MW7+ CYCLIC EARTHQUAKES SHARING THE SAME EPICENTRE

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Abstract: A list of earthquakes equal or greater than Mw7.0 that occurred between 1900 and 2012 indicates that for some areas there are precise seismic recurrences. This is the case for the so-called "Ring of Fire", running from the Middle East to Alaska. These are earthquakes with a surface hypocentre that have occurred at the same latitude and longitude, taken to the nearest whole degree. Such seismic recurrences are useful to carry out an analysis on the return times of earthquakes, with the aim of mitigating seismic effects. The mechanism to interpret these recurrences consists of an analysis of fault dynamics. The model proposed takes into account the progressive reduction in the dimensions of the rock fragments found at the heart of a fault. The dislocation of two blocks, in the same epicentre zone, occurs when the friction produced in the damage zone of the fault is lower than the tectonic stresses it is subject to. After a strong seism, disintegration of the rocks begins again and migrates around the hypocentre until, over time, it triggers a new earthquake in the same area. The investigation also included an analysis of potential relationships between seismic events and patterns of solar activity along with particular planetary configurations. For these two investigations the results were respectively, 84% and 68%.

Keywords: *cyclic earthquakes Mw7.0, fault dynamics, solar activity, probabilistic analysis, planetary alignment*

1.0 Introduction

A better understanding of the process that lies at the origin of earthquakes, their cyclicity, and the return times of potentially destructive seisms, are some of the hottest potatoes in Geophysics, and have been animating scientific debate for some years now. Understanding the key to these mechanisms is fundamental to prepare for forthcoming events and mitigate their ruinous effects, given that destructive seisms which have struck in the past can potentially reoccur in the future.

The goal of this research was to propose an interpretative model to mitigate the effects of strong earthquakes that repeat periodically in the same epicentre zone. To do so requires at least two elements: identification of zones affected periodically by strong earthquakes with a magnitude of Mw>7 to estimate the possible return times; an understanding of the relationship between faults and so-called "fossil earthquakes" that are known from the scientific literature, but have not yet been observed in real time.

This study is based on probabilistic considerations, i.e. based on a definition of the probability that a given seismic event will occur within a certain temporal interval, in the same epicentre zone. After the arbitrary time of the occurrence of a strong earthquake, the system returns temporarily to something like its initial condition, then over time it "recharges" to once again release the accumulated energy dissipated by the breaking of rock along the fault.

Analysis of these seismic recurrences and the mechanisms that govern them can be used for probabilistic forecasts and to assess the "return time", i.e. the interval of time that separates two earthquakes of the same magnitude and that occur in the same area, as referred to in well-known examples from the literature (Allegre et al., 1982; Prejean et al., 2003). The temporal scale to predict seisms that is being studied, however, has not given any positive feedback on the regularity of occurrences and the mechanisms that govern seismic cyclicity.

Sorting through the table drawn up by the USGS for seisms of Mw7+, that occurred from 1900 to 2012, in some zones a recurrence can be noted of "twin", "triplet" and even "quadruplet" earthquakes with a magnitude of Mw>7, over the years, on different dates, and with the epicentre situated at the same latitude and longitude, taken to the nearest whole degree. These particular seismic recurrences occur along the Ring of Fire around the Pacific: the arc of the Aleutian Islands, Kuril, the Sea of Japan, Alaska, and in the genetic seismic faults that lacerate Iran and Afghanistan (**Fig. 1**).

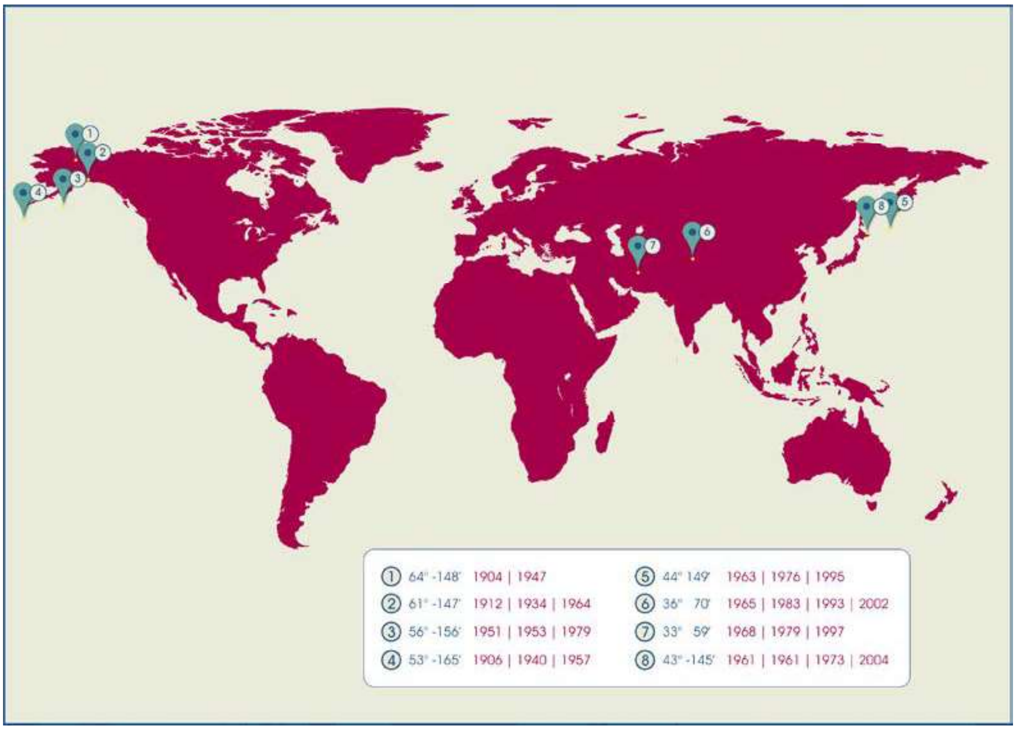

Fig. 1. Index Map. Localisation of the epicentres of recurrent earthquakes with a magnitude of Mw7+ analysed in this study.

These earthquakes, recurring in the same epicentre zone and comparable in magnitude, are particularly suitable for this study. As can be noted in the list of recurrent earthquakes (**Table 1**) the hypocentre is situated more or less at the same depth, and the seismic energy released is virtually the same.

Table 1. Earthquakes with a magnitude of Mw7+ and the same epicentre coordinates, taken to the nearest whole degree.

N	Year	Month	Day	Latitude	Longitude	Depth (km)	Mw
1a	1904	8	27	64	-148	0	7.8
1b	1947	10	16	64	-148	0	7.2
2a	1912	1	31	61	-147	80	7.2
2b	1934	5	4	61	-147	80	7.2
2c	1964	3	28	61	-147	23	8.5
3a	1951	2	13	56	-156	25	7.1
3b	1979	5	20	56	-156	9	7.0
4a	1906	12	23	53	-165	0	7.6
4b	1940	8	22	53	-165	25	7.2
4c	1957	3	22	53	-165	33	7.0
5a	1963	10	13	44	149	60	8.2
5b	1976	1	21	44	149	41	7.0
5c	1995	12	3	44	149	33	7.9
6a	1965	3	14	36	70	260	7.5
6b	1983	12	30	36	70	214	7.2
6c	1993	8	9	36	70	214	7.0
6d	2002	3	3	36	70	225	7.4
7a	1968	8	31	33	59	13	7.3
7b	1979	11	27	33	59	10	7.1
7c	1997	5	10	33	59	10	7.3
8a	1961	8	11	43	143	50	7.0
8b	1961	11	15	43	143	43	7.0
8c	1973	6	17	43	143	48	7.7
8d	2004	11	28	43	143	39	7.0

2.0 Materials and Methods

To carry out this study USGS data were used (www.usgs.gov) on earthquakes with a magnitude equal or greater than M7, plus software (www.celestia.softonic.it) to analyse the positions of the planets on days when the strong earthquakes analysed in this research occurred, along with a specific bibliography to analyse "fossil" seisms detected. The method used to build the Model proposed in this work was a comparison between the data to establish common elements and recurrences relating to the different mechanisms analysed.

3.0 Discussion

3.1 Tectonic implications and fault dynamics
Analysing the table compiled by the USGS (see: http://earthquake.usgs.gov) it can be noted that in the case of these earthquakes, there are no regular frequencies in the rate of "recharging" of the geophysical process between a seism with a magnitude of Mw7+ and successive ones: as a matter of fact, some take decades, others just a few years. The hypocentres of these particular tectonic earthquakes, even though hundreds of kilometres apart and situated in different regional contexts, share surface hypocentres that are located in high energy geodynamic systems.

From a geodynamic point of view, the faults responsible for the seismicity of the earthquakes being studied, are trench-linked strike-slip faults, with crust pressures that converge obliquely. In this geodynamic scenario, in the epicentre zones, slip partitioning occurs between a dip-slip component and a strike-slip one (Lallemant and Oldow, 2000). The focal points of the earthquakes analysed in Iran and Afghanistan are situated in the segments of faults of the strike-slip type, which were also active in the past and triggered strong destructive earthquakes (Berberian et al., 1999; Hollingsworth et al., 2006).

The seismicity of the Ring of Fire around the Pacific, where other epicentre zones from this study are located, is generated as a response to the strain induced by tectonic stress from convective movements of the mantle and, through the use of satellites, it has been possible to identify the activation forces for large earthquakes (Liu et al., 2003).

To interpret the repetitiveness of the phenomenon a concept was chosen that is complementary to the one that associates earthquakes with the breaking load of rocks: i.e., when the tension resulting from an accumulation of mechanical forces exceeds the resistance of the rocky material. In this case, the intensity of the seism would depend on the quantity of energy accumulated at the breaking point which, in turn, would depend on the types of rock involved in the process of accumulating mechanical energy, their braking load, the type of internal strain, and the type of fault.

Instead, the mechanism hypothesized in this study, is that first the rock splits into orthogonal cracks and this is followed by a progressive diminution in the granulometry of the fractured parts in the "damage zone", due to the erosion and "grinding effect" exercised in the fault. When a "critical value" is reached this causes dislocation of the two fault blocks, due to the diminution in friction, with the consequent occurrence of a new earthquake (**Fig. 2**). The mechanism just described is to be found behind many fossil earthquakes (Billi et al, 2003a-b).

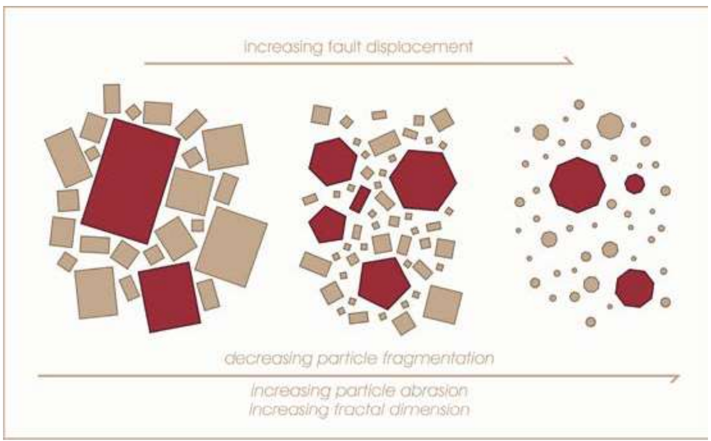

Fig. 2. Diminution, over time, in the granulometry at the heart of the fault due to erosion by the friction from tectonic stress.

Generally speaking, we can distinguish at least two cases: the first concerns seismic zones where earthquakes occur that have a magnitude lower than Mw5.5 and rarely greater than Mw6+, and the second concerns seismic zones that give rise to earthquakes with a magnitude of Mw7+.
In the first case, the stress that acts on the genetic seismic faults proceeds with gradual thrusts, allowing the grains to disintegrate more slowly and steadily, until reaching the critical value for the dislocation of the two blocks. In this case, the dislocation releases an elastic energy lower than that of the large fracture areas, since it is dissipated over time.

Instead, in the second case, the thrust in question is enough to create dislocation even when the granulometry in the damaged area is still coarse and has not yet reached a critical value. In this case, the leap in potential energy is translated into a greater elastic energy. This anticipation of the dislocation, with respect to its natural course, liberates the tensions stored up over time and releases greater seismic energy, due to the greater potential energy accumulated.

Fig. 3 schematizes the component parts of a fault: the heart, the fractured area and the undamaged protolithic block. At the heart of the fault the granulometry is notably reduced because of the friction created over time, which gave rise to earthquakes in the past. With the progressive erosion due to the tensions, the fragments of disintegrated rock at the heart of the fault are normally cemented together as an effect of the repeated dislocations. This cementation creates an impermeable area that constitutes a physical barrier for the diffusion of fluids.

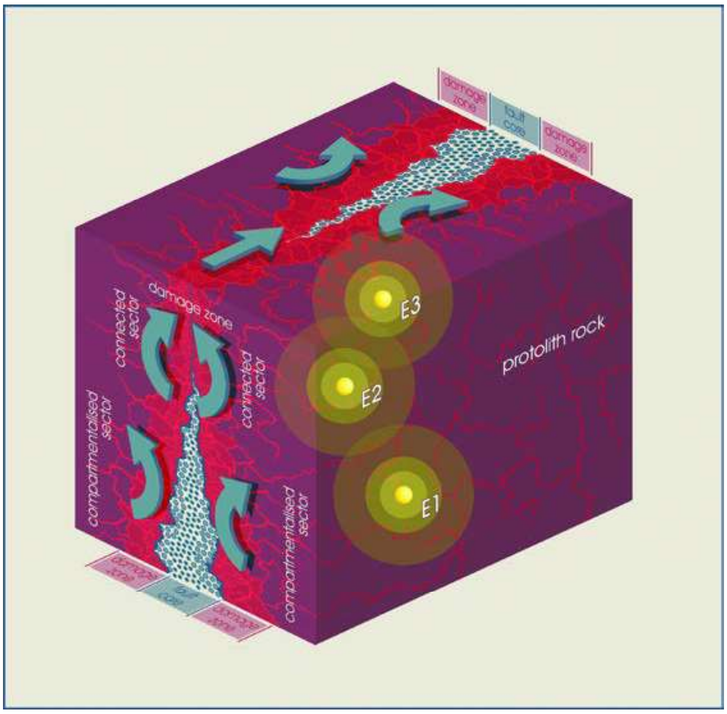

Fig. 3. General illustration of the genetic seismic fault with an indication of the damage zone, the diminution in granulometry exercised by the fault friction, and the consequent distribution of hypocentres (from Billi et al., 2003b, modified and redrawn).

Instead, the damaged part of the fault is criss-crossed by a network of channels generated by the fractures, which allows the circulation of fluids under pressure, in some cases actually accelerating the disintegration of the rock and the consequent occurrence of earthquakes (Byerlee, 1993; Tadokoro et al., 2000; Lachenbruch, 1980; McCaig, 1988). As the heart of the fault gradually spreads over time, a new damage zone is created, consisting of fractures and interstices, where fluids such as water and even hydrocarbons can circulate, in some cases creating rock reservoirs. The migration over time of the heart of the fault and the damage zone in the rocky mass, circumscribed by a determined area, is the consequence of new earthquakes with hypocentres that may be situated in the same epicentre zone, like those considered in this study.

Observing the table (**Tale 1**) it can be noted that, in most cases, the hypocentres have gradually migrated over time at surface depth and, as is well-known, it is near the surface of the crust that destructive earthquakes are generated, i.e. from 7 to 15 km in depth.

3.2 Earthquakes vs. solar activity

The majority of earthquakes with a magnitude greater than M7, considered in this study, occurred in correspondence with solar minimums and maximums (**Table 2**). In 2011, Tavares and Azavedo pointed out that the number of earthquakes at a global scale can be related to solar activity. Recent studies (Choi and Maslov, 2010; Choi, 2014) have highlighted an inverse correlation between catastrophic geodynamic events and patterns of solar activity, above all when referring to the last 100 years. Since solar activity is linked to the irradiation and circulation of the Earth's atmosphere, it can be related to terrestrial climatic variations. And given that solar activity can be correlated to both climatic variations and catastrophic geophysical events, then, through a transitive property, it is possible to associate destructive seismic events with climatic variations.

With regard to this, in 2010 Choi and Maslov wrote: '*Many of the catastrophic earthquakes and volcanic eruptions have occurred during the major solar low or lowering periods – Maunder Minimum (1645-1715), Dalton Minimum (1793-1830), "1900 trough" (1880-1915, new name), and the declining period of the long-term solar cycles, 1990-2013*.'

Similar studies, referring to the last 100 years, have confirmed that a relationship between solar activity and the number of earthquakes at a global scale is conceivable (Choi and Tsunoda, 2011; Han et al. 2004; Mazzarella and Palumbo, 1988).

Table 2. Diagram showing the relationship between the earthquakes studied in relation to patterns of solar activity and planetary configurations.

N	Year	Month	Day	Latitude	Longitude	Depth (km)	Mw	Alignments	Solar Activity
1a	1904	8	27	64	-148	0	7.8	Venus-Mercury-Moon-Earth	Max
1b	1947	10	16	64	-148	0	7.2	Venus-Mercury-Moon-Earth	Max
2a	1912	1	31	61	-147	80	7.2	Venus-Mars-Earth	Min
2b	1934	5	4	61	-147	80	7.2	Sun-Mars-Earth	Min
2c	1964	3	28	61	-147	23	8.5	Sun-Mars-Earth	Min
3a	1951	2	13	56	-156	25	7.1	Venus-Mars-Earth	Max
3b	1979	5	20	56	-156	9	7.0	Venus-Mars-Earth	Max
4a	1906	12	23	53	-165	0	7.6	Venus-Mercury-Earth	Max
4b	1940	8	22	53	-165	25	7.2	Venus-Mercury-Earth-Mars	Max
4c	1957	3	22	53	-165	33	7.0	Venus-Mercury-Earth-Sun	Max
5a	1963	10	13	44	149	60	8.2		Min
5b	1976	1	21	44	149	41	7.0	Venus-Mars-Earth	Min
5c	1995	12	3	44	149	33	7.9	Venus-Mars-Earth	Min
6a	1965	3	14	36	70	260	7.5	Venus- Mars-Earth-Sun	Min
6b	1983	12	30	36	70	214	7.2		Dim
6c	1993	8	9	36	70	214	7.0		Dim
6d	2002	3	3	36	70	225	7.4		Dim
7a	1968	8	31	33	59	13	7.3	Venus-Mercury-Earth	Max
7b	1979	11	27	33	59	10	7.1		Max
7c	1997	5	10	33	59	10	7.3		Asc
8a	1961	8	11	43	143	50	7.0		Max
8b	1961	11	15	43	143	43	7.0	Sun-Mars-Earth	Max
8c	1973	6	17	43	143	48	7.7	Venus-Mercury-Earth	Dim
8d	2004	11	28	43	143	39	7.0	Venus- Mars-Earth	Dim

Analysing the Table (**Table 2**) it can be observed that in the first zone (1904 and 1947) the two seisms occurred near the solar maximums, while in the second case, the earthquakes of 1912, 1934 and 1964, in correspondence with the solar minimum, as in Case no. 5 for the earthquakes of 1963, 1976 and 1995, and also example no. 6 in correspondence with the seisms of 1965, 1983 and 2002, in this zone the exception is that of 1993 which occurred in correspondence with the solar maximum.

The inverse relationship between earthquake frequency and solar activity, as proposed by Choi (2014) and Choi and Maslov (2010) includes a characteristic increase during the solar maximum phase. In this current study, the first five cases considered in **Table 2** reflect the pattern proposed by Choi and Maslov in 2011, while in cases 6, 7 and 8 the pattern is less homogeneous. For the latter, certain considerations may be made:

namely, that the seisms occurred at lower latitudes with respect to the others, and that the main anomalies

were caused by earthquakes that took place between 1990 and 2013, i.e. during the recovery of the activity of the nucleus that may have influenced the trigger dynamics of the earthquakes studied in this work. The hypocentres too, with the exception of case no. 6, were always superficial and in the same zone, in line with the seisms of magnitude M>7 that occurred on a global scale from 1973 to 2010 (Choi and Maslov, 2010). A more likely relationship is with the inversion of the Sun's magnetic field. In this regard, Zolotov et al., (2010) identified a relationship between the pattern of solar cyclicity, the solar wind and particle radiation.

Instead, Han et al. (2004), hypothesized that geomagnetic anomalies induce eddy currents in the fault zones, in reality generating them, from a dynamic point of view. According to Han et al. (2004), in fact, "*big earthquakes occur easily since the eddy current heats the rocks in the faults and therefore decreases the shear resistant intensity and the static friction limit of the rocks*".

In a recent study, Johnson (2014) proposed a model that relates massive solar eruptions with tectonics and the terrestrial dynamic with a vertical component.

Nonetheless, not all the earthquakes analysed in this study show a relationship with solar activity. Of the 25 seisms with a magnitude greater than M7, four occurred in the ascendant and descendant phases of the solar cycle. This suggests that the trigger of the seismic event may also be caused by other factors, not necessarily linked to solar activity.

While waiting for interdisciplinary studies to prove that a relationship does exist between solar activity and earthquakes, for the moment we can at any rate attest that such a relationship is credible in 75% of the cases analysed.

3.3 Earthquakes vs. planetary configurations

By using astronomical software and setting the coordinates of the earthquake epicentre, taken to the whole degree, we arrive at the **Table 2,** which relates planetary configurations to earthquakes. Using the same software, and changing the latitude and longitude of the alignments, even by as little as one degree, it can be seen that the celestial situation appears different. The sets of three and flour earthquakes that struck the same area, on different dates and far apart, show surprising coincidences.

Analysing the eight zones where earthquakes have recurred with the same epicentre and a magnitude greater than M7, we can observe as follows:

Case no.1: Both earthquakes occurred with the alignment Venus-Mercury-Moon-Earth (**Fig. 4)**
Case no.2: The three seisms occurred in correspondence with alignments of Mars-Earth (twice aligned with the Sun and once with Venus).
Case no.3: The earthquakes in this zone, instead, had as alignment Venus-Mars-Earth.
Case no.4: These seisms too, as in the first case, occurred with alignments of Venus-Mercury-Earth, (strengthened in two cases by alignments of the Sun and Mars)
Case no.5: Two of the three earthquakes that occurred in the same epicentre zone occurred in correspondence with alignments of Venus-Mars-Earth.
Case no.6: This same alignment, Venus-Mars-Earth, with the addition of the Sun was to be found for at least one of the three earthquakes studied.
Case no.7: As can be observed, also for this zone there was a recurring alignment of Venus-Mercury-Earth (see cases no. 1 and no.4).
Case no.8: Of the four earthquakes with a magnitude greater than M7, three recurring ones showed alignments, also in this area, of Venus-Earth (two earthquakes out of four).

10 earthquakes occurred in the presence of the alignment between Venus-Mars-Earth (40%), 4 with the alignment Sun-Mars-Earth (16%), and 4 with the alignment Sun-Mars-Earth (16%). Out of the 25 (100%) earthquakes analysed, 14 (56%) had an alignment between Venus and Earth in common.

From an interpretative standpoint, the relationships between the planetary configurations and earthquakes have been illustrated in a vast bibliography. For just one example, it is suffice to cite the study by Kokus (2011) that lists over 200 studies carried out over the last 80 years.

Nonetheless, despite the hypotheses, the trigger mechanism exercised by planetary configurations on earthquakes is not yet clear, which in the case studied accounted for 68%. Also in this case, therefore, it is opportune to consider the relationship (anything but random, as the recurrences demonstrate) as an element of coincidence between the two phenomena.

4.0 Conclusions

It has been concluded that the strong earthquakes analysed in this study recur in zones with high tectonic energy, and the same epicentre. The model put forward, which interprets the seismic recurrence of earthquakes with a magnitude eaqual or greater than M7, takes into account the fault dynamics, processes of progressive fragmentation of the rocks in the heart of the fault, and the migrations of hypocentres in the same epicentre area. These dynamics are provoked by crust tensions subjected to considerable tectonic forces. The possible trigger might be conditioned by solar activity which – for the earthquakes analysed accounts for a good 84%, and by particular planetary configurations which are repeated in 68% of the cases studied. These percentages are high but do not represent 100%, since the causes of the earthquakes are of various kinds.

Therefore, from a probabilistic point of view, it can be concluded that in the zones studied, already struck by earthquakes with a magnitude of M7+, also in the future, we can expect seisms of equal or greater energy, however only a synergic study would be able to bolster this hypothesis.

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Circumstances

Local Time	21:00:00 27 Aug 1904			Latitude	64:00:00 N
GMT	21:00:00 27 Aug 1904	Dawn	None	Longitude	148:00:00 W
Julian Date	2416720.37500	Dusk	None	Height	0 m
Local Sidereal Time	9:30:39	Night Length	0:00	Temperature	20 C
GMT - 0		Epoch	Of Date	Atm Pressure	29.53 in Hg

Ephemerides

	RA	Dec	Altitude	Azimuth	HelLong	HelLat	EaDist	SunDist	Elong	AngSize	VisMag	Phase
Sun	10:24.0	10:00	35:12	163:51	334:07	0:00	1.0099	0	0.0	1900.38	-26.8	100.0
Moon	23:38.6	-2:52	-25:24	324:24	353:58	-0:30	406053	1.0125	-160.2	1765.71	-12.7	89.0
Mercury	11:53.9	-2:56	18:02	142:05	283:47	-5:51	0.80262	0.45296	25.8	8.40	-1.6	38.3
Venus	11:18.1	6:00	28:54	149:08	187:44	3:09	1.6582	0.72065	14.0	10.20	-4.0	97.1
Mars	8:43.6	19:17	44:36	195:41	112:23	1:39	2.4698	1.6232	-26.0	3.79	1.5	98.1
Jupiter	1:54.2	10:08	-0:12	296:01	20:23	-1:17	4.3179	4.9537	-124.0	45.56	-2.7	99.3
Saturn	21:16.9	-17:03	-43:00	4:29	318:11	-1:04	8.918	9.8846	162.2	18.57	0.8	100.0
Uranus	17:42.5	-23:36	-35:20	70:29	268:46	-0:12	18.9	19.298	111.9	3.48	5.6	99.9
Neptune	6:33.0	22:14	39:04	236:31	96:02	-1:01	30.457	29.911	-56.5	2.04	7.9	100.0
Pluto	5:33.4	15:10	26:50	248:26	82:20	-8:12	47.035	46.713	-70.8	0.17	15.7	100.0

Circumstances

Local Time	2:00:00 16 Oct 1947			Latitude	64:00:00 N
GMT	2:00:00 16 Oct 1947	Dawn	14:04	Longitude	148:00:00 W
Julian Date	2432474.58333	Dusk	5:13	Height	0 m
Local Sidereal Time	17:43:01	Night Length	8:51	Temperature	20 C
GMT - 0		Epoch	Of Date	Atm Pressure	29.53 in Hg

Ephemerides

	RA	Dec	Altitude	Azimuth	HelLong	HelLat	EaDist	SunDist	Elong	AngSize	VisMag	Phase
Sun	13:20.8	-8:31	2:54	244:19	21:52	0:00	0.99691	0	0.0	1925.22	-26.8	100.0
Moon	14:49.2	-15:24	3:11	221:40	224:30	0:50	385440	0.99453	22.6	1860.13	-9.2	12.6
Mercury	14:52.9	-19:43	0:35	219:32	308:28	-6:55	0.96646	0.42461	24.9	6.97	-1.8	57.3
Venus	14:04.6	-11:55	3:48	233:03	228:46	1:34	1.6748	0.72399	11.3	10.10	-4.0	98.1
Mars	8:44.8	19:23	0:56	317:45	91:05	1:14	1.536	1.5748	-73.4	6.09	0.5	89.7
Jupiter	15:45.1	-19:10	3:57	207:46	244:44	0:45	6.1228	5.3545	36.5	32.13	-1.8	99.7
Saturn	9:32.8	15:30	1:09	305:40	135:02	0:56	9.5871	9.1511	-61.4	17.27	0.8	99.8
Uranus	5:42.9	23:31	-1:04	0:01	83:24	0:08	18.64	19.094	-115.8	3.53	5.6	99.9
Neptune	12:42.7	-2:59	3:58	255:16	190:38	1:32	31.267	30.289	-11.0	1.99	8.0	100.0
Pluto	9:20.5	22:55	6:42	311:06	133:59	7:05	37.451	37.067	-66.7	0.22	14.7	100.0

Fig. 4. Planetary configuration of the earthquakes of 1904 and 1947, with reference to the exact position of the epicentre of the two seisms.