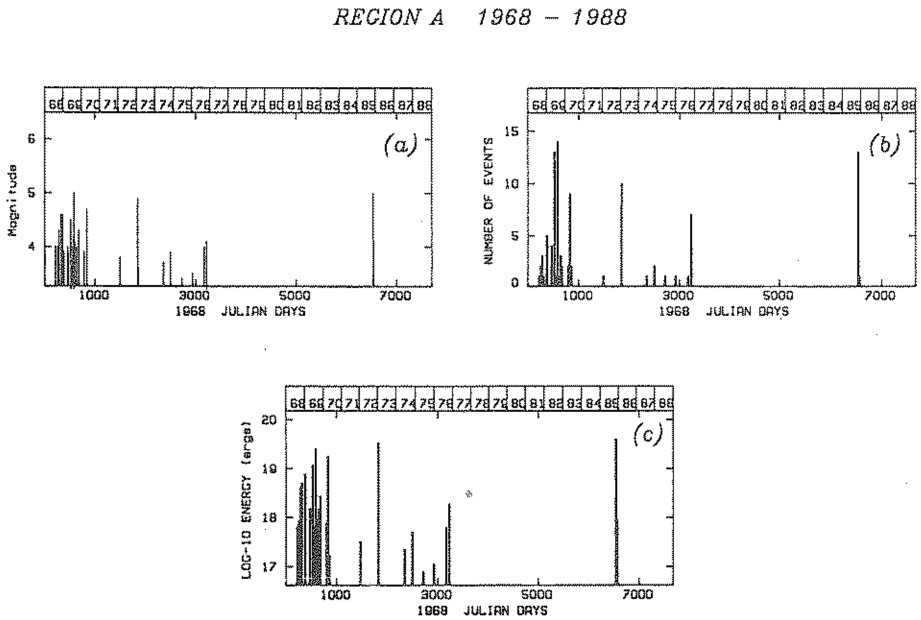


Figure A-8
Same as Figure A-1 (a, b, c) for activity at Region A, Line Islands. Time windows in (b) and (c) are 30 days.

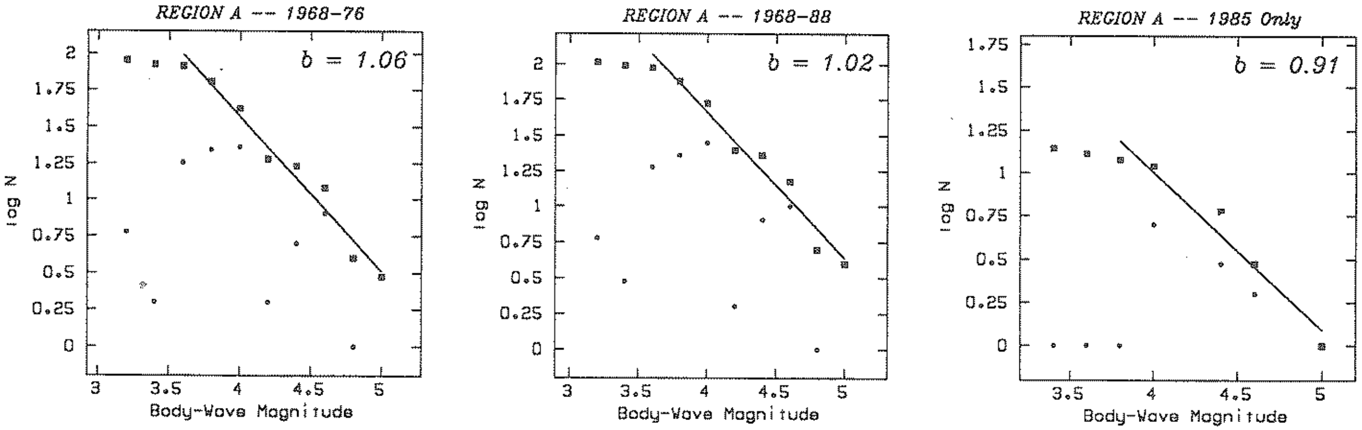


Figure A-9
Frequency-magnitude analyses for three periods of activity at Region A: *Left*: Early swarms (1968–1976); *Center*: Full dataset; *Right*: 1985 only. Symbols as on Figure A-1d.

The new events ($m_b \leq 4.8$) are too small for reliable focal mechanism studies; however, our frequency-magnitude studies revealed no significant change in b-values between the older events and the new swarm in 1985 (Figure A-9). During a 1979 cruise on *R/V Gyre*, no sign of anomalous bathymetry could be recognized at the site (SVERDRUP, 1981), and thus the origin of clustering of activity at Region A remains unclear.

Region C, East of Tuamotu Islands

Another site of particular interest is Region C, located approximately 21°S and 127°W. OKAL *et al.* (1980) documented 97 events ($m_b \leq 5.5$) during a short-lived swarm lasting from August, 1976 to June, 1979. This precise epicenter (GB-5, which JORDAN and SVERDRUP (1981) estimated to be spread over 45 km) has been quiet ever since, but significant activity has taken place at nearby locations. A major event ($m_b = 5.9$; $M_s = 5.3$), followed by a same-day aftershock ($m_b = 5.4$) occurred in 1983 at GB-8, about 75 km North of GB-5; three additional events took place in 1986 at GB-9, 200 km to the Northeast (see Figure A-10).

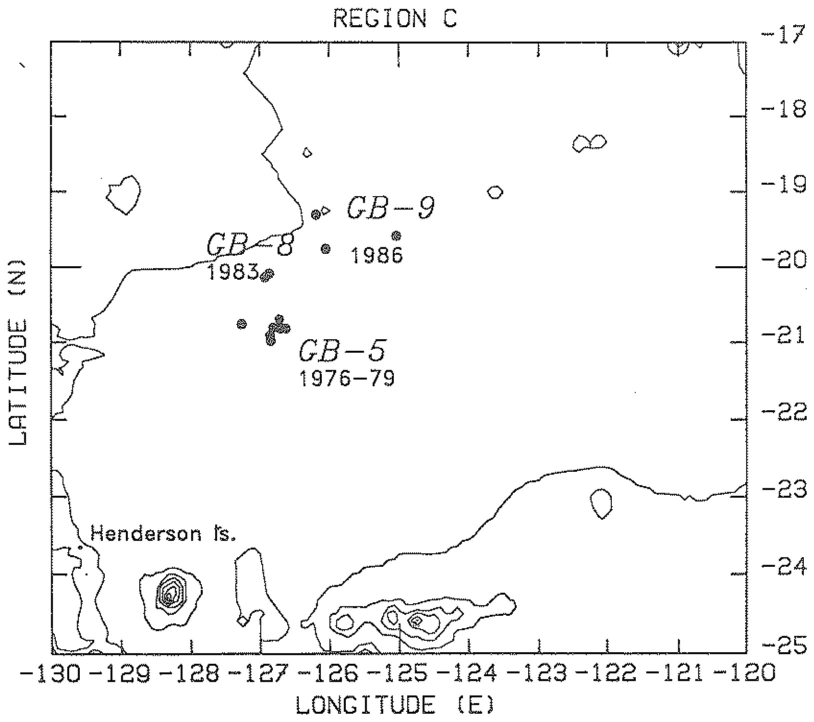


Figure A-10
Map of seismicity in Region C. There were 97 events at GB-5 in 1976–79, 2 at GB-8 in 1983 and 3 at GB-9 in 1986.

OKAL *et al.* (1980) demonstrated that the swarm had an extremely low b-value ($b = 0.55$), and obtained one strike-slip focal mechanism for the July 25, 1978 event at Region C; a CMT solution is now available for a second event (January 5, 1978) which they could only partially constrain (see Figure 12b). Both solutions are compatible with the release of ridge-push stresses. The 1983 mainshock at GB-8 features normal faulting (WIENS, 1985; DZIEWONSKI *et al.*, 1984a). The variety of mechanisms obtained in Region C is illustrative of the variation with depth of the stress regime of a young oceanic plate (BRATT *et al.*, 1985).

The origin of the activity at Region C is unclear. Little is known from *in situ* investigations, except for the presence of distorted topography on the ocean floor (J. FRANCHETEAU, pers. commun., 1980). Using satellite geodesy, OKAL and CAZENAVE (1985) have proposed a speculative model of the areas' evolution during the Miocene, in which Region C would have formed during an episode of ridge propagation of the Old Farallon spreading center, driven by the Easter Island hotspot. A more definite interpretation must await a systematic exploration of the site.

Other Polynesian Swarms

The existence of the high-gain Polynesian Seismic Network (OKAL *et al.*, 1980) has allowed the detection of a number of local swarms in and around Polynesia, the most spectacular of which, involving up to 40,000 detected events in the Tahiti-Mehetia area, resulted from underwater volcanic activity from the Society Island hotspot (TALANDIER and OKAL, 1984a, 1987). In addition, Macdonald Volcano has been the site of intense volcanoseismic activity, whose T waves are recorded routinely in Polynesia (TALANDIER and OKAL, 1982, 1984b, 1987). In keeping with our exclusion of Hawaiian seismicity, we do not list such activity anywhere in our dataset.

Weaker swarms (involving up to 25 recorded events) have been detected at other Polynesian sites, including North of the Society Islands, and in the Austral Islands (OKAL *et al.*, 1980). These events are listed as part of the Polynesian dataset in Table 1, and their location is outlined on Figure 12d.

Appendix B

Description of Individual Regions and Sites

In this Appendix, we provide a detailed account of the results of our relocations, and in particular discuss some of the more difficult cases, in which the differences in original and relocated epicenters are most drastic. We refer to the main text for a discussion of the seismic locations notably in the context of bathymetry.

The discussion is arranged geographically, starting with the 10 Pacific plate regions, followed by the Cocos, Nazca and Antarctic plates. Figures 12–24 plot the genuine intraplate seismicity over the SYNBAPS bathymetry, contoured at 1000 m intervals (2000 m in Micronesia and the Marshall Islands).

Polynesia

We define Polynesia as extending from 30°S to the Equator, between longitudes 161°W and 125°W (see Figure 12). This region is covered by the French Polynesia seismic network, which has been described in various papers (TALANDIER and KUSTER, 1976; OKAL *et al.*, 1980). In addition to the swarms at Regions A and C, the total dataset includes 200 potentially intraplate events.

Intraplate Earthquakes

- In addition to new events described in the main text, only one historical earthquake could be relocated with confidence inside Polynesia: Event 177 (July 17, 1929).

Casualties

- Event 238 (June 21, 1918) could not be relocated. The ISS indicates that it probably occurred in the midst of a local shock off the coast of Southern California. GUTENBERG and RICHTER (1941) similarly commented that the solution was defective.
- Event 237 (September 27, 1973) is listed by Wellington at 16°S and 160°W. Despite the short distance, it was not recorded in Polynesia (J. TALANDIER, pers. commun., 1989). The WEL epicenter listed by the ISC provides a very poor fit to the 4 available times ($\sigma = 7.1$ s). The only way to make the data consistent is to interpret the time at Mangaho (MNG) as S rather than P. This provides an excellent solution at the bottom of the Tonga Benioff plane.
- One event (236 on November 8, 1969; 17:05 GMT), allegedly South of the Marquesas relocates to the Region A swarm, as listed in OKAL *et al.* (1980).
- Two events (239 on April 17, 1927; and 240 on January 12, 1942) are blatant mislocations due to clerical errors.
- Finally, and as discussed in Section 4, we identified 61 events as presumed nuclear explosions (241–301).

Focal Mechanisms

Apart from mechanisms at Regions A and C (see Appendix A), focal solutions for three events at GB-4 were published by OKAL *et al.* (1980). The only new solution is for Event 211 (Location AU-6; November 20, 1979). OKAL (1984) gave a partially constrained thrust faulting mechanism; the newly available CMT solution (DZIEWONSKI *et al.*, 1987b) is in general agreement with it. Focal solutions are regrouped on Figure 12b.

Other Sites in the Southcentral Pacific

We regroup here all seismicity in the Pacific plate South of the Equator, bordered on the West by meridians 125°W to 30°S, 161°W to 43°S, and 170°W further South (Figure 13). OKAL (1984) identified 22 potentially intraplate events in this area. Access to the ISC catalogue, and to WALKER'S (1989) dataset resulted in the recognition of 27 additional, potentially intraplate earthquakes. In addition, three new events (all in 1988) occurred since the completion of OKAL's (1984) study, for a grand total of 52 potentially intraplate events, all of which were re-examined in the present study. Events are described and numbered in a geographical pattern from Northeast to Southwest. Locations codes identified in OKAL (1984) are retained. New locations are given codes starting with SP- (for "Southern Pacific"). In general, our results are similar to OKAL'S (1984), but a number of improvements were possible:

Intraplate Earthquakes

- Apart from 6 events, described in detail below, all Southcentral Pacific intraplate earthquakes in OKAL (1984) are confirmed by the present study, although one of them (Event 420 on September 5, 1938) was moved 120 km to the Northeast while still remaining inside the plate.
- Of the 30 additional events considered, only 10 were confirmed as genuine intraplate: three historical earthquakes (401, 402, 417), four more recent ones (403, 411, 412, 413), and the three 1988 earthquakes (407, 416, 425).

Casualties

- Access to the BCIS listings allowed relocations for the period 1957–1963, when the ISS listings are limited to large earthquakes. As a result, we relocated to the ridge Events 434 (July 26, 1958), 435 (July 30, 1958), and 437 (October 17, 1959; 01:23) for which OKAL (1984) could not perform relocations. Consequently, his sites IP–14 and IP–16 are eliminated.
- Confidence ellipses are computed systematically for all events, including those post-1962 earthquakes supposedly well-located by the USGS or ISC. As a result, we eliminate from the intraplate listings Event 445 (July 31, 1976). Site IP–8 is eliminated.

- Regarding Event 452 (January 13, 1938), and as mentioned by OKAL (1984), arrival times are not listed in the ISS. Access to BCIS data and to a number of seismograms resulted in an inconsistent dataset, precluding convergence to an acceptable solution. Elimination of the times at WEL, where the instrument developed instability, yields an intraplate location (26.7°S, 170.3°W), but the confidence ellipse reaches the trench. Epicenter IP–19 is eliminated.
- Finally, regarding Event 431 (September 17, 1949), we were able to duplicate OKAL'S (1984) solution at IP–13, but a statistical analysis reveals that a ridge location at 63°S and 165°W cannot be excluded. We elect to consider this event as interplate.
- Among the newly identified events, 12 were relocated to the East Pacific or Pacific-Antarctic Ridges (428–430, 433, 436, 438–442, 444 and 446), and three had confidence ellipses intersecting the plate boundary (426, 427 and 443), the latter being described in the main text and on Figure 5.
- Finally, five older events (447–451, dating from 1920 to 1924) had insufficient data to allow stable, if any, relocation.

Focal Mechanisms

OKAL (1984) obtained 5 focal mechanisms in this region. One of them (Event 424 at IP–15) is unconstrained normal faulting. New solutions are available for only two earthquakes: Events 404 and 405 at IP–1. The Harvard solution for Event 404 (DZIEWONSKI *et al.*, 1988b) is a thrust fault violating a strong, impulsive dilatation at NNA. On this basis, we prefer the strike-slip solution given in OKAL (1984).

Campbell Plateau to Kermadec

We define this area as the portion of the Pacific plate South of 27°S and West of 161°W; South of 43°S, the Eastern boundary is moved to 170°W (see Figure 14). As documented for example on WALKER'S (1989) map, this region is rich in potentially intraplate earthquakes. However, because of his coarse gridding of intraplate areas, a very incomplete picture is presented on his map. By combining Walker's dataset with the NEIC tape, and the original ISC regional catalogues, we identified a total of 76 potentially intraplate earthquakes, of which 41 were retained as truly intraplate.

Intraplate Earthquakes

Intraplate events are sorted and discussed by generally increasing latitude. See the main text for geographical discussion; among them:

- Five events (502–506) regroup into three epicenters on the Campbell plateau in the vicinity of its magnetic anomaly. While these are not high-quality location (σ reaching 3 s on 8 stations), their intraplate character is statistically significant.
- OKAL'S (1984) epicenter IP–17 (Event 507 on August 1, 1953) was confirmed at 44.2°S and 175.5°W, in the immediate vicinity of the Chatham Islands. Two additional events (508 on April 9, 1965; and 509 on July 26, 1975) are listed by the ISC in the same general area, along the Chatham Rise, and were confirmed upon relocation.
- In the vicinity of New Zealand, between approximately 45 and 40°S, lies an active seismic zone composed of two major clusters. The northern cluster is quite evident on WALKER'S (1989) map, although approximately 7 of the earthquakes he lists in the region actually qualify as interplate. However, because he limited his analysis to the quadrant East of 180°, and South and 40°S, he totally missed the existence of the second cluster further South, and a significant number of events in the Northern cluster. As a whole, we identified 16 events in the Southern cluster, and 11 in the Northern cluster. An additional event (Number 537 on March 28, 1976) is isolated on the Northeastern flank of the Campbell plateau, about 130 km North of the Northern cluster.

  In general, our relocations easily duplicated the WEL epicenters, but were often inconsistent with the ISC. This is due primarily to our use of S times. The largest magnitude for all these events was $m_b \leq 5.1$, too small to allow any focal mechanism studies.
- In the northeastern quadrant of the area under study, three events (two historical and one recent) relocate in the immediate vicinity of the Louisville Ridge (537 on March 28, 1976; 538 on May 10, 1924; and 539 on August 10, 1926), the latter being moved more than 1500 km from its listed location.
- Finally, we confirm Event 540 (January 4, 1940) at Site IP–20, as defined by OKAL (1984), and a single event (541 on August 1, 1925) relocates to 29.4°S, 164.3°W; the intraplate character of this solution being statistically significant.

Casualties

A total of 23 events were relocated to the Pacific-Australia plate boundary, two of them at significantly deep foci (546 and 547 on May 23 and July 9, 1936), and three others as recently as 1984–85 (561–563). Included are 7 events listed as intraplate by the ISC, but whose relocated epicenter (on the plate boundary, or less than 2° away) is the original WEL solution. Two events (561 and 563) had intraplate PDE listings, and relocated to an ISC interplate solution.

- In the case of Event 575 (June 30, 1985), the ISC solution on the Campbell plateau achieves a residual of only $\sigma = 3.8$ s on 3 P and 2 S times. A similarly mediocre solution ($\sigma = 4.2$ s) is obtained by locating the earthquake on the

Puységur trench, at 49.5°S, 162.3°E. The residual could be further reduced (to 3.9 s) by deepening the focus to 60 km, but it is not clear that seismicity does occur at such depths in the Puységur trench. We list the earthquake as failing to converge (code 12).

- Similarly, for Event 559 (May 27, 1982), the ISC solution on the Campbell plateau fails totally to fit *S* times, resulting in a residual $\sigma = 21$ s for the full dataset. An inversion of *P* times only provides two equally excellent solutions, one at the ISC epicenter, the other on the plate boundary at 49.7°S, 164.0°E; this latter solution also fits 3 of the 4 *S* times, and the listed *S* at OMZ, if interpreted as *P* (this station reports only an alleged *S* time), with a global residual of only $\sigma = 3.4$ s. We regard this solution as better quality than the ISC's, and classify the earthquake as interplate.
- In addition, one event (Number 550 on April 21, 1959) relocated to the Pacific-Antarctic ridge.
- The reported location of Event 576 (October 15, 1957) results from a clerical error; it actually belongs to the Kermadec Benioff zone.
- Finally, six historical events (566–569; 572 and 573, dating from 1923 to 1927), but also two recent ones (570 and 571) had too few data for stable, if any, relocation. The last event (574 on November 29, 1974) fails to converge to a satisfactory, stable epicenter, we believe that some of its readings may actually relate to a Japanese earthquake occurring only 9 minutes earlier.

Focal Mechanisms

Only one focal solution is available in this region: (Event 506, June 3, 1983; $m_b = 5.2$), its CMT mechanism featuring strike-slip (DZIEWONSKI *et al.*, 1983c).

Off Tonga and Samoa

We concentrate here on the area located East of the Tonga trench north of 27°S, and East of 172°W north of 13°S. The Equator and meridian 161°W bound it to the North and East (see Figure 15). We identified 38 potentially intraplate events.

Intraplate Earthquakes

Only 6 earthquakes were kept as truly intraplate; they are arranged from North to South, to the East of the Samoa arc.

- Regarding Event 651 (December 24, 1929), we confirm an interplate location on the basis of five arrival times ($\sigma = 1.90$ s), despite GUTENBERG and RICHTER's (1941) opinion of insufficient data.

- It is worth discussing in detail Event 656 (October 4, 1937). As mentioned in OKAL (1984), a solution cannot be found fitting all arrivals reported in the ISS. While equally mediocre solutions can be found at various depths in the Tonga trench, they all violate the arrival time at Tucson (TUC). We obtained a copy of the TUC seismogram, including time correction information, which weights this station very strongly in the available dataset. The only epicenter compatible with TUC is the retained intraplate solution (IP–18).
- Only one recent earthquake (655 on July 4, 1983) was located in the same general area, 150 km to the North.

No focal mechanisms are available for any of these events.

Casualties

- Twenty-one earthquakes were relocated to the Fiji-Tonga subduction zone, 10 of them at intermediate and deep foci. It is particularly significant that many of these events took place in the 1970s and 1980s. An additional four were listed on the NEC tape as intraplate, but had other listings (mostly ISC) in the subduction zone, three of them intermediate or deep.
- Three events (686 on July 17, 1955; 687 on October 28, 1958; and 688 on July 1, 1961) were relocated to the Vanuatu trench, their alleged location obviously the result of clerical errors.
- Two historical earthquakes (682 and 683), but also Event 684 in 1965, had too few data to allow a significant relocation.
- We could find no data regarding Event 685 in 1905, quoted by WALKER (1989).

Samoa-Phoenix-Gilbert Area

We define this area as the part of the Pacific plate South of 1°N between Longitudes 155°E and 172°W (see Figure 16). We use 1°N rather than the Equator in order to avoid splitting an interesting cluster of seismicity in the vicinity of Ocean Island and the Ralik Fracture Zone. In addition to the 225 events detected teleseismically during the 1981–1984 Gilbert Islands swarm, we identified 62 potentially intraplate earthquakes in this region, only 15 of them were determined to be truly intraplate.

Intraplate Events

- Two 1982 events (764 and 765 on February 17 and May 2, 1982) relocate to the epicenter of the Gilbert Islands swarm during its period of activity (code 6). Similarly, Event 758 (February 10, 1921) originally located at the 1982 swarm epicenter, relocates 250 km to the North, but its confidence ellipse intersects the swarm site. This event suggests that activity at the swarm site may be of a recurring nature. It is remarkable that GUTENBERG and RICHTER (1941) describe this event as "doubtful, but may be correct".

- In the case of Event 751 (April 24, 1937), we confirm the ISC's epicenter at 10.2°S and 176.0°W. The NEIC tape uses Gutenberg's solution (SEISMOLOGICAL SOCIETY OF AMERICA, 1980), at 12°S, 178°W and 200 km depth. This solution is unacceptable since its location is clearly outside the Benioff plane. Indeed, all attempts to locate this earthquake in the Fiji-Tonga subduction zone failed, and moved the epicenter to the North, regardless of starting depth and of whether or not depth was constrained in the relocation process. We confirm OKAL'S (1984) evaluation of this event as intraplate. This represents a rare case when one of B. Gutenberg's personal confident locations (SEISMOLOGICAL SOCIETY OF AMERICA, 1980) is cast in doubt. Two events in the 1950s (752, on June 26, 1956; and 753 on October 3, 1957) were relocated respectively East and West of the 1937 epicenter.
- Relocation of Event 754 (April 30, 1939) does not move it substantially from its listed epicenter on the Ontong-Java plateau. All efforts to associate it with the nearby Solomon trench, which included floating its depth, failed.
- Finally, we confirm an older event (755 on May 15, 1931) in the Tuvalu Basin, and two events (756 on March 5, 1964; and 757 on March 6, 1981) in or around the Phoenix Islands.
- We also incorporate into the catalogue four earthquakes (759–762) detected by the Enewetak and Wake Island arrays in the vicinity of Ocean Island (WALKER, 1989), as well as a teleseismically detected one at the same location (763 on November 11, 1986).

Casualties

- Of the remaining events, 35 were successfully relocated to the trenches, 21 of these relocations involving an intermediate or deep focus. In particular, we found ISC reports of epicenters determined by LASA in the late 1960s and early 1970s most unreliable. These solutions usually violate *S* arrivals, and move to the Fiji-Tonga Benioff zone once hypocentral depth is allowed to float.
- Among the earthquakes relocated deep in the Tonga trench, Event 781 (April 25, 1940) is the only casualty in this region listed (but not relocated) in OKAL (1984).
- Also, Event 776 (September 12, 1935), listed by GUTENBERG and RICHTER (1954) as the only case of erroneous ISS listing inside the Pacific Basin in the period 1931–1935 (a somewhat optimistic statement judging by this study), is relocated to the Tonga Benioff zone, but shallower than, and to the North of, Gutenberg and Richter's solution.
- Event 777 (July 23, 1936), listed on the NEIC tape as intraplate, has an ISC

listing in the Tonga trench, and Event 783 (July 18, 1949) on the Fiji plateau. One recent event, (803 on February 27, 1985) given as intraplate by the USGS, is listed at an intermediate depth in the Solomon trench by the ISC.

- Finally, 9 older earthquakes (804–812, dating from 1918 to 1928) had too few reported times to yield a stable solution.

Focal Mechanisms

Outside of the Gilbert Island swarm, only two events have available focal solutions: Event 757 in the Phoenix Island (DZIEWONSKI *et al.*, 1988b), featuring thrust faulting, and Event 763 (November 11, 1986) at the Ralik site (DZIEWONSKI *et al.*, 1987c), featuring strike-slip. They are shown on Figure 16, together with the mechanisms obtained by LAY and OKAL (1983) for the four main events in the swarm. An additional 32 swarm events have CMT solutions listed in Table 14 (DZIEWONSKI *et al.*, 1983a,b).

Micronesia and Marshall Islands

We define this area as the part of the Pacific plate bounded by Latitude 1°N, Longitude 170°W, and Latitude 30°N, and to the Northeast by a great circle from 30°N, 160°E to 15°N, 175°W. We identified in this area 76 potentially intraplate earthquakes. Epicenters are plotted on Figure 17. Because of the large number of islands and seamounts in this region, and in order to avoid cluttering of the figure, contouring of the bathymetry is only at 2000 m intervals. West of 160°E, the southern boundary is moved to the Equator.

Intraplate Earthquakes

We relocated 15 events and confirmed 5 more as genuine intraplate earthquakes. Among those, Event 914 (March 12, 1974) was felt on Moen (Truk), and Event 902 (April 18, 1981) on Mokil Atoll, halfway between Pohnpei and Kosrae.

- Also, Event 908 (May 16, 1925) is confirmed at a location not significantly different from that listed by the ISS. It is noteworthy that GUTENBERG and RICHTER (1941) list it as "cannot be rejected definitely; to bring it into the active belts would require an [unacceptable] error". In their later edition (GUTENBERG and RICHTER, 1954), they suggest that this earthquake could be in New Guinea, although that location could not match the quality of our solution.
- Finally, we regard Event 876 (September 29, 1926 at 05:16) as probably intraplate. Confidence ellipses with very large noise ($\sigma = 20$ s) do not intersect the trenches. It is probable that its aftershock 27 minutes later (Event 936) is at the

same location but data are insufficient and we could not relocate it. Both were listed as doubtful by Gutenberg and Richter.

- In addition, WALKER (1989) lists 24 events detected at the Enewetak and Wake arrays. Our index pattern follows the broad lineations described in the main text.

Casualties

We relocated 14 events as belonging to the various subductions zones around the Pacific, including New Britain, the Mariana Arc, Japan, the Kurile arc, and even the Aleutian trench near Unimak Island (Event 929 on May 2, 1939).

- Among them, Event 921 (September 19, 1923) was relocated to the Mariana trench, rather than Tonga, as proposed by GUTENBERG and RICHTER (1941).
- Of particular interest are three cases of recent events grossly mislocated by the ISC:

  * The ISC location for Event 931 (May 18, 1974) is poor ($\sigma = 5.2$ s on 6 P waves), and misfits the S time at Lae by more than one minute. See main text for discussion.
  * Regarding Event 932 (January 16, 1976, 15:34), the ISC solution is unsatisfactory ($\sigma = 6.2$ s on 14 P waves). Removal of MAT and CLL leads to an excellent solution ($\sigma = 0.8$ s on 12 times) in the Kurile subduction zone.
  * In the case of Event 933 (February 20, 1976), the ISC location, of poor quality ($\sigma = 5.2$ s on 11 stations), is totally controlled by two stations (Lae and Lamington) in Papua New Guinea. Removal of these stations yields an excellent solution ($\sigma = 0.3$ s on 9 stations) off Hokkaido. The New Guinea times are interpreted as due to local activity; indeed two other events are listed in the area less than 12 hours away from these reports.

- Five older events (934–938, dating from 1918 to 1928) had too few listings to provide a stable relocation. Among them, Event 935 (May 21, 1918) is listed by GUTENBERG and RICHTER (1941) as "may be anywhere in the Pacific area"; we also concur with these authors that Events 937 (May 14, 1923) and 938 (March 3, 1928) have insufficient data.
- Finally, six events were found to have listings clearly resulting from clerical errors (939–944), and seven are nuclear explosions at the Bikini and Enewetak test sites in the 1950s (945–951; see Section 4).

Focal Mechanisms

Only one focal solution is available in this region, a CMT mechanism for Event 885 (March 22, 1982), featuring thrust faulting (DZIEWONSKI *et al.*, 1983a).

Off the Coast of Japan and the Kuriles

We define this region as the part of the Pacific plate North of 30°N and West of 160°E (see Figure 18). It contains 43 potentially intraplate earthquakes.

Intraplate Earthquakes

- Intraplate earthquakes are indexed by order of decreasing latitude. We relocated or confirmed five recent events as intraplate (1001–1005), as well as a single older shock (1006, November 11, 1936).

Casualties

- Event 1043 (the oldest earthquake in our dataset) has no arrival time information, and Event 1042 (August 5, 1931) failed to converge to a stable solution.
- All 34 remaining earthquakes can be relocated to the subduction system. Among the latter, at least 15 are small aftershocks of major events in the Japan-Kurile subduction zone. In many instances, ISC epicenters (of poor quality in the first place) gave extremely poor fit to reported *S* arrivals. Their inclusion in the relocation algorithm, as well as the removal of a few (often a single) reported emergent *P* arrival was enough to bring the epicenter back into the cluster of aftershocks. We believe that the ISC mislocations are in such cases due to a single erroneous *P* arrival time, itself the result of a mispick due to insufficient signal-to-noise ratio in the coda of larger aftershocks.

Focal Mechanisms

Only one event has a published solution: Event 1007 (March 7, 1988), featuring thrust faulting (DZIEWONSKI *et al.*, 1989a).

Northern Boundary

We discuss here the region extending along the Northern border of the Pacific plate, East of 160°E. This area is bounded to the South by Latitudes 40°N West of 135°W, and 30°N East of that line (see Figure 19). We identified 58 potentially intraplate events in this region.

Intraplate Earthquakes

- We relocated five historical earthquakes (1105, 1112, 1113, 1114, and 1116) and two recent ones (1103, January 18, 1976; and 1106, August 14, 1980) as truly intraplate. We further confirmed 13 more from recent catalogues, including Events 1101 and 1102 (April 28, 1968), the Emperor Trough earthquakes studied by STEIN (1979). Earthquakes in this region are arranged by increasing longitude to the Alaskan corner, then by decreasing latitude.

Casualties

- We relocated 29 events to the circum-Pacific subduction zones, among which were two foreshocks (1124 and 1125) and an aftershock (1126) of the great Kamchatka earthquake of February 3, 1923. Our relocation of the main foreshock (Event 1125, February 2, 1923 at 05:07) is consistent with Gutenberg's location (SEISMOLOGICAL SOCIETY OF AMERICA, 1980). It is probable that Event 1152 (February 5, 1923), another aftershock in this sequence, for which too few data were available, is also in the subduction zone.
- Similarly, we relocate to the subduction zone four aftershocks of the great 1965 Rat Island earthquake (1140–1142 and 1144).
- Events 1123 (October 6, 1921), 1128 (August 27, 1927) and 1131 (April 21, 1930) were described by GUTENBERG and RICHTER (1941) as very doubtful. We relocate all three to the Kurile trench.
- We relocate one event (1137, July 15, 1954) to the Queen Charlotte Transform Fault, two to the Blanco Transform Fault (1135 on July 21, 1944, and 1145 on December 28, 1967) and one to the Mendocino Transform Fault (1139 on July 23, 1964).
- In addition, two old events (1154 and 1155, from 1923 and 1927 respectively) failed to converge, two were blatant clerical errors (1156 on July 29, 1958; and 1157 on June 7, 1961), and one event (1158, May 11, 1962) is the underwater nuclear test "SWORDFISH" (see Section 4).

Focal Mechanisms

In addition to STEIN'S (1979) dip-slip focal solution for Event 1101, a CMT mechanism is available for Event 1117 (DZIEWONSKI *et al.*, 1983a), featuring strike-slip.

West and South of Baja California

This region extends from 30°N to the Equator, East of 135°W (see Figure 20). In addition to the 69 earthquakes detected during the 1984 swarm South of Baja California (see Appendix A), we identified another 69 potentially intraplate events in this region.

Intraplate Earthquakes

- We retained 25 confirmed intraplate earthquakes, in addition to the 1984 swarm, in this part of the Pacific Basin. For five of those (1203, 1204, 1214, 1219, and 1223), we use the results of the WIENS and OKAL (1987) study, carried on with similar techniques. Events 1212 and 1218 were described by GUTENBERG and RICHTER (1941) as doubtful, but we confirm their intraplate character with residuals $\sigma < 3$ s.

Casualties

- Most remarkable in this region are 17 blatant mislocations due to clerical errors: 15 belong to the Philippine trench (1252–1266) between 1931 and 1941, one (1267) is in Central Utah in 1957, and another one a small Southern California shock detected only at Pasadena (1268, June 22, 1971).
- We relocated to the East Pacific Rise or the Middle America trench 21 earthquakes; two more (1239, December 12, 1938; and 1247, June 6, 1958) were listed by the NEIC tape as intraplate but had alternate listings in the Central American trench.
- Three older events (1249–1251, dating from 1919 to 1927) had too few reported times to allow a stable relocation.
- Event 1269 (May 14, 1955) is the underwater nuclear test "WIGWAM" (see Section 4).

Focal Mechanisms

Apart from three events during the 1984 swarm, WIENS and OKAL (1987) obtained a solution for Event 1204 (June 30, 1945), featuring normal faulting. No other mechanism is available in this region.

Northcentral Pacific Basin

This region comprises the rest of the Pacific plate, extending roughly from 160°E to 135°W at latitude 40°N, and from 175°W to 135°W at the Equator (see Figure 21). It excludes Hawaii, defined as extending from 17°N to 23°N and 152°W to 162°W. This area has an extremely low level of teleseismically recorded activity, with only 20 potentially intraplate events.

Intraplate Earthquakes

- We relocated or confirmed only five events as intraplate, which we have sorted by increasing longitude. By far the largest ($m_b = 5.5$) and most interesting event in this region is the Tern Island earthquake of September 22, 1988 (Event 1302). Its focal mechanism was given by JIMENEZ *et al.* (1989) and DZIEWONSKI *et al* (1989c). This is the only event known to occur on the Hawaiian ridge away from the active hotspot.

Casualties

- By letting hypocentral depth be unconstrained, we relocated deep into the Tonga Benioff plane Event 1306 (May 14, 1976). In addition, we relocate an older event (1307, October 11, 1928 at 23:32) to the Kurile subduction zone, our solution fitting all but 1 P times. It is probable that a second event (1311) 12 minutes later (and for which too few data were available for stable relocation) also belongs to this system. GUTENBERG and RICHTER (1941) had suggested that these events belong to the Aleutian trench, but no solution of comparable quality could be achieved in that region.
- Six additional events have blatantly wrong locations, presumably due to clerical errors (including Event 1315 on September 21, 1951, actually in the Hindu Kush).
- Similarly, Event 1313 (July 24, 1938) relocates to the Imperial Valley. The correct latitude in the original location, and the simultaneous occurrence of a large swarm in the Imperial Valley at the time, argue that this mislocation was the result of a clerical error.
- We refer to the main text for a detailed discussion of the "ghost" event, Number 1320 (April 9, 1967); its listing is the result of a gross misinterpretation of observations.
- Regarding Event 1312 (March 17, 1976), the ISC solution is of poor quality ($\sigma = 6$ s on 6 stations). Despite the recent date of this event, we were unable to identify more arrivals at high-quality WWSSN stations located in the vicinity of stations having reported arrivals (COL, LPS). We regard the available data as insufficient to provide a stable epicenter.
- In the case of Event 1309 (September 17, 1932), the only report is that it was felt by the *SS Mericos S. Whittier* at location 26.3°N, 148.6°W (NEUMANN, 1934). The isolated character of this location away from plate boundaries would suggest that this shock would have to be intraplate. We report this event as (code 11) "not enough information to allow relocation".
- Two older events (1308 on June 17, 1917 and 1310 on October 1, 1918) had too few data for stable, if any, relocation. GUTENBERG and RICHTER (1941) had particularly harsh comments on the quality of their ISS listings ("No evidence for the indicated epicenter" for Event 1308 and "A badly forced solution" for Event 1310).

Cocos Plate

In addition to the 28 events of the 1976 swarm, we identified a total of 62 potentially intraplate events inside the Cocos plate (see Figure 22).

Intraplate Earthquakes

- We relocated or confirmed 22 events as genuinely intraplate inside the Cocos plate. As discussed in the main text, some earthquakes have a tendency to form distinct clusters; consequently, we have identified sites with a location code starting with CO- for "Cocos".
- Regarding Event 1367 (October 11, 1975), we regard the ISC depth (127 km) as inconsistent with the location of the event removed from a Benioff zone. This depth was probably suggested by the Huancayo report of a later arrival, identified as *pP* by the ISC. While we have recognized a second arrival at Tucson, it is only 13.5 s after *P*, suggesting a depth of about 50 km, if interpreted as *pP*, or 30 km as *sP*. The latter is on the order of the maximum depth of reported intraplate seismicity for oceanic lithosphere of 40–45 Ma age (WIENS and STEIN, 1983). It is worth noting that a number of seamounts are present in the immediate vicinity of CO-5; if the event was associated with magmatic activity, higher strain rates could allow brittle fracture at greater depths. The discrepancy between the two time lags at HUA and TUC argues against a multiple event. Constraining the depth at 30 km, we obtain an excellent solution, with $\sigma < 1$ s. We can only speculate on the origin of the second arrival at HUA, which was not available for inspection.

No focal mechanisms are available for any events in the Cocos plate, excepting the 1976 swarm mainshock (see Appendix A).

Casualties

Thirty-three events had alternate bulletin listings or were relocated to the adjacent plate boundaries.

- The available dataset for January 4, 1918 is extremely confused due to the apparent occurrence of two events within 150 s of each other (1405 and 1406). As a result, no relocation of either event could be performed.
- Similarly, Event 1407 (November 16, 1918) has only three body wave arrivals listed; we list it as "unsufficient data", but it is worth noting that the 3 times converge on the Middle America trench in Southern Mexico).
- An additional historical event (1408, June 7, 1937) could not be relocated in a stable way.
- Regarding event 1409 (December 5, 1966), the ISC solution is poor ($\sigma = 6.7$ s on 7 stations). It is remarkable that the event is followed by a sequence of 4 well located shocks on the Galápagos Ridge. Such a location would fit 5 of the 7 stations with $\sigma = 1.2$ s. We list the event as having nonconverging data, but regard it as most probably interplate.
- In the case of two events (1411, March 28, 1958; and 1412, January 26, 1962), we could not obtain arrival time information.

Nazca Plate

In addition to the events recognized as part of the Galápagos swarms (see Appendix A), a total of 111 potentially intraplate events were identified in the Nazca plate (see Figure 23).

Intraplate Earthquakes

We relocated or confirmed 45 earthquakes inside the Nazca plate, the majority having a tendency to cluster at locations correlating with the main bathymetric features of the plate; we have ordered and numbered the events following decreasing latitudes of these clusters, which have been given codes starting with NZ- (for "Nazca").

- For Event 1505 on Aug 20, 1959, the interesting case arose where the *S* and *P* waves individually yielded similar epicenters but times mutually incompatible. When combined, 14 *S* waves averaged 8.8 s slower than predicted for the epicenter based on *P* arrivals (the median lag was +12.2 s). This unusual result could be the result of poorly selected *S* waves, selection of *sS* instead of *S* arrivals or perhaps even a deviation of the Poisson ratio for the upper mantle from that used in the Jeffreys-Bullen tables. This was the only event from Site NZ-2 containing a significant number of *S* arrivals.

Casualties

- We isolated 14 events for which no sufficient data were available to perform a significant relocation. Among those are six events in February 1917 and September, 1918, listed in the ISS at 26°S and 80°W (1597–1600, 1603 and 1611). It is probable, as repeatedly stated in the ISS, that these epicenters are common. If an intraplate epicenter could be confirmed, it would represent a rather unique spacio-temporal accumulation of intraplate stress release, in view of the numerous reports of Love and Rayleigh waves in Europe which would suggest magnitudes of at least 5 1/2. The 1918 events (1600 and 1611) are probably one and only, this clerical error resulting from the use of a nonstandard time at two Argentinian stations.
- Finally, we relocated 27 events to the South American or Middle American trenches, and 24 to the nearby ridge systems.

Focal Mechanisms

In addition to MENDIGUREN'S (1971) thrust solution for Event 1519, normal faulting CMT solutions are available for the Easter Island events of 1984 and 1987

(1528, 1529, 1530) (DZIEWONSKI *et al.*, 1987c; 1988c) (see Figure 23). Focal Solutions for Galápagos swarm events are given separately on Figure A-6.

Antarctic Plate

We identified 26 potentially intraplate events in the Pacific Ocean part of the Antarctic plate and relocated or confirmed 15 as genuine intraplate earthquakes (see Figure 24).

Intraplate Earthquakes

- As discussed in the main text, we confirm 11 events listed by OKAL (1981) as truly intraplate.
- In addition, we identified two events (1711 on December 5, 1927; and 1710 on April 29, 1975) listed in the ISS/ISC, but not on the NEIC tape, and two new events (1709 and 1712), since the completion of OKAL'S (1981) study in 1980.

Casualties

- Of the events listed by OKAL (1981), we did not consider the August 13, 1937 earthquake since its epicenter (57.4°S, 129.9°W) is less than 2° from the plate boundary. In addition, we confirm that Event 1720 (January 18, 1949) is actually interplate on the Nazca-Antarctica boundary.
- Relocation of Events 1717 and 1718 on December 27, 1926 moved them further inside the Antarctic plate than proposed by OKAL (1981). However, as already noted in that study, these locations are very poorly constrained and confidence ellipses run with 1-σ noise of 10 s (a conservative value in the 1920s) intersect the Menard Transform Fault at 50°S and 115°W. We regard these events as presumably interplate.
- Event 1723 (January 17, 1967) is listed in the ISC catalogue through a single report from LASA; we inspected records from regional high-gain WWSSN stations (SPA, LPB), and could find no trace of the event. In view of the large errors often associated with LASA slowness solutions, we regard this event as unsupported by data.
- As discussed in the main text, the listing for Event 1726 (September 13, 1975) is probably the result of a clerical error.

Focal Mechanisms

In addition to FORSYTH'S (1973) ridge-push mechanism for Event 1702, CMT Solutions are now available for two earthquakes in the Antarctic plate: Event 1714 was studied by OKAL (1980). The new CMT solution is basically identical to his mechanism and confirms the release of horizontal ridge-push (DZIEWONSKI *et al.*, 1988a). A thrust mechanism is available for Event 1715 (DZIEWONSKI *et al.*, 1987b).

Acknowledgments

This work would not have been feasible without the assistance of many scientists and library Staff who provided us with bulletins and seismograms. We are especially grateful to Daniel A. Walker, who gave us a computerized version of WALKER (1989) in advance of publication. Our interest in Pacific seismicity owes a great deal to many years of collaboration and friendship between one of us (EAO) and Jacques Talandier. We especially thank him for the update of the Polynesian dataset. The use of the data facilities at Lamont-Doherty Geological Observatory, Caltech's Seismological Laboratory, the Berkeley Seismographic Station, and Saint Louis University is gratefully acknowledged. Most figures were plotted using software developed by Paul Lundgren and Paul Stoddard. We thank Mark Woods for sifting through the Micronesian newspaper collection at the Hamilton Library of the University of Hawaii. Alice Gripp and Richard Gordon made available their absolute plate motions model before publication. We thank Eric Bergman and Doug Wiens for thoughtful reviews of this voluminous work. This research was supported by JOI, Inc., under Contract Number OCE-84-09478. KLM was the recipient of a Pew Foundation Fellowship at Northwestern University. Additional and Partial funding came from the Office of Naval Research, under contract N00014-89-J-1663, and a Northwestern University Research Grant.

Note added in proof (September 16, 1990)

Since this paper was accepted, we have received confirmation that events 1541 and 1542 were felt at the Juan Fernandez Islands (E. W. Bravo M., pers. comm., 1990). It is also worth mentioning a burst of activity (including a $m_b = 6.1$ event) at the eastern end of Region NZ-8, around 27°S and 104°W (August 21, 22; September 2, 1990).

REFERENCES

AKI, K., and RICHARDS, *Quantitative Seismology* (San Francisco, W. H. Freeman and Co. 1980), 932 pp.

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, *Plate Tectonic Map of the Circum Pacific Region* (Map, Tulsa 1981).

ANONYMOUS, *Announced United States Nuclear Tests, July 1945 through December 1988* (U.S. Dept. of Energy, Office of External Affairs, Publication NVO-209, Washington, D.C. 1989), 64 pp.

BERGMAN, E. A., and SOLOMON, S. C. (1980), *Oceanic Intraplate Earthquakes: Implications for Local and Regional Intraplate Stress*, J. Geophys. Res. *85*, 5389–5410.

BERGMAN, E. A., and SOLOMON, S. C. (1984), *Source Mechanisms of Earthquakes Near Mid-ocean Ridges from Body Waveform Inversion: Implications for the Early Evolution of the Oceanic Lithosphere*, J. Geophys. Res. *89*, 11415–11441.

BRATT, S. R., BERGMAN, E. A., and SOLOMON, S. C. (1985), *Thermoelastic Stress: How Important as a Cause of Earthquakes in the Young Lithosphere?*, J. Geophys. Res. *90*, 10249–10260.

CAPON, J. (1974), *Characterization of Crust and Upper Mantle Structure under LASA as a Random Medium*, Bull. Seismol. Soc. Am. *64*, 235–266.

CASTILLO, P. R., *Geology and Geochemistry of Cocos Island, Costa Rica: Implications for the Evolution of the Aseismic Cocos Ridge*, Ph.D. Thesis (Washington University, St. Louis 1987), 223 pp.

CHAPPLE, W. M., and FORSYTH, D. W. (1979), *Earthquakes and Bending of Plates at Trenches*, J. Geophys. Res. *84*, 6729–6749.

CHASE, C. G. (1971), *Tectonic History of the Fiji Plateau*, Geol. Soc. Am. Bull. *82*, 3087–3110.

CHEN, T., and FORSYTH, D. W. (1978), *A Detailed Study of Two Earthquakes Seaward of the Tonga Trench: Implications for Mechanical Behavior of the Lithosphere*, J. Geophys. Res. *83*, 4995–5003.

CHOUDHURY, M. A., *Observation des ondes de volume ayant traversé le manteau et le noyau*, In *Traîté de Géophysique Interne* (eds. Coulomb, J., and Jobert, J.) (Masson, Paris 1973), pp. 283–320.

DAVEY, F. J., and CHRISTOFFEL, D. A. (1978), *Magnetic Anomalies across Campbell Plateau, New Zealand*, Earth Planet. Sci. Letts. *41*, 14–20.

DUDA, S. J. (1965), *Secular Seismic Energy Release in the Circum-Pacific Belt*, Tectonophysics *2*, 409–452.

DZIEWONSKI, A. M., FRIEDMAN, A., GIARDINI, D., and WOODHOUSE, J. H. (1983a), *Global Seismicity of 1982: Centroid Moment-tensor Solutions for 308 Earthquakes*, Phys. Earth Planet. Inter. *33*, 76–90.

DZIEWONSKI, A. M., FRIEDMAN, A., and WOODHOUSE, J. H. (1983b), *Centroid Moment-tensor Solutions for January-March 1983*, Phys. Earth Planet. Inter. *33*, 71–75.

DZIEWONSKI, A. M., FRANZEN, J. E., and WOODHOUSE, J. H. (1983c), *Centroid Moment-tensor Solutions for April-June 1983*, Phys. Earth Planet. Inter. *33*, 243–249.

DZIEWONSKI, A. M., FRANZEN, J. E., and WOODHOUSE, J. H. (1984a), *Centroid Moment-tensor Solutions for July-September 1983*, Phys. Earth Planet. Inter. *34*, 1–8.

DZIEWONSKI, A. M., FRANZEN, J. E., and WOODHOUSE, J. H. (1984b), *Centroid Moment-tensor Solutions for January-March 1984*, Phys. Earth Planet. Inter. *34*, 209–219.

DZIEWONSKI, A. M., EKSTRÖM, G., FRANZEN, J. E., and WOODHOUSE, J. H. (1987a), *Global Seismicity of 1978; Centroid Moment-tensor Solutions for 512 Earthquakes*, Phys. Earth Planet. Inter. *46*, 316–342.

DZIEWONSKI, A. M., EKSTRÖM, G., FRANZEN, J. E., and WOODHOUSE, J. H. (1987b), *Global Seismicity of 1979; Centroid Moment-tensor Solutions for 524 Earthquakes*, Phys. Earth Planet. Inter. *48*, 18–46.

DZIEWONSKI, A. M., EKSTRÖM, G., WOODHOUSE, J. H., and ZWART, G. (1987c), *Centroid Moment-tensor Solutions for October-December 1986*, Phys. Earth Planet. Inter. *48*, 5–17.

DZIEWONSKI, A. M., EKSTRÖM, G., FRANZEN, J. E., and WOODHOUSE, J. H. (1988a), *Global Seismicity of 1980; Centroid Moment-tensor Solutions for 515 earthquakes*, Phys. Earth Planet. Inter. *50*, 127–154.

DZIEWONSKI, A. M., EKSTRÖM, G., FRANZEN, J. E., and WOODHOUSE, J. H. (1988b), *Global Seismicity of 1981; Centroid Moment-tensor Solutions for 542 Earthquakes*, Phys. Earth Planet. Inter. *50*, 155–182.

DZIEWONSKI, A. M., EKSTRÖM, G., WOODHOUSE, J. H., and ZWART, G. (1988c), *Centroid Moment-tensor Solutions for July-September 1987*, Phys. Earth Planet. Inter. *53*, 1–11.

DZIEWONSKI, A. M., EKSTRÖM, G., WOODHOUSE, J. H., and ZWART, G. (1989a), *Centroid Moment-tensor Solutions for January-March 1988*, Phys. Earth Planet. Inter. *54*, 22–32.

DZIEWONSKI, A. M., EKSTRÖM, G., WOODHOUSE, J. H., and ZWART, G. (1989b), *Centroid Moment-tensor Solutions for April-June 1988*, Phys. Earth Planet. Inter. *54*, 199–209.

DZIEWONSKI, A. M., EKSTRÖM, G., WOODHOUSE, J. H., and ZWART, G. (1989c), *Centroid Moment-tensor Solutions for July-September 1988*, Phys. Earth Planet. Inter. *56*, 165–180.

FILSON, J., SIMKIN, T., and LEU, L.-K. (1973), *Seismicity of a Caldera Collapse: Galápagos Islands, 1968*, J. Geophys. Res. *78*, 8591–8622.

FLEMING, C. A. (1970), *The Mesozoic of New Zealand: Chapters in the History of the Circum-Pacific Mobile Belt*, Quat. J. Geol. Soc. London *125*, 125–170.

FORSYTH, D. W. (1973), *Compressive Stress Between two Mid-oceanic Ridges*, Nature *243*, 78–79.

FORSYTH, D. W., and UYEDA, S. (1975), *On the Relative Importance of the Driving Forces of Plate Motion*, Geophys. J. Roy. astr. Soc., *43*, 163–200.

FUKAO, Y. (1979), *Tsunami Earthquakes and Subduction Processes near Deep-sea Trenches*, J. Geophys. Res. *84*, 2303–2314.

GRIPP, A. E., and GORDON, R. G. (1989), *Current Plate Motions Relative to the Hotspots*, EOS, Trans. Am. Geophys. Un. *70*, 1351 [abstract].

GUTENBERG, B., and RICHTER, C. F. (1941), *Seismicity of the Earth*, Geol. Soc. Am. Spec. Pap. *34*, 1–31.

GUTENBERG, B., and RICHTER, C. F., *Seismicity of the Earth and Associated Phenomena* (Princeton University Press 1954), 2nd ed., 310 pp.

HAMBURGER, M. W., EVERINGHAM, I. B., ISACKS, B. L., and BARAZANGI, M. (1990), *Seismicity and Crustal Structure of the Fiji Platform, Southwest Pacific*, J. Geophys. Res. *95*, 2553–2573.

HAYES, D. E., and EWING, M., *The Louisville Ridge: a possible extension of the Eltanin fracture zone*, In *Antarctic Oceanology* 1, (ed. Reid, J.L.) Antarctic Res. Ser. *15* (Amer. Geophys. Un., Washington, D.C. 1971), pp. 223–228.

HERRON, E. M. (1972), *Sea-floor Spreading and the Cenozoic History of the Eastcentral Pacific*, Geol. Soc. Am. Bull. *83*, 1671–1692.

HEY, R. N. (1977), *Tectonic Evolution of the Cocos-Nazca Spreading Center*, Geol. Soc. Am. Bull. *88*, 1404–1420.

HOLDEN, J. C., and DIETZ, R. S. (1972), *Galápagos Gore, NazCoPac Triple Junction, and Carnegie/Cocos Ridges*, Nature *235*, 266–269.

HOUTZ, R. E. (1975), *South Tasman Basin and Borderlands: A Geophysical Summary*, Init. Repts. Deep Sea Drilling Proj. *29*, 1135–1146.

JIMENEZ, E., CARA, M., ROULAND, D., and OKAL, E. A. (1989), *Fault Plane Solutions from Single-station Surface-wave Data*, EOS, Trans. Am. Geophys. Un. *70*, 397 [abstract].

JORDON, T. H., and SVERDRUP, K. A. (1981), *Teleseismic Location Techniques and their Application to Earthquake Clusters in the Southcentral Pacific*, Bull. Seismol. Soc. Amer. *71*, 1105–1130.

KAUFMAN, K., and BURDICK, L. J. (1980), *The Reproducible Earthquakes of the Galápagos Islands*, Bull. Seismol. Soc. Am. *70*, 1759–1770.

KLEIN, F. W., KOYANAGI, R. Y., NAKATA, J. S., and TANIGAWA, W. R. (1987), The *Seismicity of Kilauea's Magma System*, U.S. Geological Survey Prof. Paper *1350*, 1010–1186.

KLITGORD, K. D., and MAMMERICKX, J. (1982), *Northern East Pacific Rise: Magnetic Anomaly and Bathymetric Framework*, J. Geophys. Res. *87*, 6725–6750.

KROENKE, L. W., and WALKER, D. A. (1986), *Evidence for the Formation of a New Trench in the Western Pacific*, EOS, Trans. Am. Geophys. Un. *67*, 145–146.

LAHR, J. C., PAGE, R. A., STEPHENS, C. D., and CHRISTENSEN, D. H. (1988), *Unusual Earthquakes in the Gulf of Alaska and Fragmentation of the Pacific Plate*, Geophys. Res. Letts. *15*, 1483–1486.

LAY, T., and OKAL, E. A. (1983), *The Gilbert Islands (Republic of Kiribati) Earthquake Swarm of 1981–83*, Phys. Earth Planet. Inter. *33*, 284–303.

MAMMERICKX, J., and KLITGORD, K. D. (1982), *Northern East Pacific Rise: Evolution from 25 m.y.b.p. to the Present*, J. Geophys. Res. *87*, 6751–6759.

MAMMERICKX, J., HERRON, E. M., and DORMAN, L. M. (1980), *Evidence for two Fossil Ridges in the Southeast Pacific*, Geol. Soc. Am. Bull. *91*, 263–271.

MENDIGUREN, J. A. (1971), *Focal Mechanism of a Shock in the Middle of the Nazca Plate*, J. Geophys. Res. *76*, 3861–3879.

MINSTER, J.-B., JORDAN, T. H., MOLNAR, P., and HAINES, E. (1974), *Numerical Modelling of Instantaneous Plate Tectonics*, Geophys. J. Roy. astr. Soc. *36*, 541–576.

MIYAMURA, S., *Some remarks on historical seismograms and the microfilming project*, In *Historical Seismograms and Earthquakes of the World* (eds. Lee, W. H. K., Meyers, H., and Shimazaki, K.) (San Diego, Academic Press 1988), pp. 401–419.

MOLNAR, P. (1988), *Continental Tectonics in the Aftermath of Plate Tectonics*, Nature *335*, 131–137.

MUIRHEAD, K., and ADAMS, R. D. (1986), *Earthquakes in the "Aseismic" Regions of the Western Pacific*, Geophys. Res. Letts. *13*, 169–172.

NEUMAN, F., *United States Earthquakes, 1932* (U.S. Dept. Commerce, Washington, D.C. 1934), 21 pp.

OKAL, E. A. (1980), *The Bellingshausen Sea Earthquake of February 5, 1977: Evidence for Ridge-generated Compression in the Antarctic Plate*, Earth Planet. Sci. Lett. *46*, 306–310.

OKAL, E. A. (1981), *Intraplate Seismicity of Antarctica and Tectonic Implications*, Earth Planet Sci. Lett. *52*, 397–409.

OKAL, E. A. (1983), *Oceanic Intraplate Seismicity*, Annual Rev. Earth Planet. Sci. *11*, 195–214.

OKAL, E. A. (1984), *Intraplate Seismicity of the Southern Part of the Pacific Plate*, J. Geophys. Res. *89*, 10053–10071.

OKAL, E. A., and BERGEAL, J.-M. (1983), *A Model for the Plate Tectonics Evolution of the Eastcentral Pacific Based on SEASAT Investigations*, Earth Planet. Sci. Lets. *72*, 99–116.

OKAL, E. A., and KUSTER, G. (1975), *A Teleseismic Array Study in French Polynesia: Implications for Local and Distant Structures*, Geophys. Res. Lett. *2*, 5–8.

OKAL, E. A., TALANDIER, J., SVERDRUP, K. A., and JORDAN, T. H. (1980), *Seismicity and Tectonic Stress in the Southcentral Pacific*, J. Geophys. Res. *85*, 6479–6495.

OKAL, E. A., WOODS, D. F., and LAY, T (1986), *Intraplate Deformation in the Samoa—Gilbert—Ralik Area: A Prelude to a Change of Plate Boundaries in the Southwest Pacific?*, Tectonophysics *132*, 69–78.

PELAYO, A. M., and WIENS, D. A. (1989), *Seismotectonics and Relative Plate Motions in the Scotia Sea Region*, J. Geophys. Res. *94*, 7293–7320.

RICHARDSON, R. M., SOLOMON, S. C., and SLEEP, N. H. (1979), *Tectonic Stress in the Plates*, Rev. Geophys. Space Phys. *17*, 981–1008.

SBAR, M. L., and SYKES, L. R. (1977), *Seismicity and Lithospheric Stress in New York and Adjoining Areas*, J. Geophys. Res. *82*, 5771–5786.

SEISMOLOGICAL SOCIETY OF AMERICA, *Seismology Microfiche Publications from the Caltech Archives, Ser. II and III* (eds. Goodstein, J. R., Kanamori, H., and Lee, W. H. K.) (Berkeley, 1980).

SIMKIN, T., SIEBERT, L., MCCLELLAND, L., BRIDGE, D., NEWHALL, C., and LATTER, J. H., *Volcanoes of the World* (Stroudsburg, Pennsylvania, H. Ross Publishing Co. 1981), 233 pp.

STEIN, S., (1979), *Intraplate Seismicity on Bathymetric Features: The 1968 Emperor Trough Earthquake*, J. Geophys. Res. *84*, 4763–4768.

STEIN, S., and OKAL, E. A., *Seismological studies of the deformation of oceanic lithosphere*, In *Space Geodesy and Geodynamics* (eds. Anderson, A. J., and Cazenave, A.) (London, Academic Press 1986), pp. 407–450.

STEIN, S., OKAL., E. A., and WIENS, D. A., *Application of modern techniques to analysis of historical earthquakes*, In *Historical Seismograms and Earthquakes of the World* (eds. Lee, W. H. K., Meyers, H., and Shimazaki, H.) (London, Academic Press 1988), pp. 85–104.

STEWART, L. M., and OKAL, E. A. (1983), *Seismicity and Aseismic Slip along the Eltanin Fracture Zone, J. Geophys. Res. 88*, 10495–10507.

STODDARD, P. R. (1987), *A Kinematic Model for the Evolution of the Gorda Plate*, J. Geophys. Res. *92*, 11524–11532.

SVERDRUP, K. A., *Seismotectonic Studies in the Pacific Ocean Basin*, Ph.D. Thesis (University of California, San Diego 1981), 436 pp.

SVERDRUP, K. A., and OKAL, E. A. (1987), *Cluster Relocations of the Gilbert Islands Swarm*, EOS, Trans. Am. Geophys. Un. *68*, 363 [abstract].

SYKES, L. R. (1978), *Intraplate Seismicity, Reactivation of Preexisting Zones of Weakness, Alkaline Magmatism and Other Forms of Tectonism Postdating Continental Fragmentation*, Rev. Geophys. Space Phys. *16*, 621–688.

SYKES, L. R., and SBAR, M. L., *Focal mechanism solutions of intraplate earthquakes and stresses in the lithosphere*, In *Geodynamics of Iceland and the North Atlantic Area* (ed. Kristjansson, L.) (Dordrecht, D. Reidel 1974), pp. 207–224.

TAGGART, J. N., LEE, W. H. K., and MEAGHER, K. L., *The U.S. Geological Survey's databases of seismic events*, In *Historical Seismograms and Earthquakes of the World* (eds. Lee, W. H. K., Meyers, H., and Shimazaki, K.) (London, Academic Press 1988), pp. 142–149.

TALANDIER, J., and KUSTER, G. T. (1976), *Seismicity and Submarine Volcanic Activity in French Polynesia*, J. Geophys. Res. *81*, 936–948.

TALANDIER, J., and OKAL, E. A. (1982), *Crises sismiques au volcan Macdonald (Océan Pacifique Sud)*, C.R. Acad. Sci. Paris, Sér. II. *295*, 195–200.

TALANDIER, J., and OKAL, E. A. (1984a), *The Volcanoseismic Swarms of 1981–1983 in the Tahiti-Mehetia Area, French Polynesia*, J. Geophys. Res. *89*, 11216–11234.

TALANDIER, J., and OKAL, E. A. (1984b), *New Surveys of Macdonald Seamount, Southcentral Pacific, Following Volcanoseismic Activity, 1977–1983*, Geophys. Res. Lett. *11*, 813–816.

TALANDIER, J., and OKAL, E. A. (1987), *Seismic Detection of Underwater Volcanism: The Example of French Polynesia*, Pure Appl. Geophys. *125*, 919–950.

TURCOTTE, D. L. (1974), *Are Transform Faults Thermal Contraction Cracks*?, J. Geophys. Res. *79*, 2573–2577.

WALKER, D. A., and MCCREERY, C. S. (1985), *Significant Unreported Earthquakes in "Aseismic" Regions of the Western Pacific*, Geophys. Res. Letts. *12*, 433–436.

WALKER, D. A. (1989), *Seismicity of the Interiors of Plates and in the Pacific Basin*, EOS, Trans. Am. Geophys. Un. *70*, 1543–1544.

WEISSEL, J. K., and ANDERSON, R. N. (1978), *Is There a Caroline Plate*?, Earth Planet. Sci. Letts. *41*, 143–158.

WIENS, D. A., *Oceanic Intraplate Seismicity: Implications for the Rheology and Tectonics of the Oceanic Lithosphere*, Ph.D. Thesis (Northwestern University, Evanston, Illinois), 220 pp.

WIENS, D. A. (1987), *Effects of Near-source Bathymetry on Teleseismic P Waveforms*, Geophys. Res. Letts. *14*, 761–764.

WIENS, D. A., and OKAL, E. A. (1987), *Tensional Intraplate Seismicity in the Eastcentral Pacific*, Phys. Earth Planet. Inter. *49*, 264–282.

WIENS, D. A., and STEIN, S. (1983), *Age Dependence of Oceanic Intraplate Seismicity and Implications for Lithospheric Evolution*, J. Geophys. Res. *88*, 6455–6458.

WIENS, D. A., and STEIN, S. (1984), *Intraplate Seismicity and Stresses in Young Oceanic Lithosphere*, J. Geophys. Res. *89*, 11442–11464.

(Received February 28, 1990, revised/accepted June 6, 1990)