Δελτίο της Ελληνικής Γεωλογικής Εταιρίας, Τομ. XXXIV/4, 1555-1562, 2001 Bulletin of the Geological Society of Greece, Vol. XXXIV/4, 1555-1562, 2001
Πρακτικά 9ου Διεθνούς Συνεδρίου, Αθήνα, Σεπτέμβριος 2001 Proceedings of the 9th International Congress, Athens, September 2001

THE KONITSA, EPIRUS-NW GREECE, JULY 26 (MS=5.4) AND AUGUST 5, 1996, (MS=5.7) EARTHQUAKES SEQUENCE

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ABSTRACT

On August 5, 1996, at 22:46 GMT (August 6, 01:46 local time), a strong shallow earthquake of M_s=5.7 occurred at the area of Konitsa, Epirus-northwestern Greece. The earthquake caused significant damage in the city of Konitsa as well as the neighbouring villages. In the same area on July 26, at 18:55 GMT (21:55 local time), another strong earthquake of M_s=5.4 had occurred, mainly causing damage at the lower part of Konitsa.

In this study, data from seismological stations located in the broader area of NE Greece and neighbouring countries were used in order to study the spatial and temporal characteristics of this earthquake sequence. Focal mechanisms of the stronger shocks were also plotted. All the observations are combined, in order to obtain a better understanding of the regional tectonics and its seismic activity.

KEY WORDS: earthquake sequence, seismicity, earthquake mechanisms, seismotectonics, Epirus, Western Greece,

1. INTRODUCTION

The Epirus area is located along the northwestern margin of Greek mainland, at the border of the Aegean and Apullian blocks, where collision occurs. Due to the important location that this area has to understand the current deformation of Aegean, the tectonics and seismicity of the area is relatively well studied. However, the historical seismicity of the area is not well known and our knowledge doesn't go very far in the past. The instrumental seismicity (Makropoulos et al. 1989; Papanastassiou et al. 2001) is shown not to be as high as in other nearby areas like the Ionian sea or the Gulf of Corinth. The seismicity in this area is concentrated along the coast, while the mainland of Epirus seems to be free of earthquakes (Fig. 1).

The tectonic framework of the area is mainly compressive, so reverse faulting is observed along the westernmost mainland of Epirus, while extensional tectonics are observed in the interior (Sorel 1989; Underhill 1989; Waters 1993; Hatzfeld et al. 1995; Baker et al. 1997). The transition between compression and extension, however, is not precisely located as microearthquake surveys contacted in the area have shown a wide variety of fault types and orientations which are not consistent with simple zones of shortening or extension (King et al. 1983; Kiratzi et al. 1987; Amorese 1993).

As the events of 26th of July and 6th of August 1996, are the strongest instrumentally recorded earthquakes in this area, it was a great opportunity to study them and drew conclusions for the tectonics and seismicity of the area.

In this work the results of the spatial and temporal distribution of the earthquake sequence are presented, lasted from the beginning of July through the end of December of 1996. Data from seismological stations located in the broader area of western Greece, southern Albania, and FYROM were used. Focal mechanisms of the stronger events were also plotted.

The results suggest that this earthquake sequence can be correlated to the activation of the Konitsa normal fault zone having a SW-NE direction and dipping to the NW.

2. GENERAL GEOLOGIC AND TECTONIC SETTING OF THE AREA

The geology and tectonics of Epirus have been carefully studied by different researchers like Aubouin (1959); the "Institut Greque de Geologie et de Recherches Sous Sol–Institut Francais du Petrole" (1966); BP (1971); Bousquet (1974); Anderson and Jackson (1987); Brooks et al. (1988); Underhill (1989); King et al. (1993).

The main topographic features of the area of Epirus, NW Greece, follow the Pindus mountain chain, having a northwest - southeast strike. Subsequently, the area is characterized by the existence of a series of ridges,

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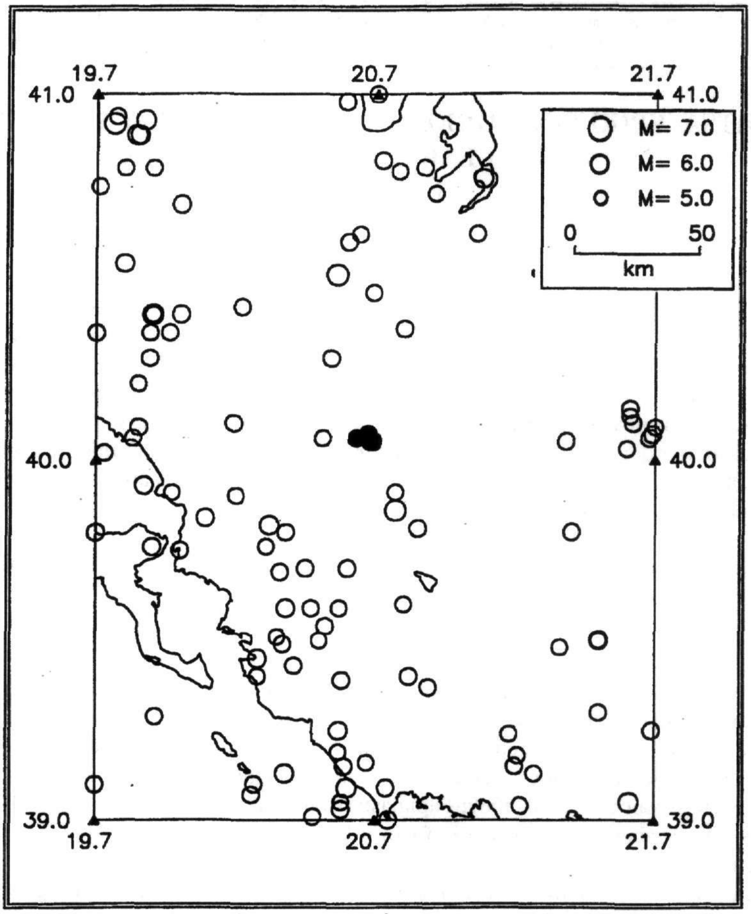

Figure 1. Background seismicity of the broader area of Epirus, for the period 1900-2000. Solid circles represent the epicenters of the strongest events of the studied sequence.

which are composed of Mesozoic carbonates. This structure is the expression of large synclines and anticlines, having a NNW-SSE direction, accompanied with several thrusts, and is the result of extensive compression resulted in the shortening of the area by several tens of Kilometers. Characteristic for the area is the existence of large strike slip faults, almost E-W direction, with horizontal throws of tenths of kilometers (Figure 2).

Moreover, N-S extension is taking place across normal fault zones, with mean E-W direction, which have affected the limestone bedrock with vertical displacement of several hundreds of meters.

One of these normal fault zones is the Konitsa fault group (Doutsos & Koukouvelas 1998). Three faults trending SW-NE, consist this group: the Sarantaporos fault in the northern part, the Konitsa fault in the middle and the Aristi fault in the southern part. These faults are the southern bounds of three homonymous asymmetric grabens. Konitsa fault is the biggest of all three having a length of almost 15km, a direction of N55° and a dip to the NW. The southern last 3km are turning at a N15° direction. In the central part vertical displacement of almost 1000m could be measured.

3. THE EARTHQUAKE SEQUENCE

The strong Konitsa earthquakes of July 26, August 6, 1996 and the resulted aftershock sequence occurred in a mountainous area very close to Albania, as the borders are at a distance of 5 to 10Km. Although these shocks are the strongest in this area and their study is of great importance, the deployment of a seismic array was very difficult till impossible. In order to study these events, seismological data from Greek and Albanian stations as well from FYROM, covering the period of the last 6 months of 1996, were used. The events were located using

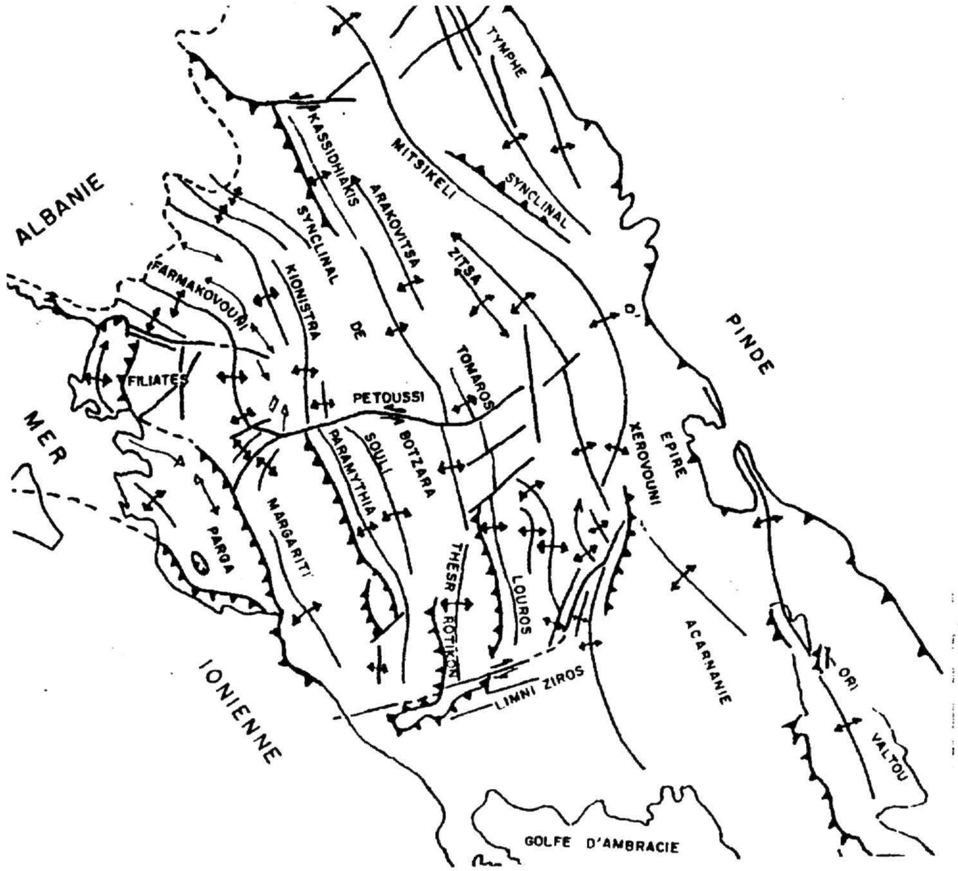

Figure 2. Tectonic sketch map of Epirus region (from Boussquet 1976). Circle includes the area of the Konitsa normal fault.

a velocity model based on previous local seismological studies (King et al. 1983; Kiratzi et al. 1986; Amorese 1993) which has as follows: {layer width (km)/ Vp (km/sec)}: 0 - 4 / 5.0, 4 - 10 / 5.5, 10 - 20 / 6.0, 20 - 30 / 6.8 and > 35 / 8.0. For the Vp/Vs ratio the value 1.75 was used. The events were located by applying the HYPOELLIPSE computer program (Lahr 1996).

183 events, of Ml ³ 2.5, were located at depths shallower than 15km and are plotted in figure 2. The source parameters of these events are listed in the Appendix. The seismic activity was intense during the period end of July – beginning of September. From different International centers, Harvard provided a CMT solution only for the event of July 26. So in order to determine the focal mechanisms of the strongest of these events, polarities of P-waves provided by the International Seismological Centre were used. The solutions of 3 well-constrained mechanisms are determined showing normal faulting. These are presented in Table 1 and are plotted in Figure 3. In Table 1 the Harvard solution for the event of July 26 is also given, indicating that our solution is in good accordance with that one.

Moreover a cross-section perpendicular to the fault trace was drawn (Fig. 4), as well as time-spatial distribution plots at directions along and perpendicular to the Konitsa fault (Fig. 5).

TABLE 1

No	DATE	ORIGIN TIME	LAT N°	LON E°	DPT Km	MAG Ms	PLANE 1 AZM	PLANE 1 DIP	PLANE 1 RAKE	PLANE 2 AZM	PLANE 2 DIP	PLANE 2 RAKE
1	1996 JUL 26	18:55	40.03	20.63	9.3	5.4	247	46	-85	59	44	-95
2	1996 AUG 5	22:46	40.08	20.67	8.0	5.7	202	61	-78	358	31	-110
3	1996 AUG 20	01:26	40.11	20.70	8.7	5.3	251	58	-86	64	32	-96
Harvard solution for the event no 1												
	1996 JUL 26	18:55	39.92	20.77	15.0	5.3(Mw)	225	36	-79	32	54	-98

4. CONCLUTIONS

In this study, from the spatial distribution of well located earthquakes occurred in the area of Konitsa, NW Greece, in the time period of the last 6 months of 1996, the determined focal mechanism of some of the strongest events and the local seismotectonic characteristics of the area, it is concluded that this sequence was caused by the reactivation of a normal fault, having direction N 55° and dipping to the NW, which is in accordance with the characteristics of the Konitsa fault.

Concerning the relation of the spatial distribution of the aftershocks with the morphological surface traces of the faults of the area, the shocks are located on the hanging wall of the Konitsa fault, north of the fault trace.

A cross section perpendicular to the fault trace was also drawn (Fig. 4). In this some interesting points of the aftershock's distribution in depth could be seen. The majority of the aftershocks are located in the depth range of 2 to 10km. This observation is in accordance with previous studies, which have shown that the seismogenic layer has a width of 15km. The aftershocks could be located north of a fault dipping to the NW with a dip of about 55°-60° near the surface, which decreases, 45°-55° at depth. The seismic activity started at the greater depths at about 10Km, earthquake of 26[th] of July, afterwards it expanded at shallower depths, 8km. The late aftershock on November 14 had a depth of only 5km.

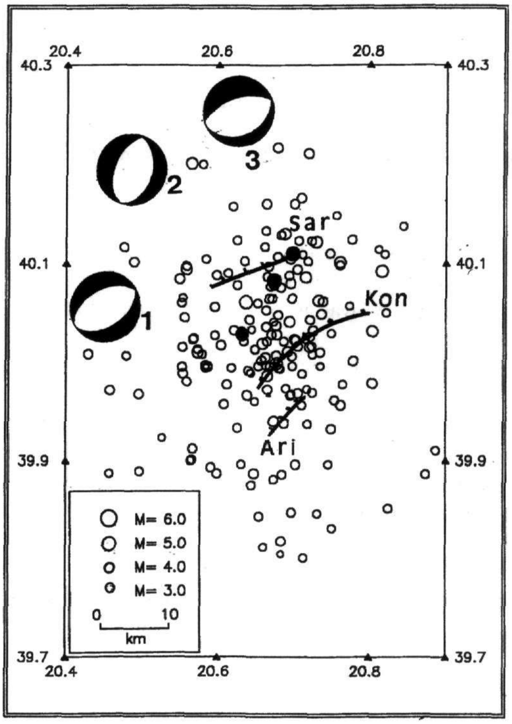

Figure 3. Map view of the well-located earthquakes. The main faults are also shown, Sar for Sarantaporos, Kon for Konitsa and Ari for the Aristi faults after Doutsos and Koukouvelas (1998), as well as the determined fault plane solutions. Their focal parameters are given in Table 1.

The time - spatial distribution plots, at directions NE-SW, along the Konitsa fault trace and NW-SE perpendicular to it (Fig. 5), show that the foreshock of the 26th of July, followed by an intense activity which moved to the NE, where the epicentre of the strong event of 5th of August occurred. After this event it expanded and lasted as intense for a month. A late aftershock, November 14th, occurred after a quiet period of 2 months.

Moreover the fault plane solutions of the most important events show normal faulting with characteristics compatible with the local tectonics.

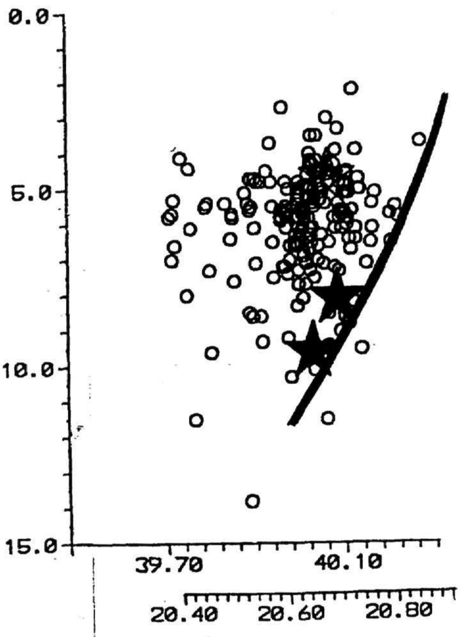

*Figure 4: **Cross section perpendicular to the fault zone.***

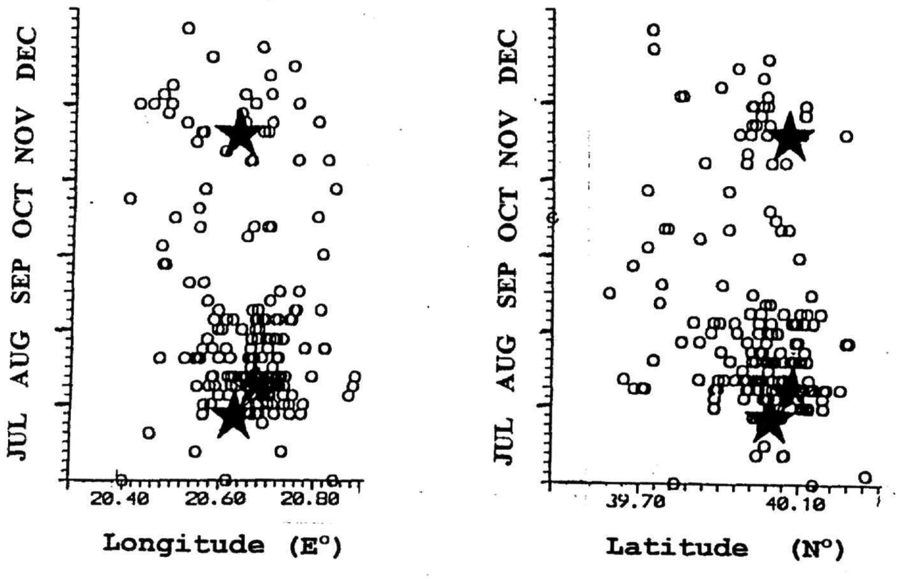

Figure 5: Spatial distribution versus time of the earthquake sequence

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APENDIX

DATE	ORIGIN TIME GMT			LAT N	LON E	DPT Km	MAG Ml
1996 JUL 1	22	08	13.4	40.137	20.844	9.5	2.6
1996 JUL 3	12	27	23.7	40.268	20.379	3.7	3.0
1996 JUL 10	04	51	49.4	40.063	20.733	9.5	3.9
1996 JUL 10	08	12	27.3	40.065	20.553	9.4	2.5
1996 JUL 24	10	03	39.0	40.011	20.692	5.7	3.3
1996 JUL 26	18	55	50.6	40.028	20.632	9.5	4.6
1996 JUL 26	19	27	31.6	40.023	20.716	4.2	2.5
1996 JUL 27	01	16	58.3	40.021	20.634	4.0	3.0
1996 JUL 27	14	12	4.1	40.037	20.677	4.2	3.3
1996 JUL 27	14	51	19.6	40.023	20.567	7.3	3.0
1996 JUL 27	20	29	28.2	39.993	20.683	5.0	2.5
1996 JUL 27	20	48	2.4	40.029	20.750	4.3	2.5
1996 JUL 27	21	29	32.1	40.057	20.774	4.6	2.5
1996 JUL 28	01	12	6.1	39.986	20.666	5.5	3.8
1996 JUL 28	04	47	39.2	40.036	20.664	3.5	3.0
1996 JUL 29	01	19	48.6	39.887	20.457	4.7	2.6
1996 JUL 29	02	57	37.9	40.124	20.777	3.9	2.9
1996 JUL 29	03	57	50.1	40.049	20.737	5.0	3.3
1996 JUL 30	16	48	33.7	40.110	20.748	6.4	3.0
1996 JUL 31	02	19	11.4	40.117	20.662	2.2	2.7
1996 JUL 31	02	47	59.6	40.109	20.712	5.1	2.5
1996 JUL 31	04	29	28.7	40.028	20.678	5.4	3.3
1996 JUL 31	14	00	20.6	40.104	20.584	4.5	2.7
1996 JUL 31	15	18	26.5	40.160	20.701	5.4	3.2
1996 JUL 31	20	33	17.3	40.024	20.568	3.5	2.9
1996 AUG 1	20	19	45.8	39.886	20.874	8.5	2.8
1996 AUG 1	21	07	8.5	40.097	20.667	5.1	3.0
1996 AUG 2	07	00	12.4	40.065	20.672	8.5	2.8
1996 AUG 2	19	14	39.2	39.887	20.599	13.8	3.0
1996 AUG 2	21	56	53.7	40.016	20.706	5.3	3.0
1996 AUG 3	02	30	31.8	39.961	20.754	7.2	2.9
1996 AUG 3	08	24	14.4	40.157	20.619	6.5	2.8
1996 AUG 3	13	20	12.3	40.010	20.735	5.6	3.0
1996 AUG 4	08	03	23.2	40.023	20.701	4.3	3.4
1996 AUG 4	10	08	49.5	40.041	20.695	6.6	3.8
1996 AUG 5	19.	00	56.8	39.997	20.664	5.8	2.9
1996 AUG 5	22.	46.	35.8	39.886	20.685	5.6	2.9
1996 AUG 5	22	46	42.9	40.083	20.674	8.0	5.1
1996 AUG 5	23	58	47.9	40.032	20.726	7.5	3.3
1996 AUG 6	02	43	3.0	40.015	20.721	6.4	3.2
1996 AUG 6	05	13	53.4	40.080	20.696	3.9	3.5
1996 AUG 6	05	37	20.5	40.166	20.710	5.1	3.1
1996 AUG 6	06	19	8.2	40.105	20.696	6.0	3.6
1996 AUG 6	07	49	.1	40.129	20.683	4.7	2.7
1996 AUG 6	08	03	31.4	40.160	20.664	6.1	3.2
1996 AUG 6	10	03	26.8	39.967	20.697	5.5	2.8
1996 AUG 6	13	29	10.7	39.805	20.684	5.8	2.0
1996 AUG 6	18	24	14.0	39.972	20.718	7.4	2.5
1996 AUG 7	01	13	29.7	39.893	20.591	8.6	3.0
1996 AUG 7	13	56	22.4	39.973	20.690	9.2	2.7
1996 AUG 7	14	16	18.6	40.043	20.722	5.3	3.0

DATE	ORIGIN TIME GMT			LAT N	LON E	DPT Km	MAG Ml
1996 AUG 7	18	52	38.7	40.123	20.625	6.1	2.9
1996 AUG 7	19	49	57.6	40.102	20.635	5.8	2.9
1996 AUG 7	20	53	20.6	39.812	20.661	5.7	2.4
1996 AUG 7	21	33	4.9	39.996	20.736	6.1	2.3
1996 AUG 8	02	29	38.7	39.995	20.553	8.3	2.9
1996 AUG 8	02	50	46.7	39.996	20.654	5.2	2.9
1996 AUG 8	06	12	21.5	40.133	20.663	5.0	2.7
1996 AUG 8	07	32	15.6	40.123	20.707	6.4	2.8
1996 AUG 8	09	54	4.0	40.200	20.579	5.7	2.6
1996 AUG 8	11	32	10.2	39.937	20.719	5.5	2.7
1996 AUG 8	18	33	41.5	40.048	20.680	6.3	2.9
1996 AUG 9	04	20	41.4	39.960	20.649	2.7	2.5
1996 AUG 9	08	11	23.6	39.994	20.618	6.6	2.7
1996 AUG 10	03	22	16.7	40.076	20.683	5.8	2.9
1996 AUG 10	05	55	41.2	40.031	20.631	5.5	2.9
1996 AUG 10	10	15	55.1	39.969	20.725	5.8	2.9
1996 AUG 10	23	25	31.1	39.910	20.887	4.8	2.6
1996 AUG 11	01	40	30.2	39.896	20.631	6.1	2.7
1996 AUG 11	02	51	14.7	39.989	20.644	6.3	2.4
1996 AUG 11	03	08	45.3	40.008	20.725	6.9	2.7
1996 AUG 11	04	21	5.4	40.033	20.645	10.1	2.3
1996 AUG 11	07	57	16.8	40.122	20.730	8.2	4.1
1996 AUG 11	08	14	29.7	39.988	20.712	6.6	2.7
1996 AUG 11	08	30	29.1	40.062	20.739	4.8	3.1
1996 AUG 11	09	24	57.6	40.002	20.658	5.6	3.0
1996 AUG 11	13	16	23.2	39.994	20.584	5.3	2.7
1996 AUG 11	15	19	52.0	40.060	20.653	11.5	2.8
1996 AUG 11	20	39	21.1	40.007	20.677	8.1	3.1
1996 AUG 11	21	00	27.3	40.078	20.625	6.1	2.9
1996 AUG 11	21	03	09.3	39.996	20.587	7.7	2.9
1996 AUG 12	04	36	47.0	40.021	20.665	6.1	2.9
1999 AUG 11	23	59	19.9	39.847	20.698	5.8	3.0
1996 AUG 15	03	30	23.1	39.956	20.711	5.9	2.8
1996 AUG 15	17	30	28.3	40.036	20.664	4.2	3.1
1996 AUG 16	05	02	33.8	40.021	20.687	6.7	2.8
1996 AUG 16	05	32	58.7	40.077	20.669	4.3	2.6
1996 AUG 16	09	57	8.9	40.102	20.719	5.1	2.6
1996 AUG 16	10	28	16.2	40.028	20.671	6.1	3.0
1996 AUG 17	01	49	42.0	40.016	20.724	4.6	2.9
1996 AUG 18	03	23	44.8	39.923	20.527	4.5	2.3
1996 AUG 18	03	35	21.5	39.980	20.559	10.3	2.9
1996 AUG 18	05	26	37.7	39.988	20.554	6.5	3.2
1996 AUG 18	06	44	26.1	40.084	20.549	3.3	3.3
1996 AUG 18	07	05	37.7	40.032	20.621	5.3	3.0
1996 AUG 18	08	05	53.5	40.088	20.598	4.8	2.9
1996 AUG 18	09	08	04.3	40.116	20.476	5.6	2.9
1996 AUG 18	13	48	19.5	40.097	20.558	5.6	2.9
1996 AUG 18	16	57	59.5	40.060	20.552	3.0	2.8
1996 AUG 20	01	26	50.7	40.110	20.699	8.7	5.1
1996 AUG 20	05	48	21.2	40.005	20.663	5.7	3.3
1996 AUG 20	06	05	25.8	40.109	20.820	8.8	2.5

DATE	ORIGIN TIME GMT			LAT N	LON E	DPT Km	MAG Ml
1996 AUG 20	06	50	13.4	39.900	20.564	7.1	2.6
1996 AUG 20	17	02	13.7	39.977	20.612	6.6	3.0
1996 AUG 20	17	36	45.2	39.997	20.584	7.7	2.9
1996 AUG 21	07	10	36.0	40.001	20.779	6.2	3.2
1996 AUG 23	00	25	5.5	40.050	20.822	5.1	2.6
1996 AUG 23	01	55	22.1	39.846	20.732	5.7	2.5
1996 AUG 23	09	54	7.4	39.966	20.696	4.8	2.9
1996 AUG 23	17	53	57.9	40.217	20.678	5.8	3.3
1996 AUG 23	19	42	9.0	40.211	20.719	5.5	3.4
1996 AUG 24	04	34	07.3	40.087	20.665	7.3	2.9
1996 AUG 24	08	23	24.5	40.094	20.705	5.7	3.1
1996 AUG 24	15	14	40.1	40.013	20.573	7.7	2.7
1996 AUG 26	02	12	21.7	39.801	20.714	9.6	2.6
1996 AUG 26	20	55	43.9	40.041	20.674	7.0	2.4
1996 AUG 28	04	06	52.7	39.875	20.645	5.1	2.9
1996 AUG 28	10	08	31.0	39.940	20.674	7.5	3.5
1996 AUG 29	02	28	48.6	40.027	20.596	6.1	2.7
1996 AUG 29	02	32	13.8	39.994	20.681	5.1	2.9
1996 AUG 29	03	47	51.2	40.017	20.604	4.9	3.1
1996 AUG 30	18	41	22.8	40.026	20.722	6.5	2.9
1996 SEP 1	06	36	47.9	40.090	20.613	5.6	2.7
1996 SEP 1	06	54	7.8	39.896	20.746	4.7	2.6
1996 SEP 1	06	56	13.4	40.078	20.674	7.2	2.9
1996 SEP 1	07	10	43.5	40.088	20.694	5.8	2.9
1996 SEP 1	07	12	7.0	39.831	20.751	5.4	2.5
1996 SEP 1	07	41	46.1	40.086	20.716	5.4	3.8
1996 SEP 1	18	10	33.8	40.107	20.679	5.8	2.9
1996 SEP 1	21	15	26.2	40.130	20.688	5.0	3.9
1996 SEP 1	21	40	6.5	39.933	20.626	4.8	2.9
1996 SEP 1	21	55	47.0	39.881	20.674	5.4	2.7
1996 SEP 2	15	05	03.9	39.995	20.587	6.6	2.9
1996 SEP 3	10	10	59.7	40.098	20.761	4.8	2.9
1996 SEP 3	12	29	44.7	40.114	20.812	6.7	2.3
1996 SEP 3	19	02	59.1	40.148	20.756	7.1	2.4
1996 SEP 3	21	05	39.2	39.972	20.666	5.0	3.1
1996 SEP 4	08	17	24.4	40.056	20.596	5.4	3.0
1996 SEP 6	13	47	32.9	39.999	20.678	6.3	4.4
1996 SEP 7	19	39	32.7	40.022	20.703	5.0	3.3
1996 SEP 8	11	20	2.2	40.010	20.573	5.8	3.9
1996 SEP 11	11	06	57.6	40.123	20.724	6.1	2.9
1996 SEP 11	12	55	44.5	39.977	20.765	7.0	2.7
1996 SEP 14	13	36	44.5	39.901	20.566	4.8	2.8
1996 SEP 26	12	31	49.9	40.092	20.816	9.0	4.3
1996 OCT 5	13	12	54.3	39.843	20.655	6.4	2.9
1996 OCT 8	22	41	38.5	40.045	20.556	5.3	3.1
1996 OCT 8	22	49	17.8	40.065	20.668	6.5	3.1
1996 OCT 9	07	39	45.6	40.065	20.698	4.8	2.9
1996 OCT 10	15	18	16.8	40.031	20.804	5.5	3.9
1996 OCT 16	20	48	13.1	40.015	20.553	7.1	2.9
1996 OCT 23	02	44	42.3	39.912	20.567	8.6	3.0
1996 NOV 2	00	11	43.6	40.019	20.659	5.8	3.8
1996 NOV 2	10	39	34.7	39.851	20.825	7.6	2.8
1996 NOV 2	21	13	21.8	39.956	20.762	5.8	3.2
1996 NOV 3	15	09	54.4	40.053	20.664	7.1	2.9
1996 NOV 4	08	57	36.7	39.957	20.608	5.6	3.0
1996 NOV 14	03	03	37.6	40.061	20.637	4.6	4.8
1996 NOV 14	03	16	26.8	40.094	20.558	6.1	4.0
1996 NOV 14	03	38	43.3	39.966	20.639	7.2	3.3
1996 NOV 14	04	31	59.7	40.006	20.698	5.5	2.9
1996 NOV 14	14	14	56.1	40.201	20.564	6.5	4.1
1996 NOV 14	15	28	8.3	40.043	20.642	4.9	3.0
1996 NOV 14	1553 5		9.1	39.938	20.688	6.5	3.1
1996 NOV 15	22	06	2.5	40.013	20.649	7.1	2.8
1996 NOV 16	14	12	00.1	39.968	20.706	6.1	3.2
1996 NOV 18	16	21	25.8	39.978	20.804	6.6	3.4
1996 NOV 19	04	22	47.9	39.991	20.641	5.8	3.1
1996 NOV 21	13	27	19.9	40.101	20.489	4.9	3.2
1996 NOV 22	14	20	24.0	40.008	20.429	6.8	3.1
1996 NOV 22	14	24	18.0	39.996	20.669	7.3	2.6
1996 NOV 22	21	05	47.2	40.101	20.761	8.6	4.0
1996 NOV 24	04	10	54.6	39.967	20.496	5.7	3.1
1996 NOV 24	04	28	33.8	39.971	20.458	5.6	3.1
1996 NOV 27	04	18	42.5	40.006	20.479	6.1	2.7
1996 NOV 29	00	44	57.9	39.896	20.703	7.3	3.1
1996 NOV 29	04	31	59.4	39.887	20.648	5.5	3.4
1996 NOV 30	21	01	04.1	39.889	20.497	5.5	2.8
1996 DEC 5	00	11	05.3	39.996	20.699	4.8	2.8
1996 DEC 7	17	59	53.1	39.932	20.750	3.7	3.0
1996 DEC 14	07	22	59.1	40.008	20.579	4.9	2.6
1996 DEC 17	23	10	59.5	39.818	20.684	6.6	3.1
1996 DEC 23	15	47	38.1	39.816	20.528	5.3	2.8