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STRONG-MOTION DATA FROM THE SUPERSTITION HILLS EARTHQUAKES OF 0154 AND 1315 (GMT), NOVEMBER 24, 1987

By

R. Porcella, E. Etheredge, R. Maley, and J. Switzer

With contributions from

A. Acosta, R. Forshee, D. Johnson,

J. Nielson, and M. Salsman

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INTRODUCTION

On November 24, 1987 at 0132 G.m.t. an ML=4.3 earthquake occurred in southeastern California near the southern margin of the Salton Sea. This event was followed by an ML=4.0 earthquake at 0153 and an Ms=6.2 earthquake at 0154. During the first 18 hours at least 19 earthquakes of magnitude 4.0 or greater occurred, including an Ms=6.6 earthquake at 1315 (U.S. Geological Survey, 1987). This largest event was felt as far away as San Diego and Los Angeles, Calif., Tempe, Ariz., and Las Vegas, Nevada; the earthquake caused at least 2 deaths and more than $4 million in property damage in the Imperial Valley of southeastern Calif. and northeastern Baja Calif. (Imperial Valley Press, Nov. 27, 1987). The purpose of this report is to disseminate information about strong-motion data recorded at USGS stations in the Imperial Valley, Calif. region during the two earthquakes that occurred on November 24 at 0154 and 1315 G.m.t. (Ms=6.2 and 6.6). Additionally, we include a brief history of strong-motion recording in this region, and finally, some results of recent geotechnical investigations at strong-motion stations in the Imperial Valley, Calif.

THE IMPERIAL VALLEY STRONG-MOTION NETWORK

Background

In July 1932 a U.S. Coast and Geodetic Survey standard accelerograph was installed in the Southern Sierra Power Co. substation at 302 Commercial Ave. in El Centro, Calif. (This station is now designated El Centro array station 9). This initial Imperial Valley station was one part of a regional network designed to gather strong-motion data from active regions in the western United States (Matthiesen and Porcella, 1980). On May 18, 1940 an M=7.0 earthquake near El Centro triggered the standard accelerograph as well as

strong-motion instruments located in San Diego, San Bernardino, and Los Angeles. One recording, the well-known El Centro accelerogram, has been used worldwide in earthquake engineering studies as representative of ground motion from a strong local earthquake. On February 9, 1971 a moderate earthquake near San Fernando, Calif., caused extensive property damage, including failure of several recently designed structures in the Los Angeles area. One result of this event was a substantial increase in the 1970's in the rate of installation of strong-motion stations operated by several organizations, including the U.S. Geological Survey, the Calif. Division of Mines and Geology, the University of Southern Calif., and the Calif. Institute of Technology. By October 15, 1979, when an M=6.5 earthquake ruptured the Imperial fault near El Centro, there were more than 30 USGS strong-motion stations operating in the Imperial Valley region.

Historical Strong-Motion Data

Approximately 700 strong-motion records have been recovered from USGS stations in the Imperial Valley since the first accelerograph was installed in 1932. About 250 of these records were recovered prior to the 1979 Imperial Valley earthquake. This M=6.5 event triggered 43 stations including the 13-station El Centro Array (see figure 1), a 42-km long array perpendicular to the Imperial fault, and produced maximum horizontal ground accelerations greater than 0.5 g at seven stations within 10 km of the Imperial fault rupture. The 1979 data set also contains 260 aftershock records from 21 stations within 30 km of the main shock surface rupture, and now constitutes the most comprehensive collection of near-source strong ground motion ever recorded (Porcella and others, 1982). On April 26, 1981 the entire El Centro Array was triggered for the second time; an ML=5.6 earthquake near Westmorland, Calif.

was recorded by 22 USGS strong-motion stations at epicentral distances as large as 70 km. The maximum recorded ground acceleration was 0.23 g at the Parachute Test Site, epicentral distance 20 km (Maley and Etheredge, 1981).

The two largest shocks (Ms=6.2 and Ms=6.6) of the November 1987 Superstition Hills earthquakes produced at least 65 accelerograms from nearly 40 stations in the greater Imperial Valley region. The accelerogram from Superstition Mtn. contains one of the most significant combinations of high acceleration/long duration yet recorded at any ground station. Perhaps an equal number of accelerograms was recorded during the more than 20 ML=4.0 or greater foreshocks and aftershocks that occurred during the first 72 hours. The Ms=6.6 shock was the third time the 13-station El Centro Array was triggered by a single event, and the third time in less than fifty years a magnitude 6.5-7 local earthquake was recorded at the El Centro Commercial Ave. station.

DATA FROM STATIONS IN THE NATIONAL STRONG-MOTION INSTRUMENTATION NETWORK

At least 33 earthquakes of ML=3.5 or greater were recorded during an 18-hour period on November 24, 1987 (G.m.t.), in the Imperial Valley of southeastern California (fig. 1), including the Ms=6.2 event at 0154 and Ms=6.6 event at 1315 G.m.t. (see tables 1 and 2, beginning on page 15). This section contains information about the strong-motion data recorded during these two earthquakes at National Strong-Motion Instrumentation Network (NSMIN) stations in the greater Imperial Valley region, including copies of the records from both events (see figures 2 and 3, beginning on page 22).

Ms=6.2 Earthquake Data

Peak horizontal ground accelerations recorded during the Ms=6.2 shock

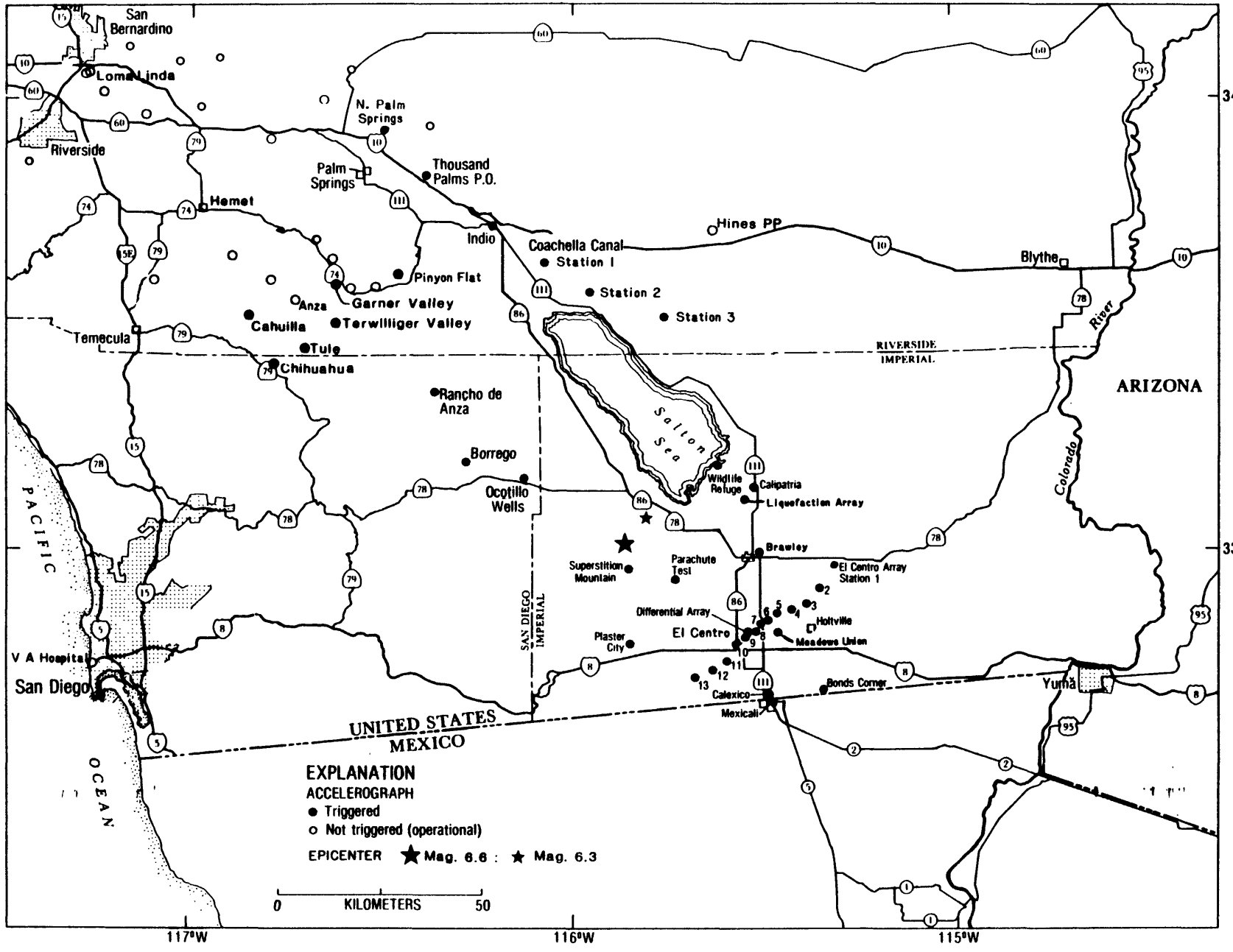

Figure 1. USGS strong-motion stations in the region of the November 24, 1987 Superstition Hills earthquakes. Trigger information refers to the 1315 G.m.t. event.

exceed 0.1 g at six stations. These stations, and their corresponding epicentral distances and peak motions include Superstition Mountain, 13 km, 0.13 g; Parachute Test Site, 18 km, 0.13 g; Salton Sea, 20 km, 0.18 g; Imperial Wildlife, 24 km, 0.13 g; and Calipatria, 26 km, 0.22 g. Peak motions are significantly smaller at most stations beyond 26 km (see table 1), and appear to be low for an event of this magnitude. However, these peak-motion versus distance data compare favorably with data recorded at similar distances during the ML=5.6 Westmorland earthquake of April 26, 1981 (Maley and Etheredge, 1981).

Ms=6.6 Earthquake Data

Accelerographs at 39 NSMIN stations were triggered during the Ms=6.6 shock (fig. 1). One station, Holtville, failed completely because of a faulty accelerograph starter. Maximum horizontal ground accelerations exceed 0.1 g at 25 stations within an epicentral distance of 60 km. Peak motion data from these 25 stations, excluding Calipatria (0.32 g, 34 km), approach or exceed 0.3 g only at those stations within a relatively narrow band extending southeast of the epicenter, approximately parallel to the Superstition Hills fault (see figure 1 and table 2). Stations within an epicentral distance of 60 km outside of this band recorded peak motions in the 0.1 g - 0.2 g range or less; and several of these lower peak motions are from sites at distances closer than the stations to the southeast.

Superstition Mountain station. The Superstition Mountain accelerograph, the closest NSMIN instrument (7 km), recorded approximately 30 "events" during an uninterrupted duration of about 7 1/2 minutes after triggering. This accelerogram contains information that was not recorded at any other station, including S-P intervals for many of the earliest aftershocks. Superstition

Mountain is a linear granitic block that protrudes approximately 180 m above the valley floor. The accelerograph is installed at ground level in a garage-size one-story reinforced concrete building used as a camera site for U.S. Navy operations. The record contains peak horizontal accelerations and strong durations that are among the largest and longest ever recorded in the 55 year history of the program.

Maximum accelerations exceeded 0.9 g and 0.7 g in the two horizontal directions and more than 0.6 g in the vertical direction (fig. 3, page 35). The duration of strong shaking, defined as the number of seconds acceleration pulses exceed 0.1 g, ranged from 15.8 to 16.9 s in the three directions (table 2). This range of strong shaking may be compared with those recorded at strong-motion stations during other significant earthquakes, for example:

Long Beach	March 10, 1933	2.5 - 5.0 s
El Centro	May 18, 1940	9.0 - 26.0 s
Taft	July 21, 1952	14.0 - 26.0 s
Pacoima Dam	February 9, 1971	9.0 - 10.0 s
Bonds Corner	October 15, 1979	12.0 - 13.3 s

A comparison of the Superstition Mountain record, which had numerous acceleration pulses greater than 0.5 g, with records from the two stations with substantially longer durations of strong shaking, that is, El Centro (1940) and Taft (1952), shows the latter contain much lower peak accelerations (in the range 0.2 g - 0.3 g). Topographic effects, if any, that could contribute to such amplification are unknown at this time. Comparisons of the records from Superstition Mountain and the nearby Parachute Test Site from this event and those records from the Imperial Valley earthquake of 1979 and the Westmorland earthquake of April 26, 1981, suggest that amplification may not be significant. The two later earthquakes produced generally equal or greater peak accelerations and considerably longer durations of strong shaking, generally 3

to 4 times longer at the Parachute Test Site than at the Superstition Mountain site.

Several aftershock accelerographs were installed after the Ms=6.6 earthquake, including one at the base of Superstition Mountain to assist in evaluating possible topographic amplification. The two records thus far correlated between the base and top accelerograph stations (approx. 1 km apart) indicate that for these two events there was no significant amplification at the top of Superstition Mountain. Peak recorded accelerations and event data are as follows:

Earthquake	Base Station		Top Station
November 28, 1987	Horiz. accel.	0.04 g	0.08 g
0039:10.3 G.m.t.	Vert. accel.	0.03 g	0.06 g
ML=4.2	Horiz. accel.	0.11 g	0.07 g
33.130°N, 115.818°W			
December 2, 1987	Horiz. accel.	0.06 g	0.08 g
0403:6.1 G.m.t.	Vert. accel.	0.03 g	0.06 g
ML=4.6	Horiz. accel.	0.09 g	0.08 g
33.157°N, 115.792°W			

Parachute Test Site station. The second closest NSMIN accelerograph was located at ground level in a large, reinforced concrete building approx. 15 m wide by 40 m long and of widely varying height; it is located at the Parachute Test Site, approx. 55 m southwest of the November 1987 Superstition Hills fault surface displacement. The record from this site also shows a relatively long duration of strong shaking, ranging from 11.3 to 14.5 s (table 2), with peak accelerations of 0.45 g to 0.53 g in both horizontal and vertical directions (fig. 3, page 35). This site's recorded strong ground motion is nearer to ground rupture than motion recorded at any other site during any previous California earthquake. The record exhibits long period characteristics observed on other records from stations near fault zones, such as Cholame-Shandon station 2 during the June 27, 1966 earthquake and El Centro Array

stations 5 and 7 during the October 15, 1979 earthquake. Downhole shear-wave velocities were measured in 1981 at a 30 m borehole approximately 100 m southwest of the building. The near surface material consists of coarse sand and fine gravel with a shear-wave velocity measured at 443 m/s between depths of about 10 and 30 m -- the highest near-surface S-wave velocity at any of the 22 Imperial Valley sites investigated during the 1981 survey (Porcella, 1984).

Special Arrays

Records were obtained from both the Ms=6.2 and Ms=6.6 earthquakes at co-located SMA-1 and RFT-250 accelerographs at Bonds Corner, nominally 60 km distant from each event. The RFT-250 instrument was installed in 1982 as part of an experiment to investigate the cause of high frequency acceleration spikes observed on the SMA-1 record from this site during the M=6.5 Imperial Valley earthquake of October 15, 1979. It has been speculated that these spikes may have been a result of site response, instrumental peculiarity, structural effects, or some other environmental factor such as an object impacting the instrument during strong shaking. These two accelerographs have very different motion sensing pendulums. The SMA-1 pendulum has a gate-type hinge suspension whereas the RFT-250 pendulum has a unifilar wire suspension. The latter pendulum system was the standard for the NSMIN for more than 40 years and its response characteristics were extensively investigated during those years. The newer gate-type pendulum has been highly successful for nearly 20 years though not as thoroughly studied. By co-locating the two accelerographs any difference in response would be easily observed. The level of shaking at Bonds Corner approached 0.1 g and 0.3 g for the Ms=6.2 and Ms=6.6 Superstition Hills earthquakes, respectively, considerably less than the 0.8 g recorded in 1979; and none of the high frequency pulses recorded in 1979 were recorded by

either instrument in 1987. Comparison of the records from the 1987 events indicates that acceleration traces in common directions are virtual overlays.

A third accelerograph, an RFT-250, also was installed in 1982 in a small fiberglass housing, approximately 27 m from the co-located pair, to act as a free field instrument. However, no records were obtained at this site during the Superstition Hills earthquakes because of an electronic malfunction. Without the free field record it is impossible to determine if the structure was related to the high frequency pulses observed in 1979.

A unique record of the Ms=6.6 earthquake was obtained on the Alamo River flood plain, at the Imperial Wildlife Liquefaction Array 32 km from the epicenter. This array consists of two triaxial accelerometers, one located at the surface and the second 6.7 m deep, below a potentially liquefiable zone; and six pore pressure transducers located within and below the liquefiable zone (see figure 4). Output from the transducers is transmitted by cable to a central recorder located at the surface. It was intended that the array data be used to determine the relations between strong ground motion, pore-water pressure, and liquefaction (Bennett and others, 1984).

The record, reproduced on page 37, shows acceleration channels 1, 2, and 3 measured at the surface and acceleration channels 4, 5, and 6 measured at a 6.7 m depth. The lower six traces are pore pressure channels, P6 through P1 as shown in figure 4. Peak surface accelerations were nominally 0.2 g with the exception of a 0.5 s envelope of high frequency vertical motion where accelerations were larger than 0.4 g. Accelerations measured below the liquefiable zone were somewhat lower, generally in the range 0.10 g to 0.15 g. Liquefaction occurred during the earthquake, resulting in numerous sand boils in the immediate vicinity of the instrumentation array. The pore pressure data and their relationship to strong shaking and liquefaction are currently

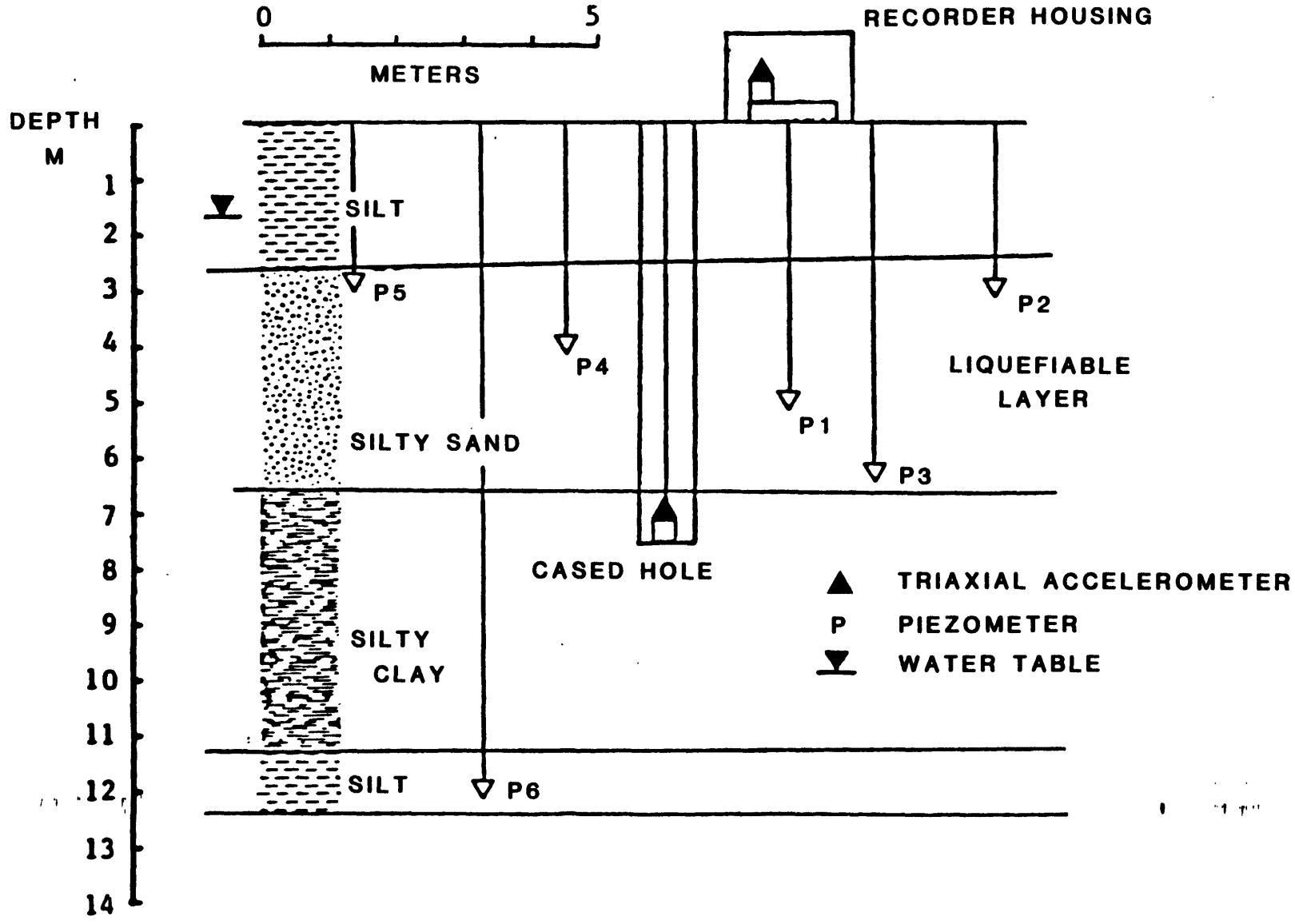

Figure 4. Cross section showing sensor locations at the Imperial Wildlife Liquefaction Array.

being investigated.

GEOTECHNICAL DATA FROM IMPERIAL VALLEY ACCELEROGRAPH STATIONS

Geotechnical investigations in the Los Angeles and San Francisco Bay regions suggest significant correlations may exist between the shear-wave velocity and certain physical properties of near-surface materials (Fumal and others, 1981). The results of these investigations are used to make detailed comparisons of those geotechnical and seismic characteristics that will allow quantitative estimates of strong ground motion for a given site, and ultimately development of seismic zonation techniques applicable to other regions. Site selection criteria for these investigations include distribution of intensity data and availability of detailed geologic maps and ground motion data. The Imperial Valley Strong-Motion Network stations thus became prime candidates for geotechnical investigations after the M=6.5, October 15, 1979 earthquake.

The U.S. Geological Survey began such an investigation in the summer of 1980, including shear-wave velocity surveys at 22 of the 25 stations where significant ground motions were recorded during the 1979 event (Porcella, 1984). S-wave velocities ranged from 115 m/s in near-surface silty-clay at Array Station 3 on the east side of the valley to 443 m/s at depths between 10 and 30 m in coarse sand/fine gravel at the Parachute Test site near the west side of the valley. Although this study measured S-wave velocities for the first time at many of the 22 sites, there were measurements made by previous workers at the original Commercial Ave. station and others that were available for comparison (see figure 5). In general, S-wave velocities were similar at sites throughout the valley; they averaged about 170 m/s near the surface and gradually increased to about 340 m/s near a 70 m depth. The Imperial Valley

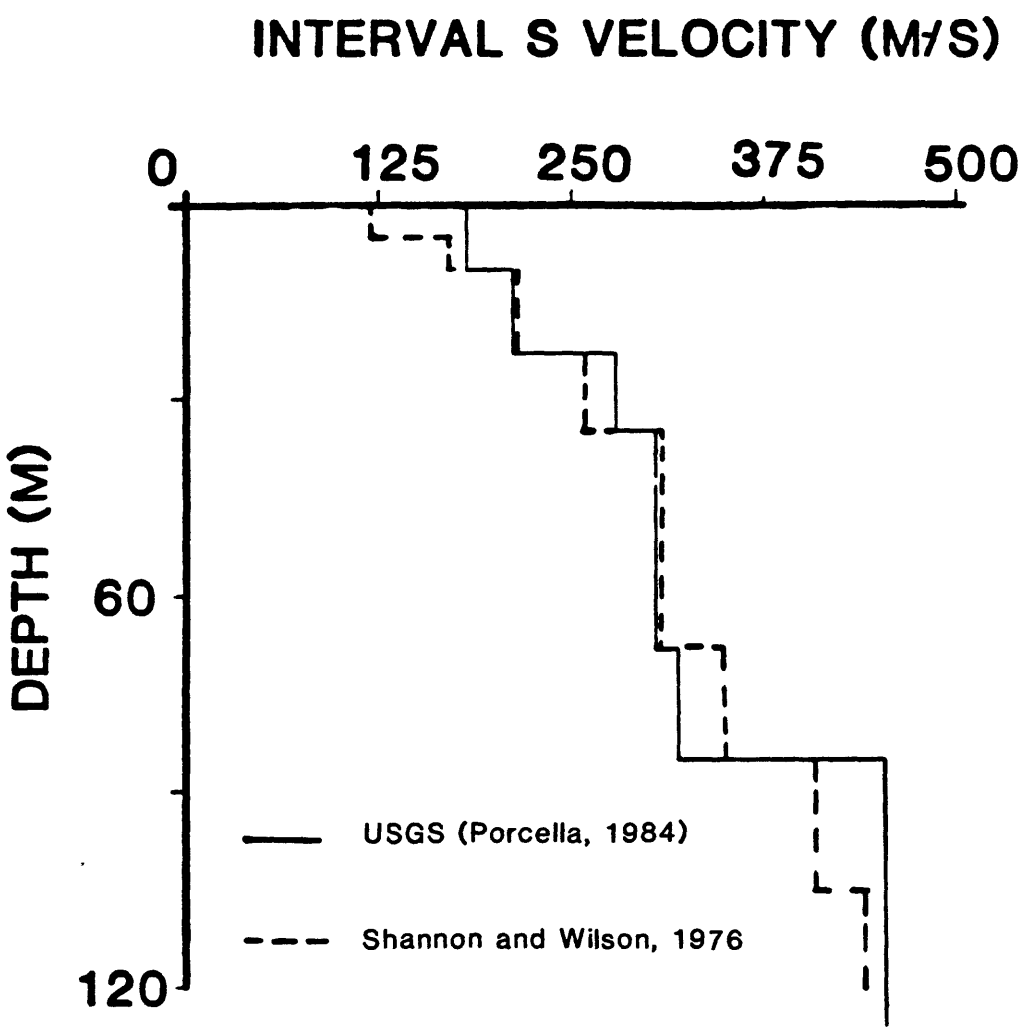

Figure 5. Comparison of interval S-wave velocities at the original El Centro Commercial Avenue strong-motion station (from Porcella, 1984).

geotechnical study included the following investigations: (1) electronic cone-penetrometer soundings at nine stations; (2) drilling, sampling, and logging of 22 borings to depths ranging from about 30 to 244 m; (3) downhole P- and S-wave velocity surveys at 22 stations; (4) high-amplitude resonant column tests of undisturbed samples from several stations; and (5) gamma, S-P, and resistivity logs and caliper and temperature measurements at selected stations (Porcella, 1984).

TEMPORARY AFTERSHOCK SITES

Temporary strong-motion aftershock stations were established in the epicentral area south of the Salton Sea by USGS personnel from Pasadena and Menlo Park, Calif. Copies of two accelerograms from Pasadena instruments installed prior to the Ms=6.6 event have been included at the end of figure 3 on page 56. The aftershock sites, instruments, and recordings are the result of last minute efforts; related data, therefore, have not been documented and reported to the same extent as the NSMIN data. Future reports will be issued that include additional aftershock data from both temporary and NSMIN stations.

ACKNOWLEDGEMENTS

The highly successful operation of the USGS Imperial Valley Strong-Motion Network, as evidenced by the extensive collection of engineering data recorded in this region over the past 55 years, is a direct result of the personal interest and assistance of many local residents in the operation of this Network. We recognize the cooperation of those individuals associated with Imperial Valley city and county government agencies, local school and fire districts, the Imperial Irrigation District, and the U.S. Navy. Special appreciation is extended to the many private citizens who have allowed

installation and long-term operation of instrumentation on their property.

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Table 1.- *Strong-motion data from the Ms=6.2 Superstition Hills earthquake of November 24, 1987 (0154 G.m.t.)*

[Epicentral distance is measured from station to epicenter at lat. 33.07N., long. 115.79W. Direction of acceleration is for upward trace deflection on the accelerogram.]

STATION IDENTIFICATION				ACCELERATION		
USGS Number	Name (Location)	Coordinates (degrees N. lat. and W. long.)	Epicentral Distance (km)	Direction (degrees)	Maximum (g)	Duration (s>0.10 g)
286	Superstition Mtn.	32.955	13	135	0.13	4.8
	Site 8	115.823		Up	.12	1-peak
	(Ground floor)			045	.11	2.6
5051	Parachute Test Site	32.93	18	315	.10	2-peaks
	Imler Road	115.70		Up	.10	1-peak
	(Ground floor)			225	.13	3.3
5062	Salton Sea	33.18	20	315	.18	2.4
	Wildlife Refuge	115.62		Up	.20	3.9
	(Ground floor)			225	.13	0.8
5210	Imperial Wildlife	33.10	24	Ch. (1) 360	.13	1.4
	Liquefaction Array	115.53		Ch. (2) Up	.18	2.7
	(Ground level and Downhole)			Ch. (3) 090	.13	0.9
				Ch. (4) 360	.08	---
				Ch. (5) Up	.09	---
				Ch. (6) 090	.08	---
	Note: Ch. 1-3 are mounted at surface, ch. 4-6 are 6.7 m downhole.					
5061	Calipatria	33.13	26	315	.15	0.6
	Fire Station	115.52		Up	.18	1.6
	(Ground floor)			225	.22	0.7
5060	Brawley	32.988	28	315	.06	---
	Airport Hanger	115.509		Up	.04	---
	(Ground floor)			225	.06	---
5052	Plaster City	32.79	32	135	.05	---
	Storehouse	115.86		Up	.03	---
	(Ground floor)			045	.04	---
5050	Ocotillo Wells	33.14	33	315	.03	---
	Burro Bend Cafe	116.13		Up	.04	---
	(Ground floor)			225	.03	---
412	El Centro Array 10	32.780	38	230	.04	---
	Community Hospital	115.567		Up	.03	---
	(Ground floor)			140	.05	---
117	El Centro Array 9	32.794	38	360	.04	---
	Commercial Ave	115.549		Up	.03	---
	(Ground floor)			270	.05	---

Table 1.- *Strong-motion data from the Ms=6.2 Superstition Hills earthquake of November 24, 1987 (0154 G.m.t.)* - continued

STATION IDENTIFICATION				ACCELERATION		
USGS Number	Name (Location)	Coordinates Degrees N. lat. and W. long.	Epicentral Distance (km)	Direction (degrees)	Maximum (g)	Duration (s>0.10 g)
958	El Centro Array 8	32.811	38	230	.06	---
	Cruickshank Road	115.532		Up	.04	---
	(Ground level)			140	.04	---
5028	El Centro Array 7	32.829	38	230	.05	---
	Imperial Valley College	115.504		Up	.03	---
	(Ground floor)			140	.03	---
5158	El Centro Array 6	32.839	38	230	.05	---
	Huston Road	115.487		Up	.02	---
	(Ground level)			140	.05	---
952	El Centro Array 5	32.855	39	230	.11	1-peak
	James Road	115.466		Up	.02	---
	(Ground level)			140	.08	---
5165	El Centro Diff. Array	32.796	39	360	.07	---
	Dogwood Road	115.535		Up	.03	---
	(Ground level)			270	.07	---
955	El Centro Array 4	32.864	40	230	.03	---
	Anderson Road	115.432		Up	.02	---
	(Ground level)			140	.02	---
5058	El Centro Array 11	32.752	40	230	.05	---
	McCabe School	115.594		Up	.03	---
	(Ground floor)			140	.04	---
464	El Centro	32.800	42	230	.05	---
	Meadows Union School	115.473		Up	.02	---
	(Ground floor)			140	.05	---
931	El Centro Array 12	32.718	42	230	.05	---
	Brockman Road	115.637		Up	.01	---
	(Ground level)			140	.04	---
5065	Coachella Canal	33.51	49	135	.04	---
	Station 3	115.77		Up	.04	---
	(Ground floor)			045	.03	---
5053	Calexico	32.669	53	315	.04	---
	Fire Station	115.492		Up	.03	---
	(Ground floor)			225	.05	---
5064	Coachella Canal	33.56	56	135	.03	---
	Station 2	115.95		Up	.02	---
	(Ground floor)			045	.02	---

Table 1.- *Strong-motion data from the Ms=6.2 Superstition Hills earthquake of November 24, 1987 (0154 G.m.t.)* - continued

STATION IDENTIFICATION				ACCELERATION		
USGS Number	Name (Location)	Coordinates Degrees N. lat. and W. long.	Epicentral Distance (km)	Direction (degrees)	Maximum (g)	Duration (s>0.10 g)
5054	Bonds Corner	32.693	59	230	0.09	---
	Highway 98 at 115	115.338		Up	.02	---
	(Ground floor, SMA)			140	.06	---
5054	Bonds Corner	32.693	59	230	.09	---
	Highway 98 at 115	115.338		Up	.02	---
	(Ground floor, RFT)			140	.06	---
5063	Coachella Canal	33.64	69	135	.08	---
	Station 1	116.08		Up	.05	---
	(Ground floor)			045	.08	---

Table 2.- *Strong-motion data from the Ms=6.6 Superstition Hills earthquake of November 24, 1987 (1315 G.m.t.)*

[Epicentral distance is measured from station to epicenter at lat. 33.01N., long. 115.86W. Direction of acceleration is for upward trace deflection on the accelerogram.]

STATION IDENTIFICATION				ACCELERATION		
USGS Number	Name (Location)	Coordinates (degrees N. lat. and W. long.)	Epicentral Distance (km)	Direction (degrees)	Maximum (g)	Duration (s>0.10 g
286	Superstition Mtn.	32.955	7	135	0.91	16.5
	Site 8	115.823		Up	.65	16.9
	(Ground floor)			045	.73	15.8
___	POE, Temporary	33.097	14	180	.33	14.8
	Aftershock Station	115.751		Up	.51	17.3
	(Ground level)			090	.54	18.1
5051	Parachute Test Site	32.93	17	315	.53	11.3
	Imler Road	115.70		Up	.45	14.5
	(Ground floor)			225	.49	13.7
___	KNB, Temporary	33.125	22	180	.19	7.6
	Aftershock Station	115.665		Up	.18	1.5
	(Ground level)			090	.15	8.8
5052	Plaster City	32.79	24	135	.19	10.4
	Storehouse	115.86		Up	.11	1-peak
	(Ground floor)			045	.15	2.5
5050	Ocotillo Wells	33.14	29	315	.11	1-peak
	Burro Bend Cafe	116.13		Up	.09	---
	(Ground floor)			225	.08	---
5062	Salton Sea	33.18	29	315	.15	9.2
	Wildlife Refuge	115.62		Up	.17	12.1
	(Ground floor)			225	.14	11.6
5210	Imperial Wildlife	33.10	32	Ch. (1) 360	.21	13.2
	Liquefaction Array	115.53		Ch. (2) Up	.44	10.4
	(Ground level and Downhole)			Ch. (3) 090	.19	5.9
				Ch. (4) 360	.16	1.9
				Ch. (5) Up	.11	1-peak
				Ch. (6) 090	.11	1-peak
	Note: Ch. 1-3 are mounted at surface, ch. 4-6 are 6.7 m downhole.					
5060	Brawley	32.988	33	315	.15	9.5
	Airport Hanger	115.509		Up	.13	3.6
	(Ground level)			225	.15	2.4
5061	Calipatria	33.13	34	315	.32	10.7
	Fire Station	115.52		Up	.21	10.8
	(Ground floor)			225	.24	10.8
5059	El Centro Array 13	32.709	37	230	.19	0.8
	Strobel Residence	115.683		Up	.07	---
	(Ground floor)			140	.17	0.7

Table 2.- *Strong-motion data from the Ms=6.6 Superstition Hills earthquake of November 24, 1987 (1315 G.m.t.)* - continued

STATION IDENTIFICATION				ACCELERATION		
USGS Number	Name (Location)	Coordinates Degrees N. lat. and W. long.	Epicentral Distance (km)	Direction (degrees)	Maximum (g)	Duration (s>0.10 g)
412	El Centro Array 10	32.780	37	230	.27	7.6
	Community Hospital	115.567		Up	.07	---
	(Ground floor)			140	.22	9.3
5058	El Centro Array 11	32.752	38	230	0.32	15.7
	McCabe School	115.594		Up	.13	6.9
	(Ground floor)			140	.21	9.4
117	El Centro Array 9	32.794	38	360	.30	3.6
	Commercial Ave.	115.549		Up	.15	2.6
	(Ground floor)			270	.20	2.8
958	El Centro Array 8	32.811	38	230	.35	10.1
	E. Cruickshank Road	115.532		Up	.21	4.9
	(Ground level)			140	.33	10.1
931	El Centro Array 12	32.718	39	230	.27*	2*
	Brockman Road	115.637		Up	.08*	---
	(Ground level)			140	.19*	2*
5028	El Centro Array 7	32.829	39	230	.20	3.6
	Imperial Valley College	115.504		Up	.18	0.5
	(Ground floor)			140	.26	2.9
5165	El Centro Diff. Array	32.796	39	360	.29	13.4
	Dogwood Road	115.535		Up	.14	3.4
	(Ground level)			270	.23	11.7
5158	El Centro Array 6	32.839	40	230	.16	2.4
	Huston Road	115.487		Up	.14	2.0
	(Ground level)			140	.19	0.7
952	El Centro Array 5	32.855	41	230	.19	3.9
	James Road	115.466		Up	.11	1-peak
	(Ground level)			140	.20	2.6
464	El Centro	32.800	43	230	.27	8.7
	Meadows Union School	115.473		Up	.12	1-peak
	(Ground floor)			140	.26	9.3
955	El Centro Array 4	32.864	43	230	.10	1-peak
	Anderson Road	115.432		Up	.12	1-peak
	(Ground level)			140	.11	0.8
5220	Borrego Springs	33.210	44	315	.06	---
	Scripps Clinic	116.330		Up	.05	---
	(Ground floor)			225	.06	---

*Instrument malfunction, partial record (approx. 10 seconds).

Table 2.- *Strong-motion data from the Ms=6.6 Superstition Hills earthquake of November 24, 1987 (1315 G.m.t.)* - continued

STATION IDENTIFICATION				ACCELERATION		
USGS Number	Name (Location)	Coordinates Degrees N. lat. and W. long.	Epicentral Distance (km)	Direction (degrees)	Maximum (g)	Duration (s>0.10 g)
5057	El Centro Array 3	32.894	47	230	.11	1.8
	Pine Union School	115.380		Up	.08	---
	(Ground floor)			140	.11	1-peak
5115	El Centro Array 2	32.916	47	230	0.12	0.9
	Keystone Road	115.366		Up	.05	---
	(Ground level)			140	.10	1-peak
5056	El Centro Array 1	32.960	51	230	.09	---
	Borchard Ranches	115.319		Up	.06	---
	(Ground level)			140	.09	---
5053	Calexico	32.669	51	315	.21	10.5
	Fire Station	115.492		Up	.10	6.0
	(Ground floor)			225	.21	11.7
5065	Coachella Canal	33.51	56	135	.09	---
	Station 3	115.77		Up	.05	---
	(Ground floor)			045	.08	---
5054	Bonds Corner	32.693	60	230	.28	9.9
	Highway 98 at 115	115.338		Up	.09	---
	(Ground floor, SMA)			140	.28	9.4
5054	Bonds Corner	32.693	60	230	.27	9.8
	Highway 98 at 115	115.338		Up	.08	---
	(Ground floor, RFT)			140	.29	9.5
5064	Coachella Canal	33.56	62	135	.04	---
	Station 2	115.95		Up	.03	---
	(Ground floor)			045	.04	---
5047	Rancho de Anza	33.35	63	135	.06	---
	Anza-Borrego Park	116.40		Up	.03	---
	(Ground level)			045	.06	---
5063	Coachella Canal	33.64	73	135	.08	---
	Station 1	116.08		Up	.05	---
	(Ground floor)			045	.09	---
5045	Terwilliger Valley	33.48	86	135	.02	---
	Anza Array	116.59		Up	.01	---
	(Ground floor)			045	.02	---
5221	Chihuahua	33.38	87	360	.02	---
	Anza Array	116.68		Up	.01	---
	(Ground floor)			270	.03	---
5044	Pinyon Flat Observatory	33.61	87	135	.01	---
	Anza Array	116.46		Up	.01	---
	(Ground level)			045	.01	---

Table 2.- *Strong-motion data from the Ms=6.6 Superstition Hills earthquake of November 24, 1987 (1315 G.m.t.)* - continued

STATION IDENTIFICATION				ACCELERATION		
USGS Number	Name (Location)	Coordinates Degrees N. lat. and W. long.	Epicentral Distance (km)	Direction (degrees)	Maximum (g)	Duration (s>0.10 g)
5067	Indio	33.747	88	315	.03	---
	So. Calif. Gas Co.	116.214		Up	.03	---
	(Ground floor)			225	.04	---
5231	Tule Canyon	33.47	89	360	.03*	---
	Anza Array	116.64		Up	.02*	---
	(Ground level)			270	.02*	---
5241	Cahuilla Valley	33.512	89	360	.05	---
	Anza Array	116.798		Up	.01	---
	(Ground floor)			270	.04	---
5242	Garner Valley	33.615	98	360	.02	---
	Anza Array	116.626		Up	.01	---
	(Ground floor)			270	.02	---
5068	Thousand Palms	33.82	103	135	.02*	---
	Post Office	116.40		Up	.02*	---
	(Ground floor)			045	.03*	---
5070	N. Palm Springs	33.924	120	300	.02	---
	Post Office	116.543		Up	.01	---
	(Ground floor)			210	.02	---

*Event/record correlation questionable.

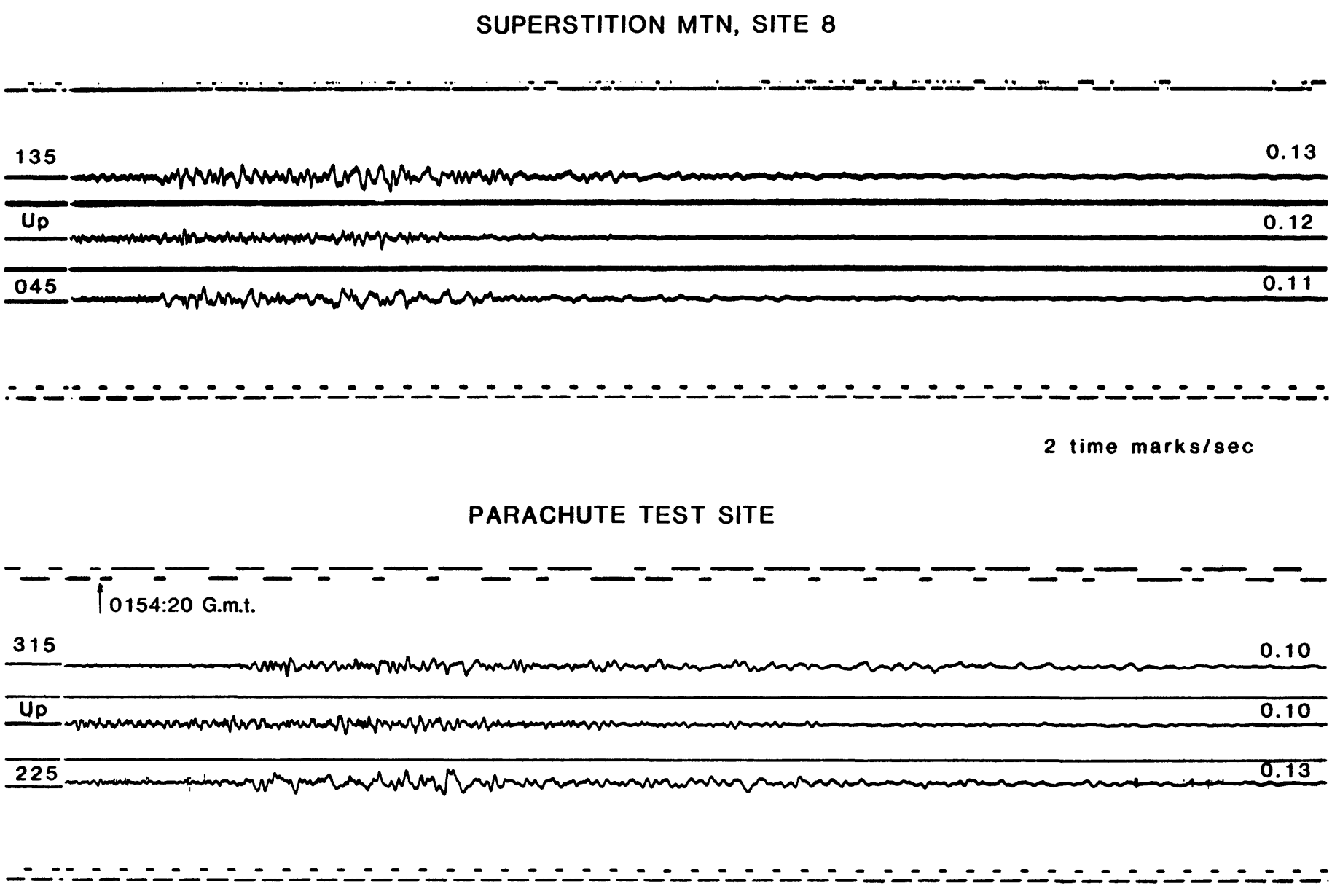
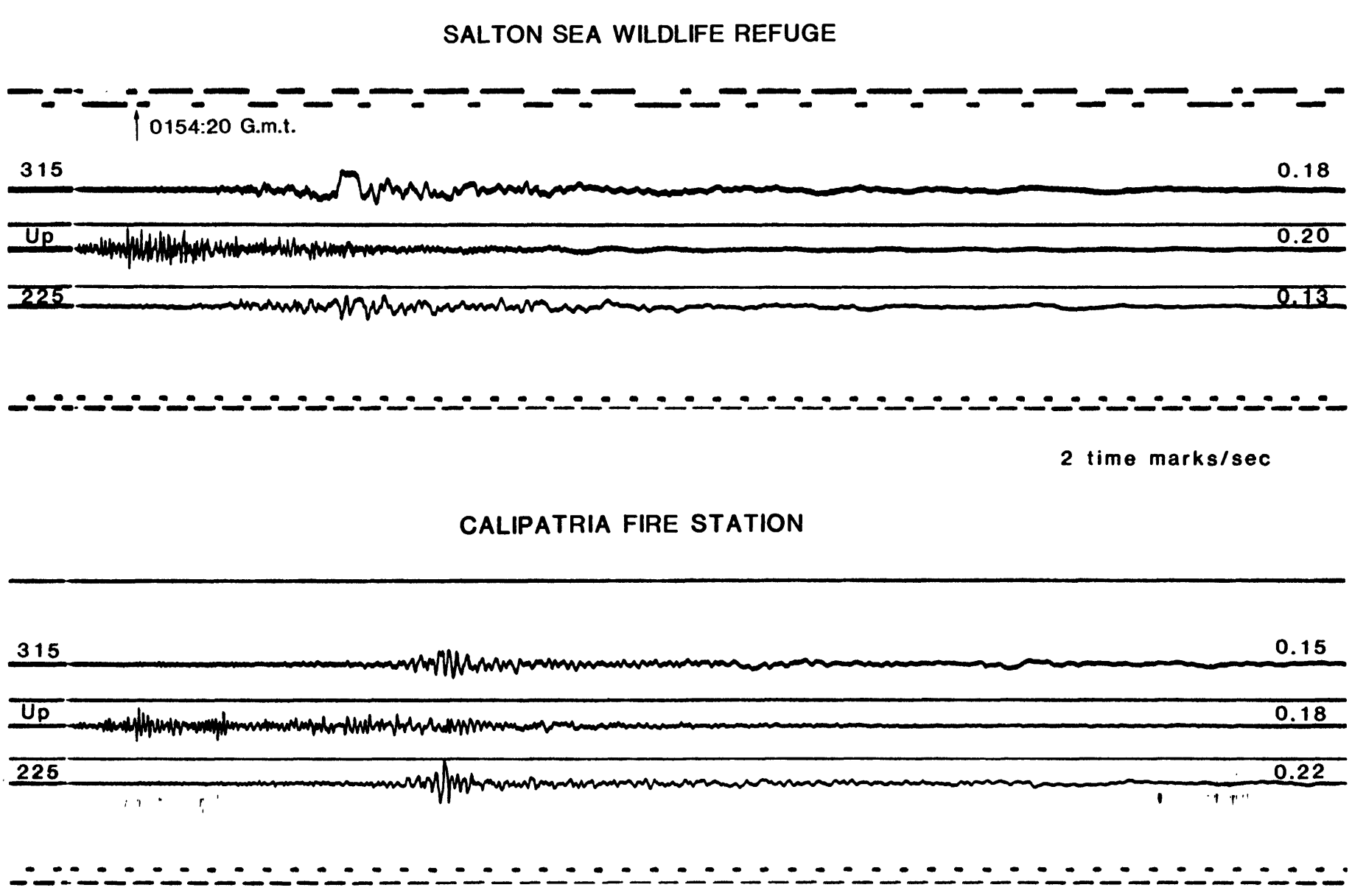


Figure 2. Accelerograms from the Ms=6.2 earthquake.



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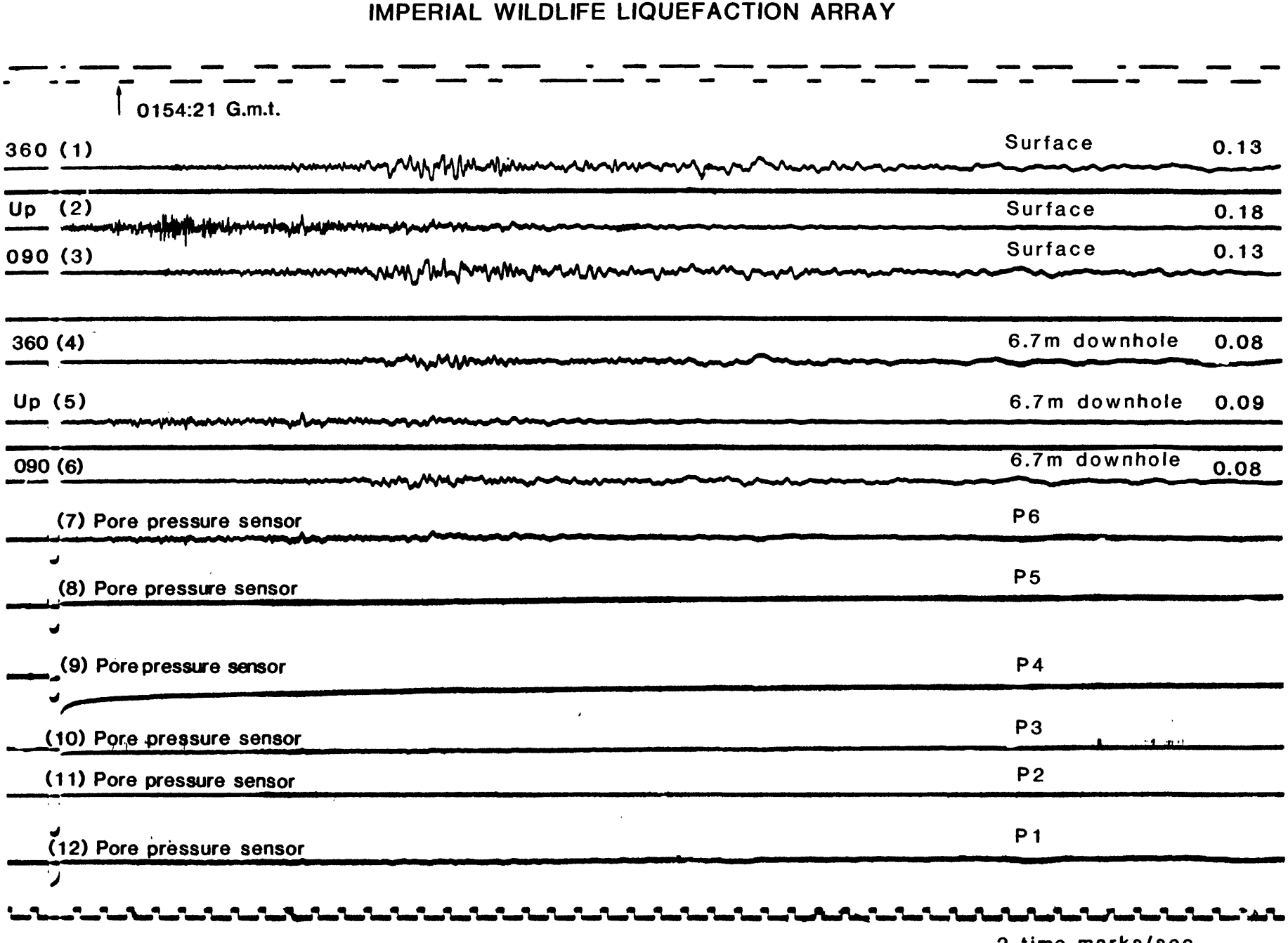

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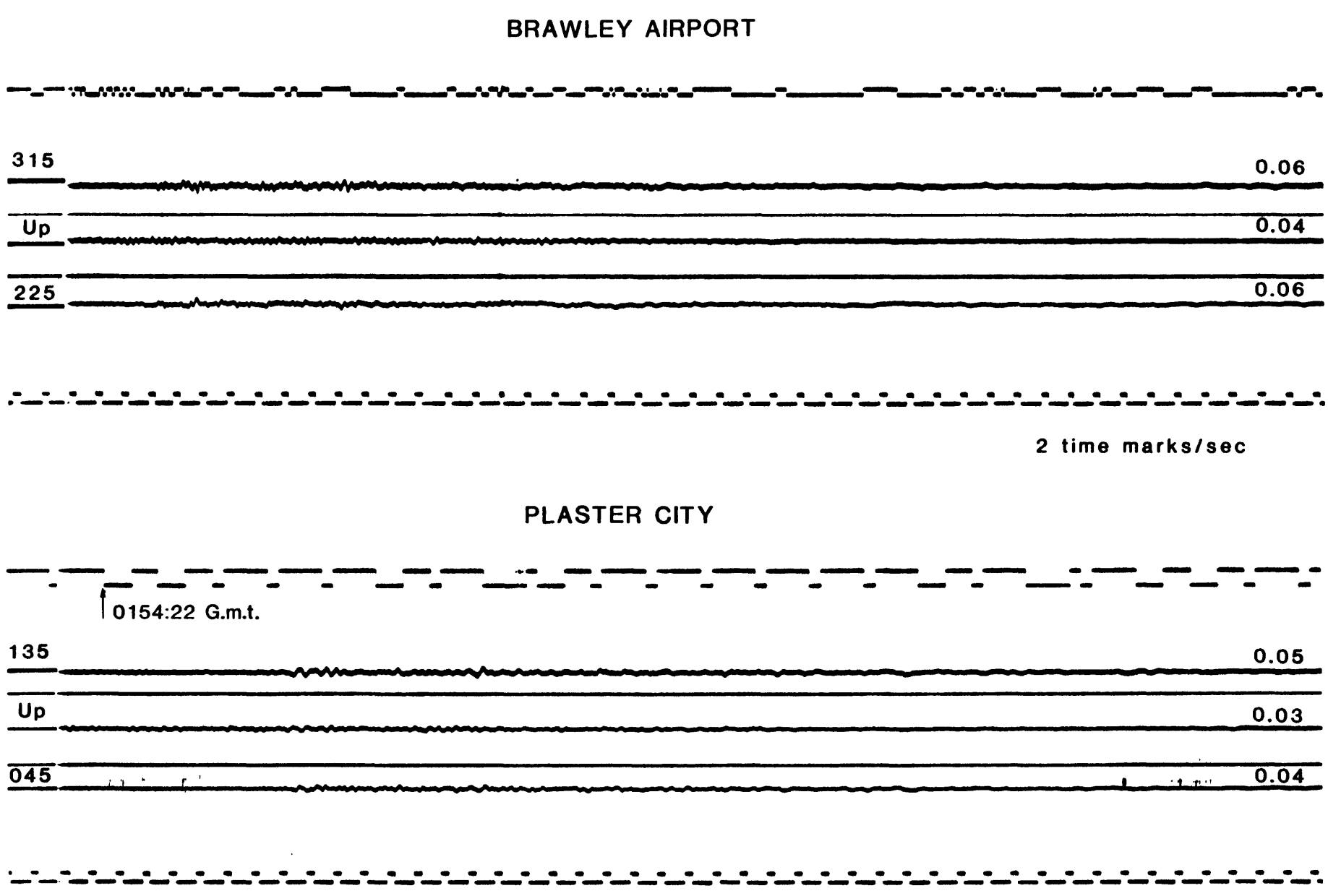
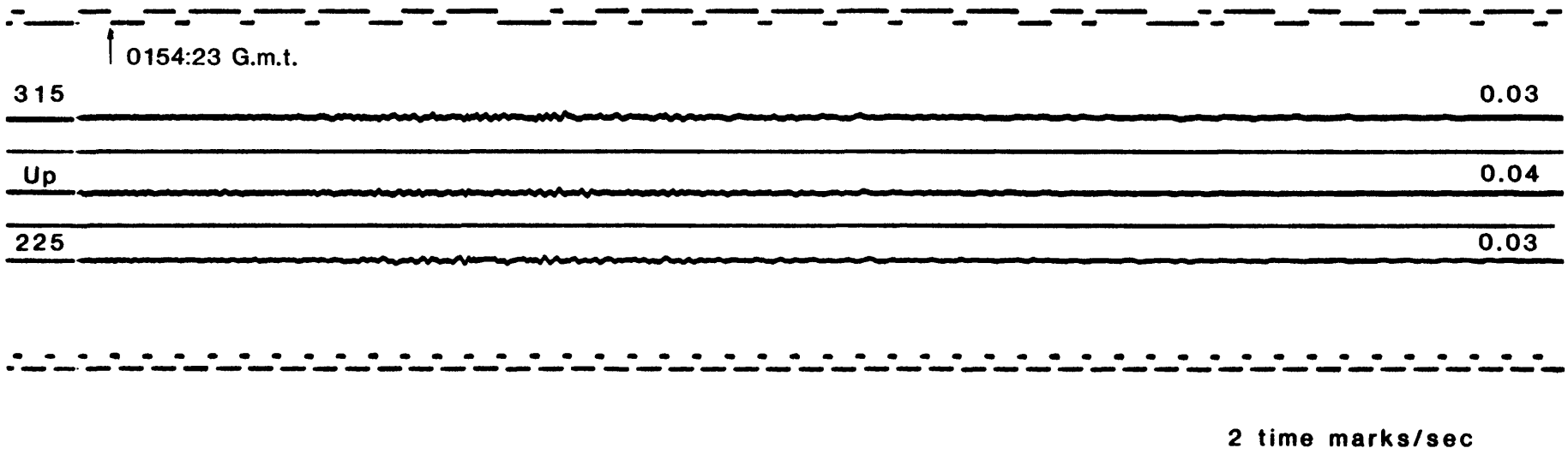
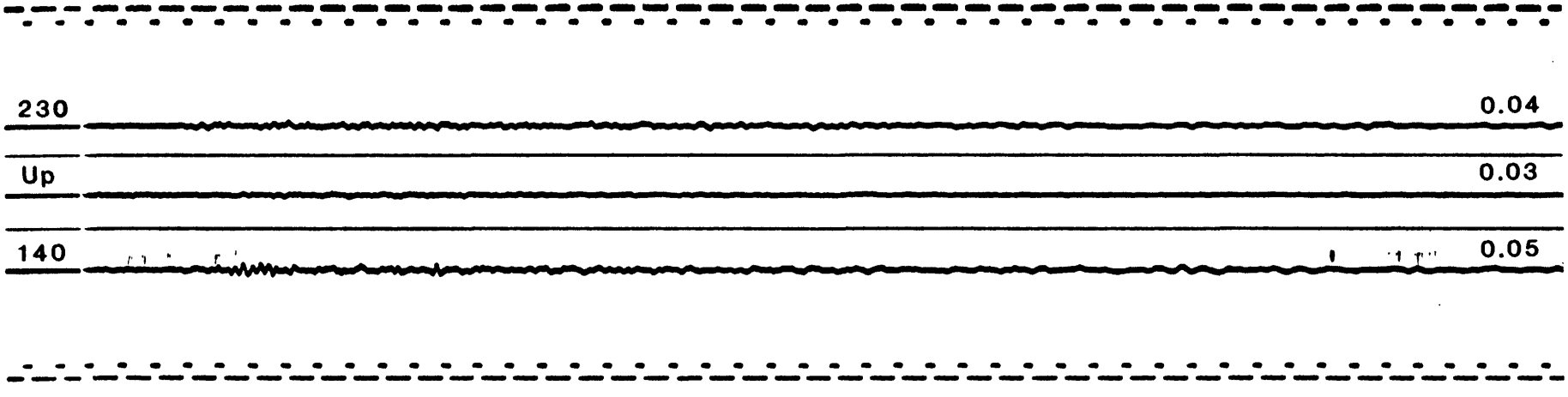


Figure 2. Continued.

OCOTILLO WELLS



EL CENTRO ARRAY 10



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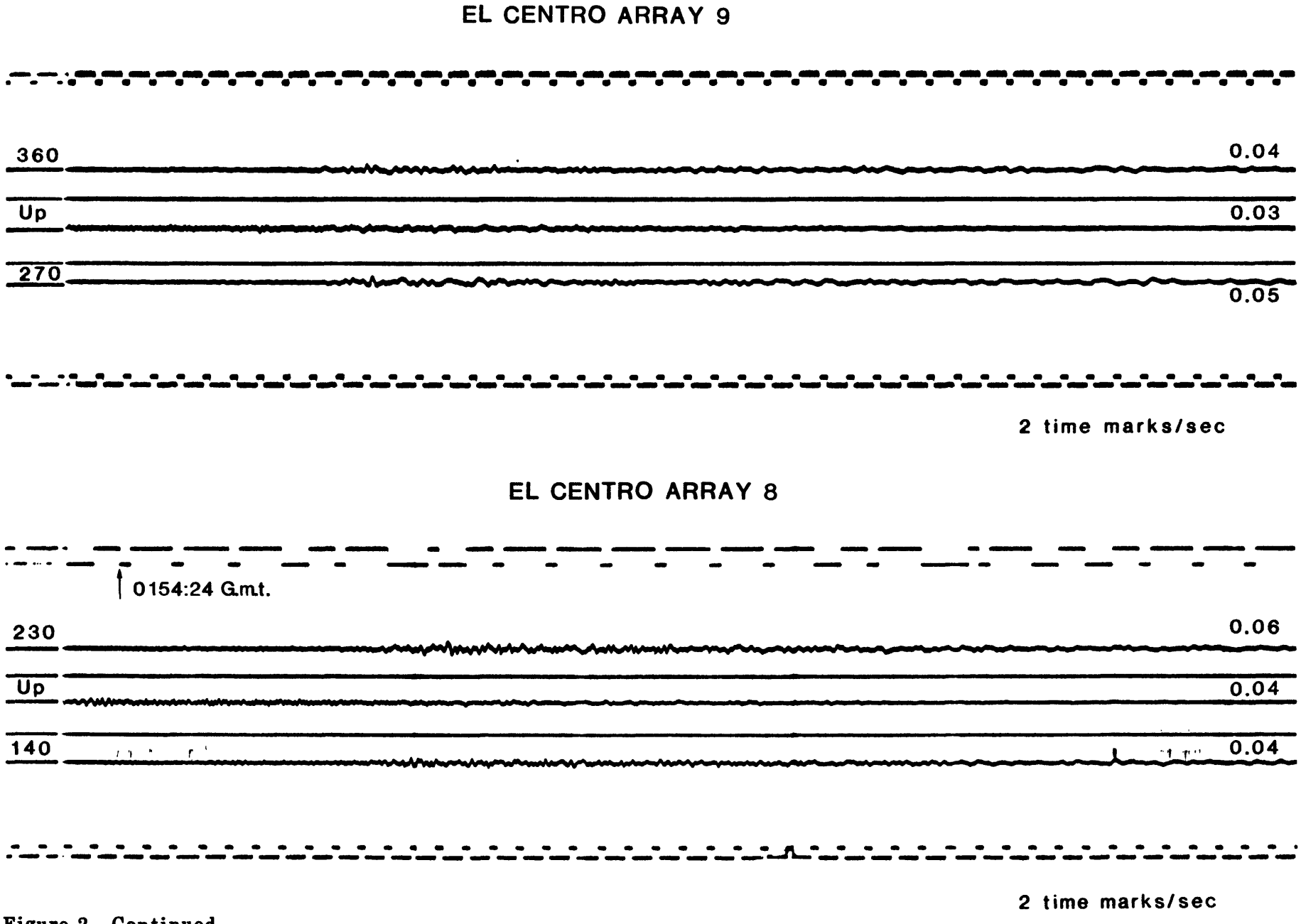

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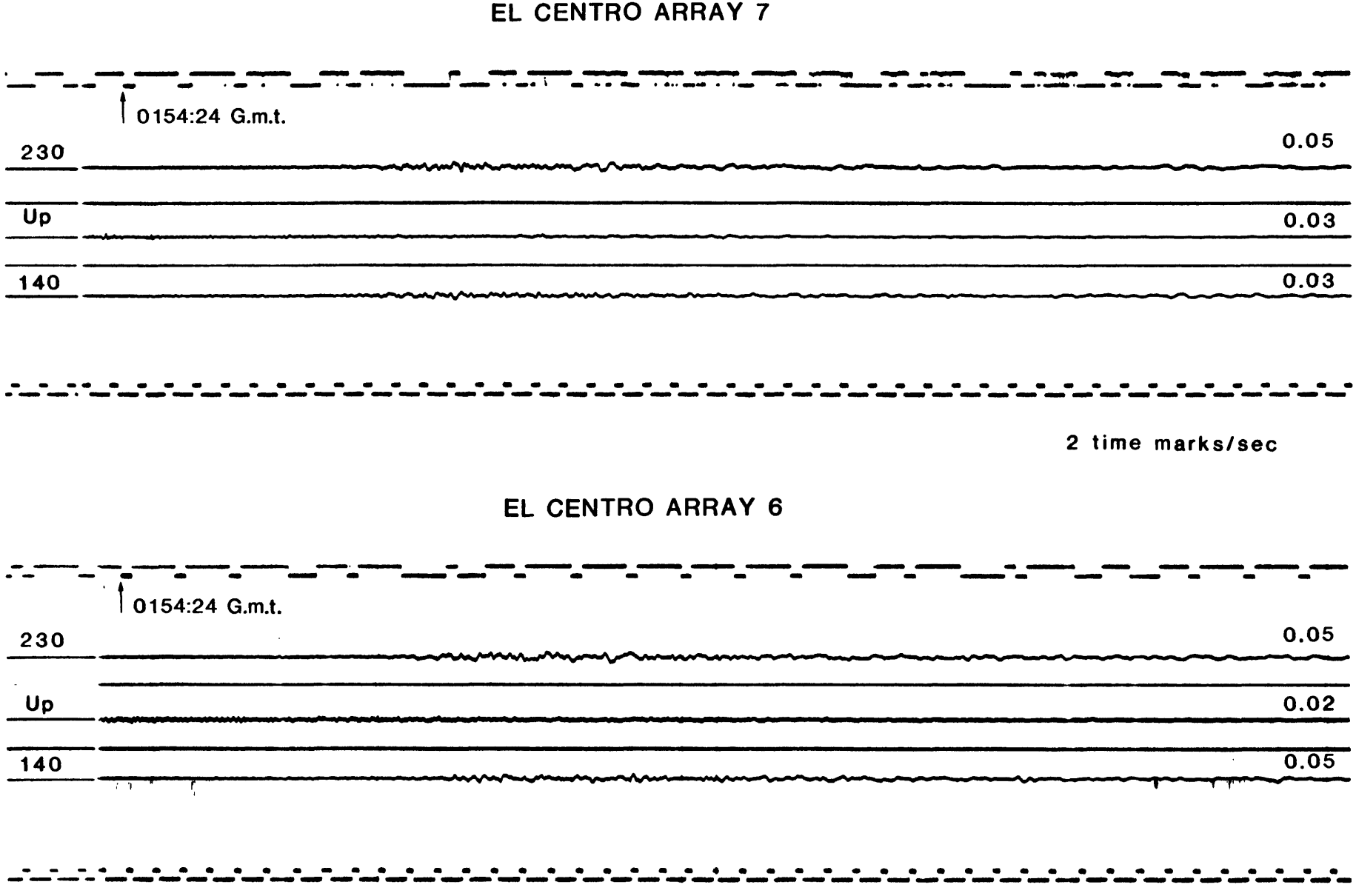

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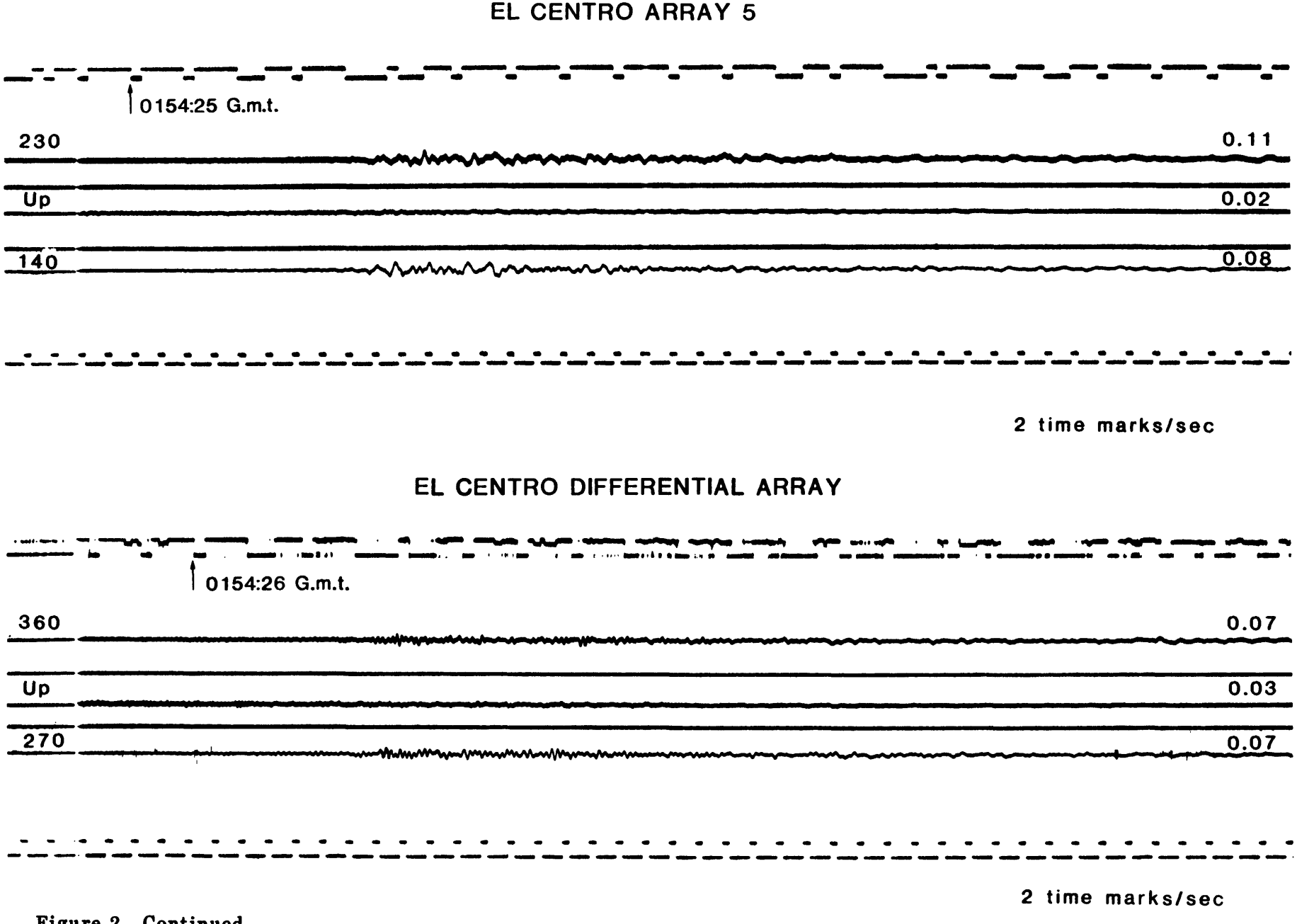

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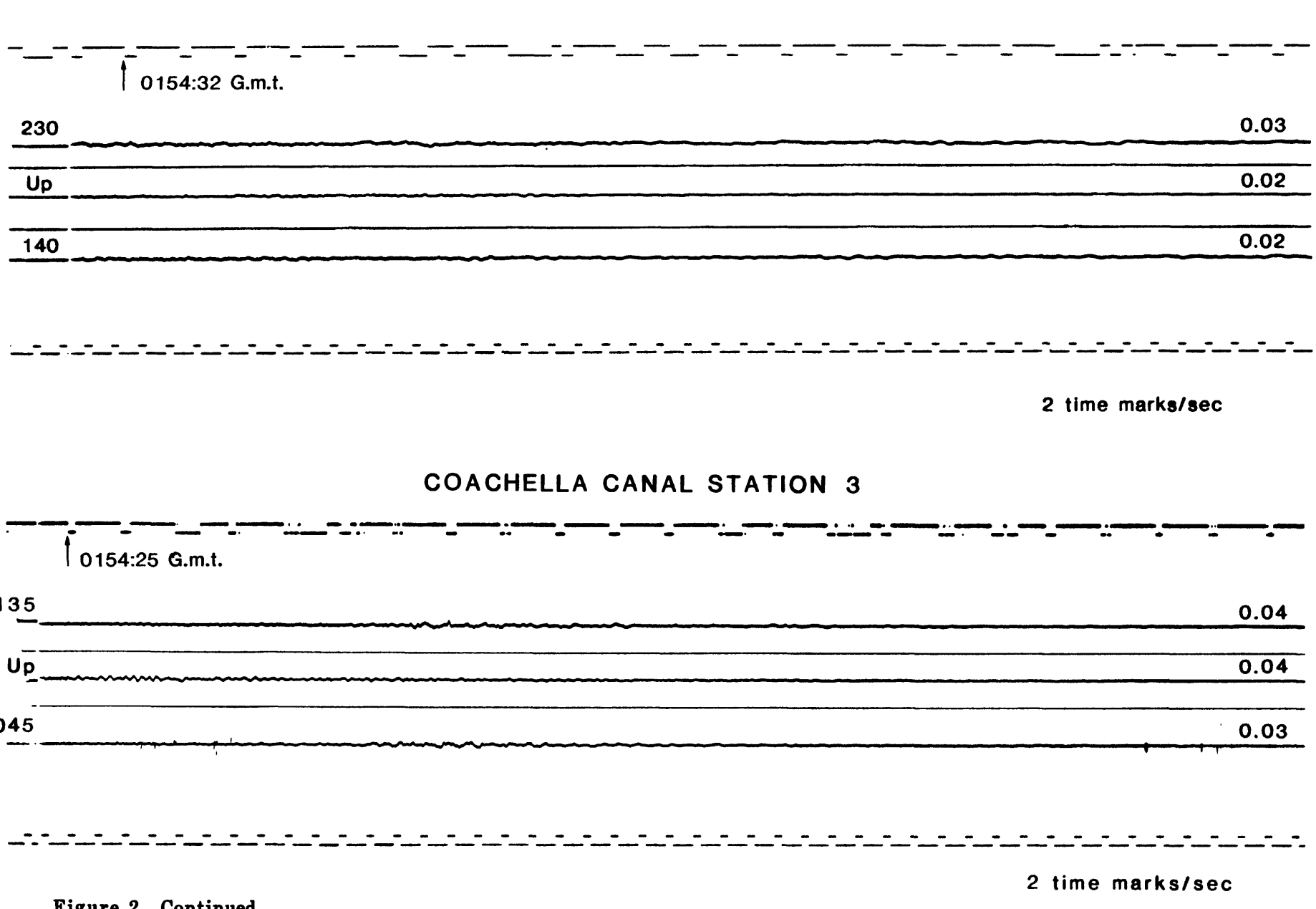

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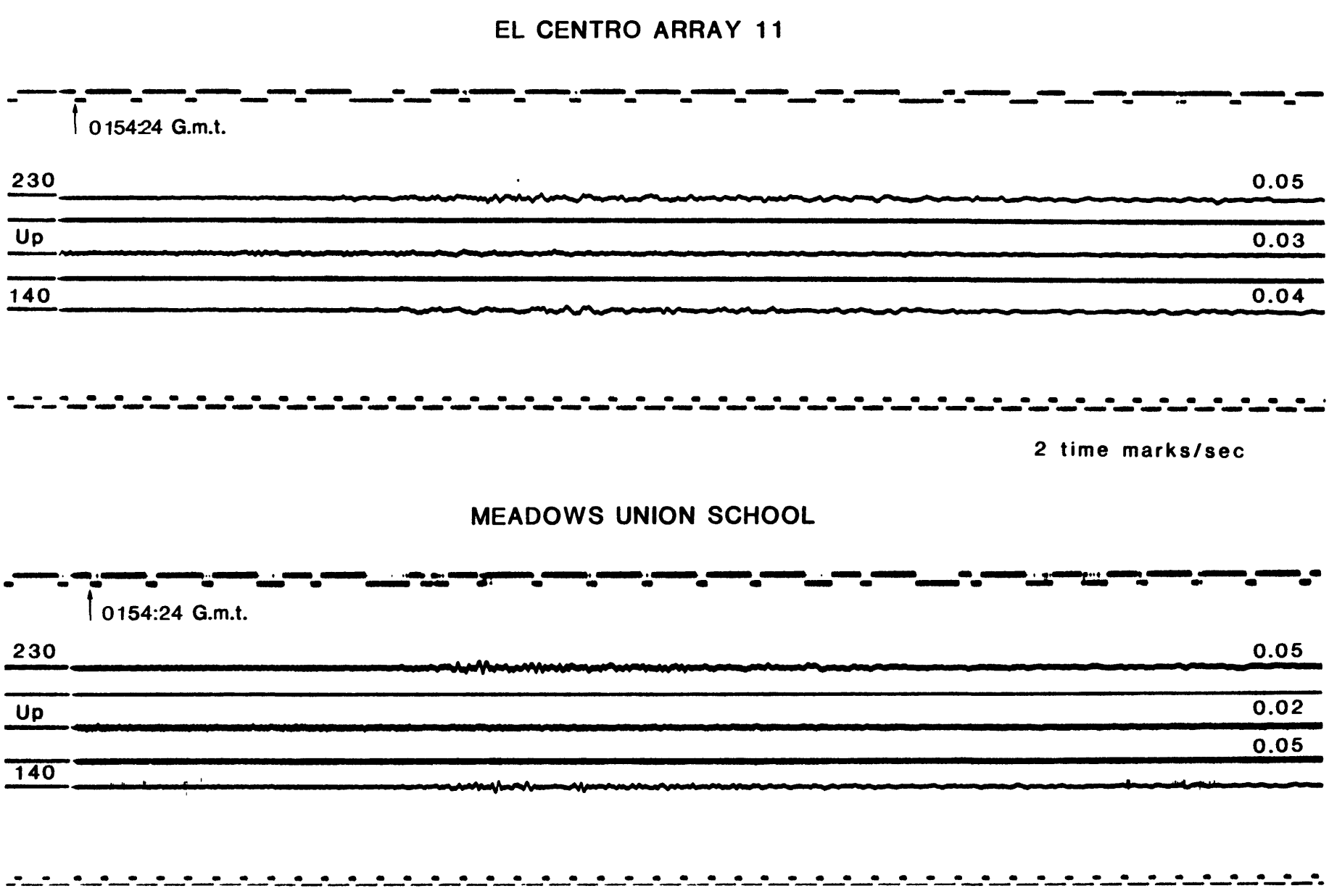

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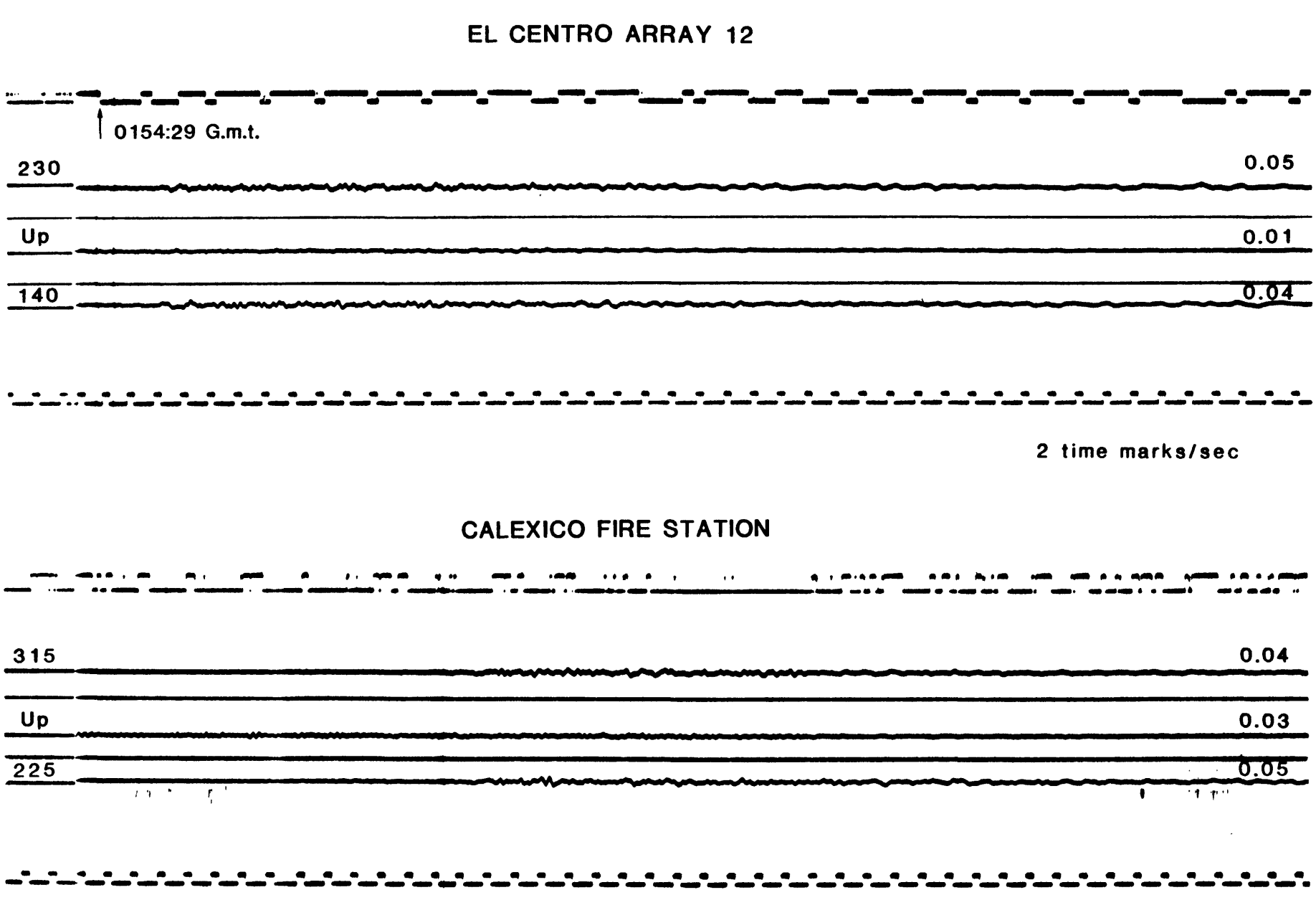

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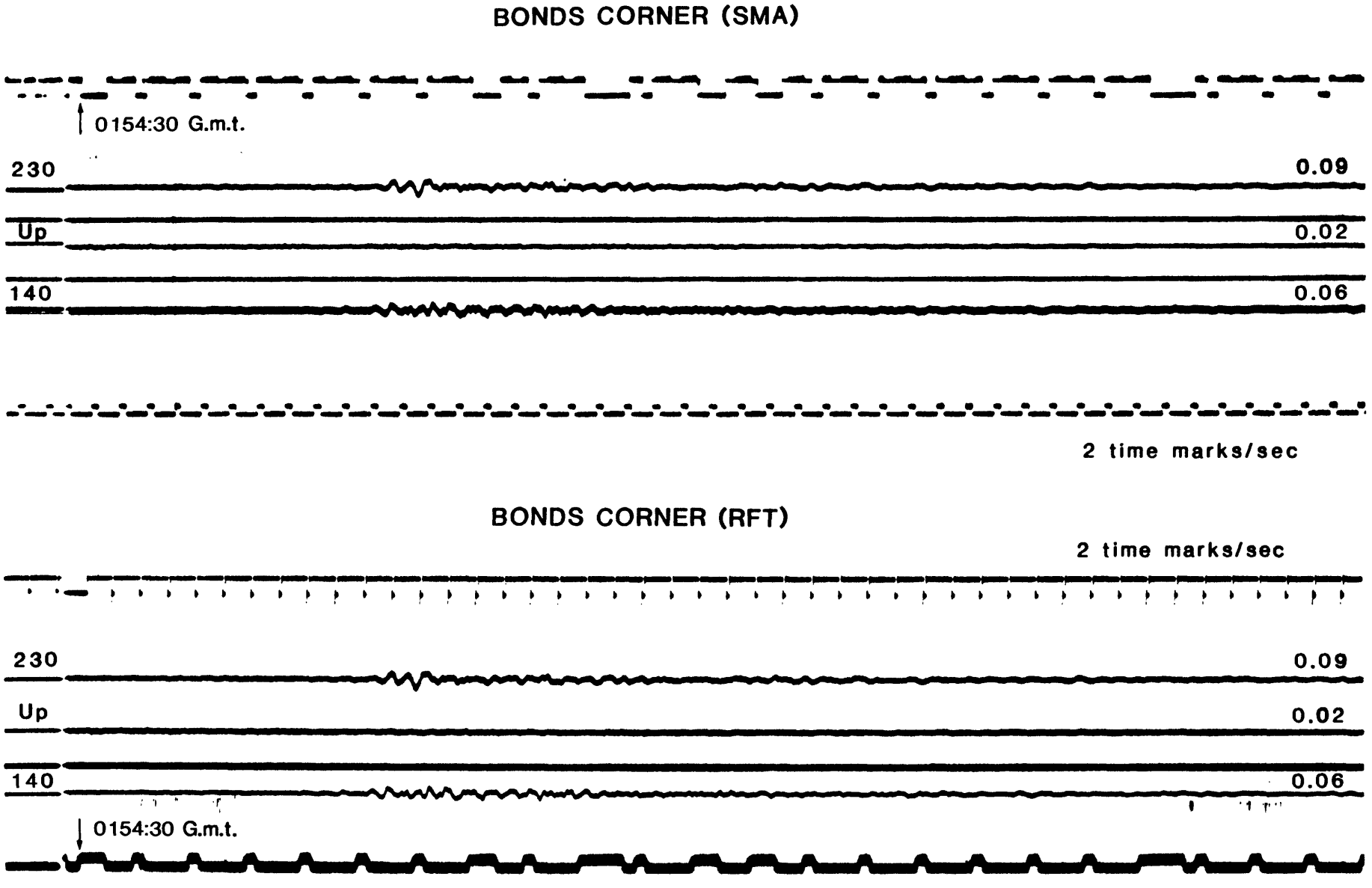

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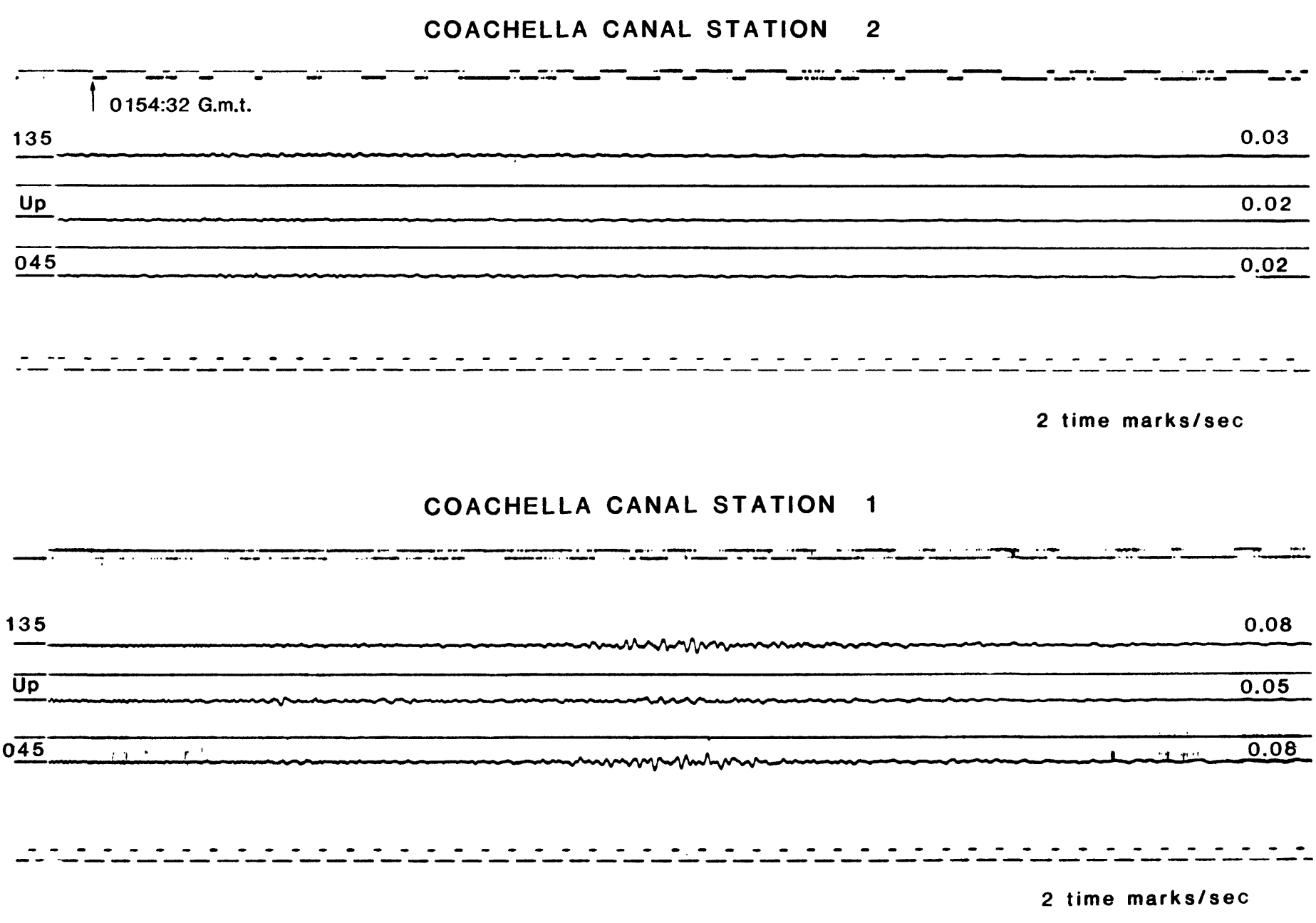

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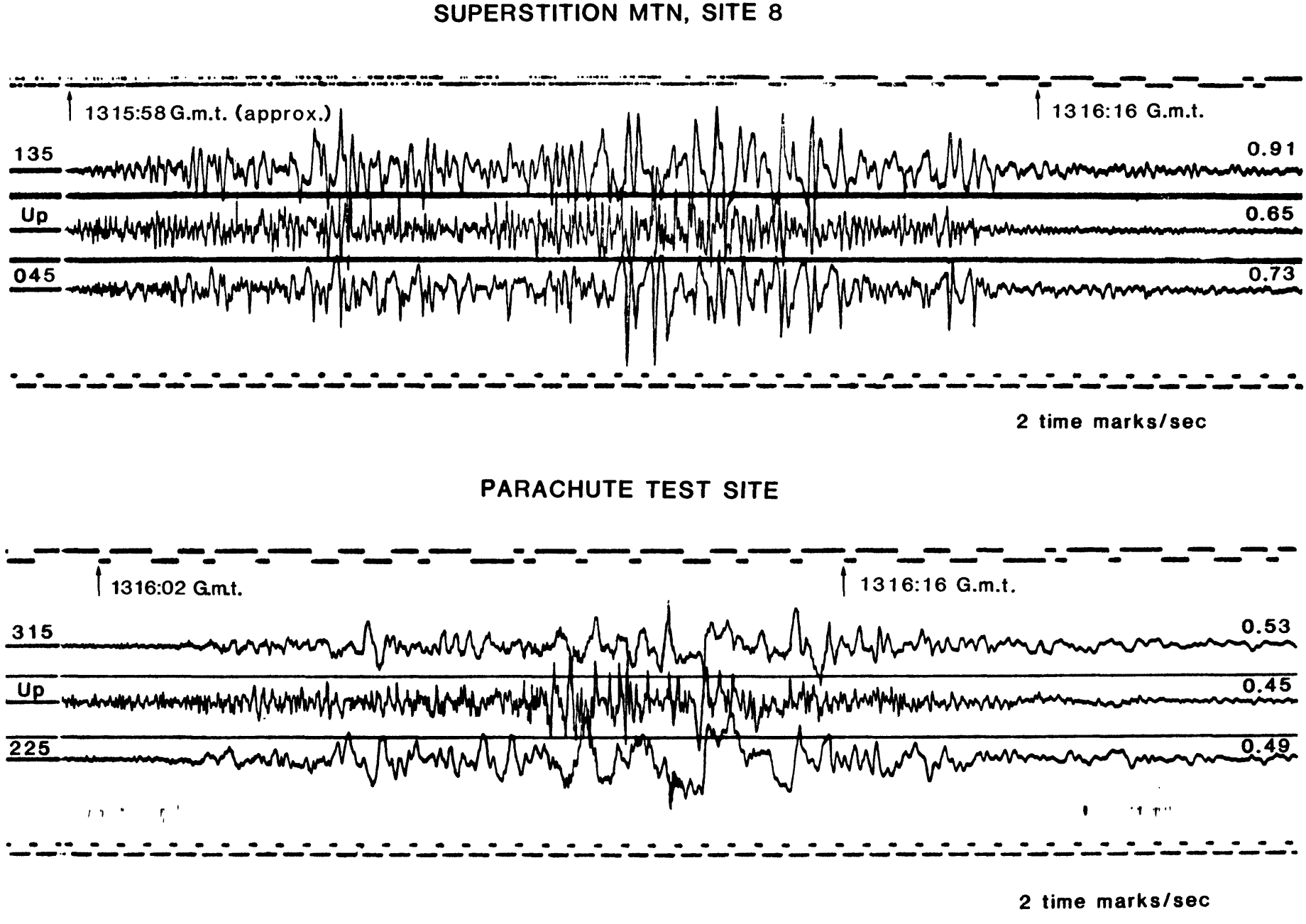
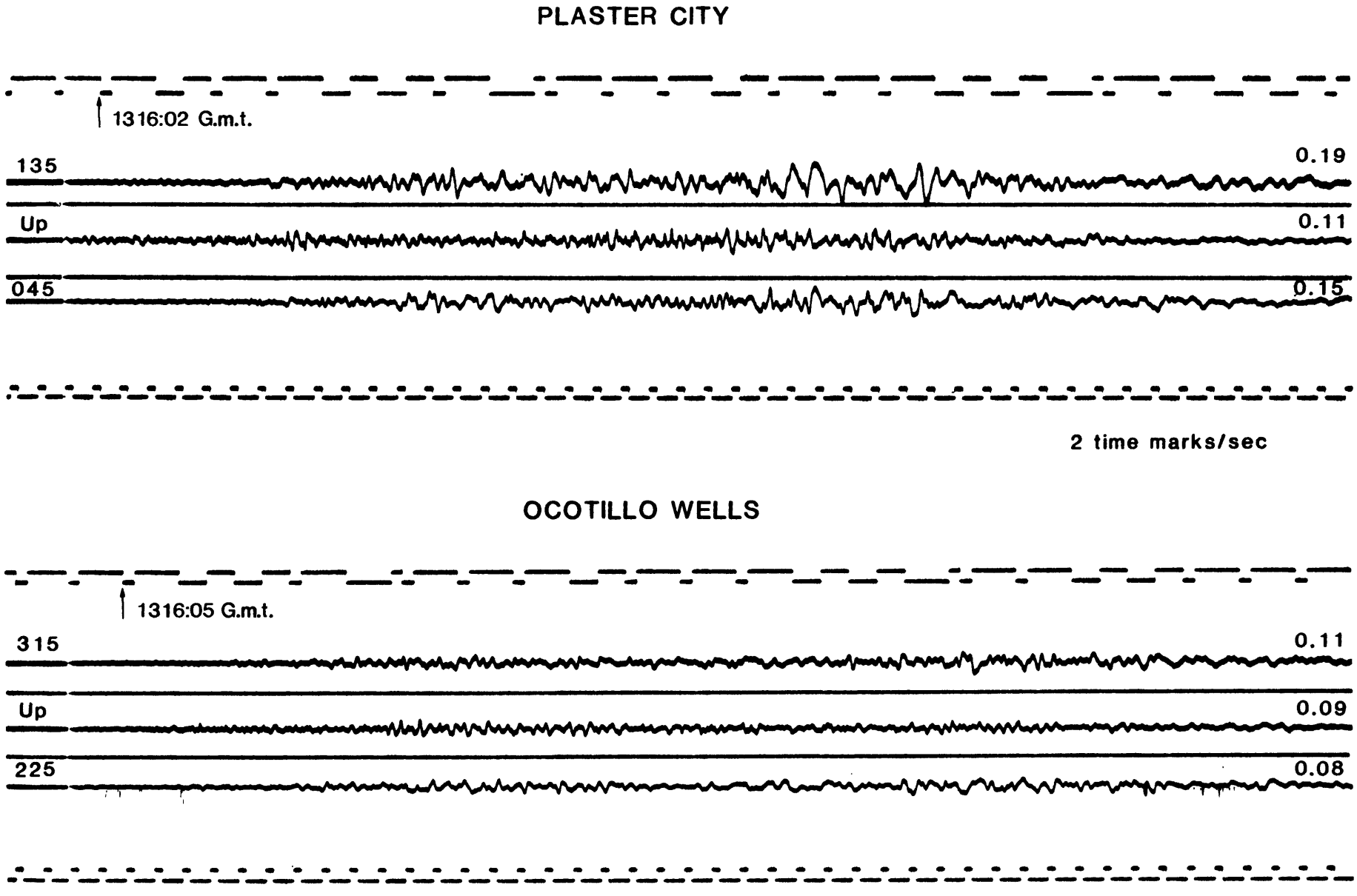


Figure 3. Accelerograms from the Ms=6.6 earthquake.



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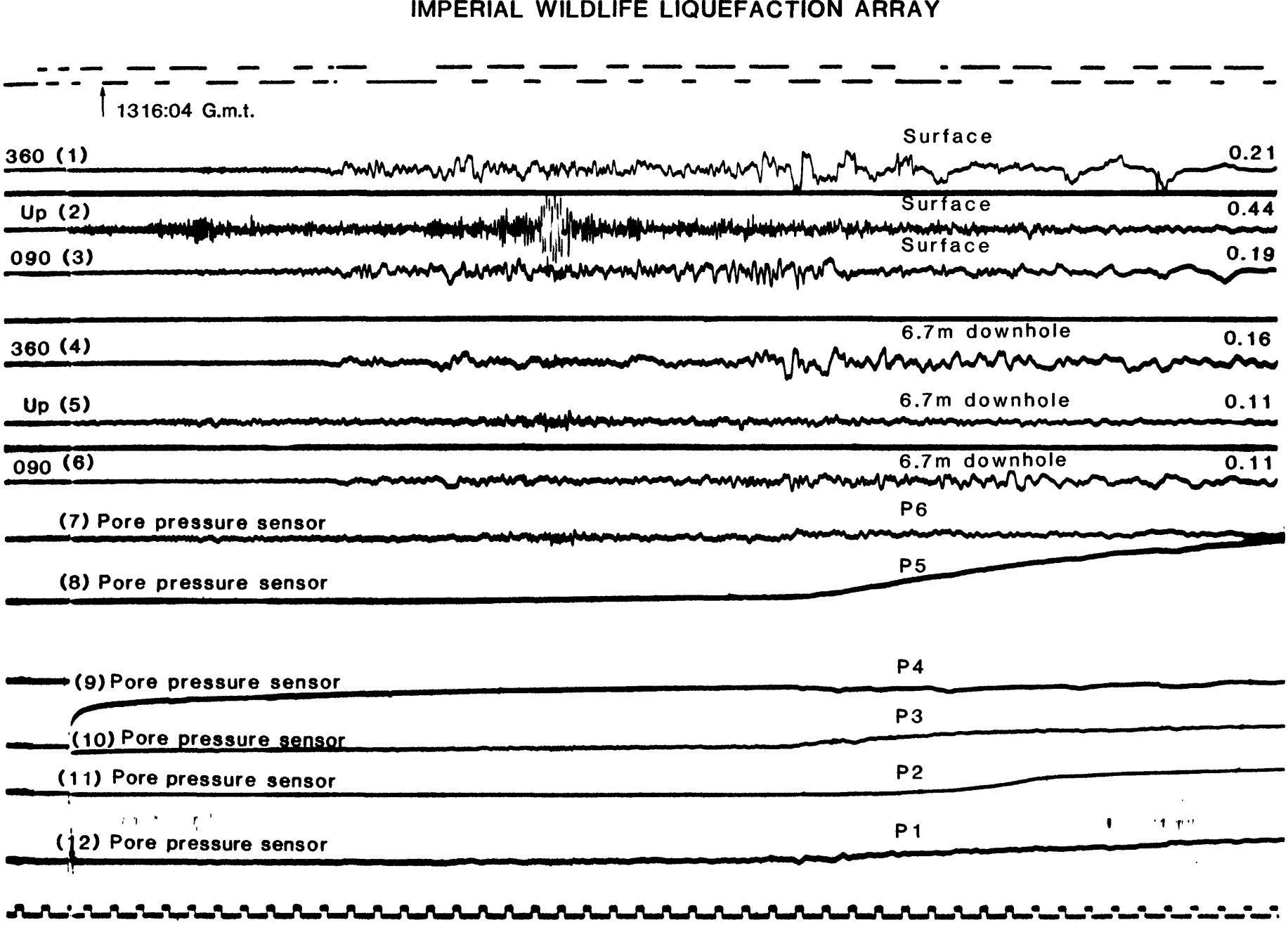
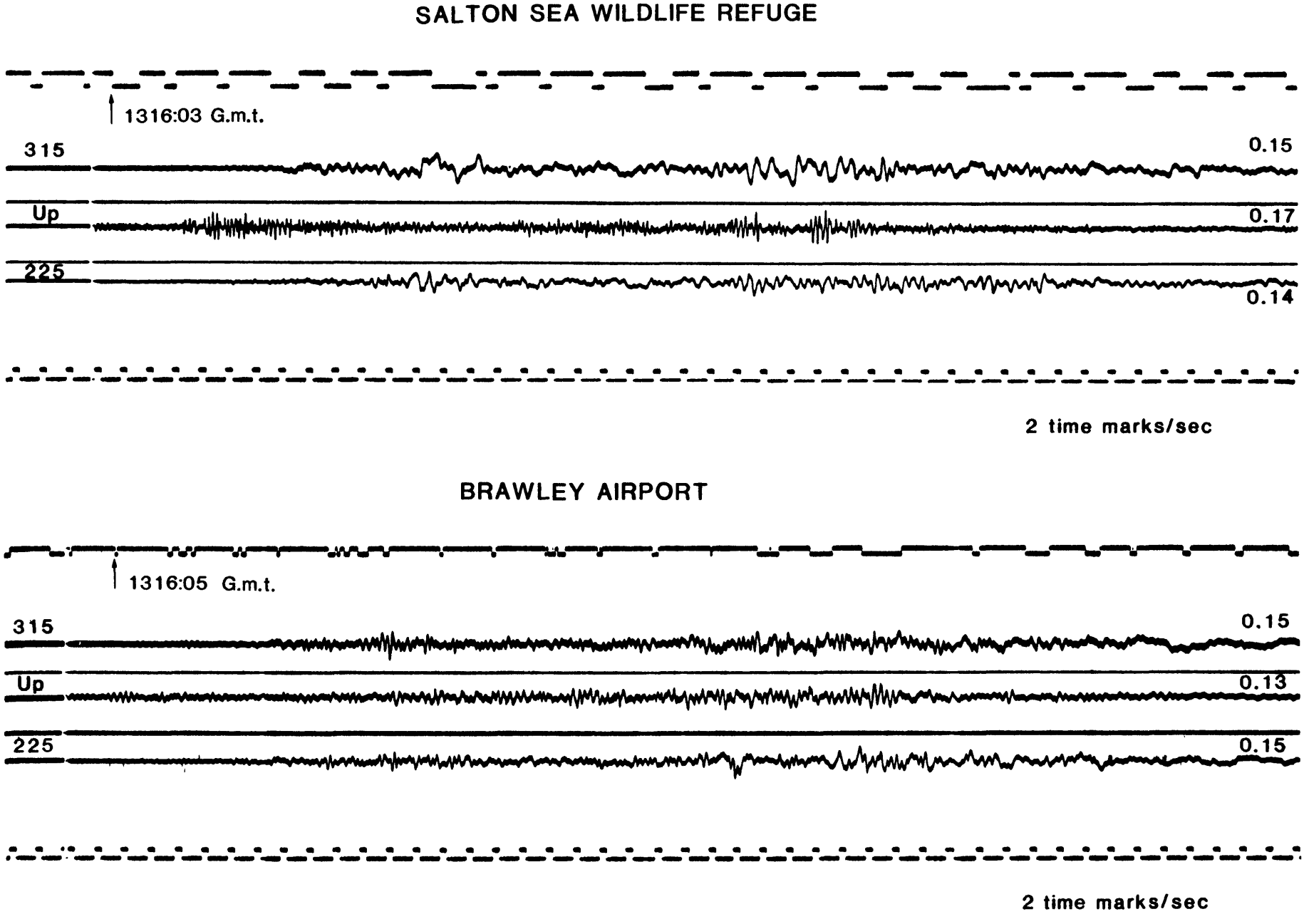


Figure 3. Continued.



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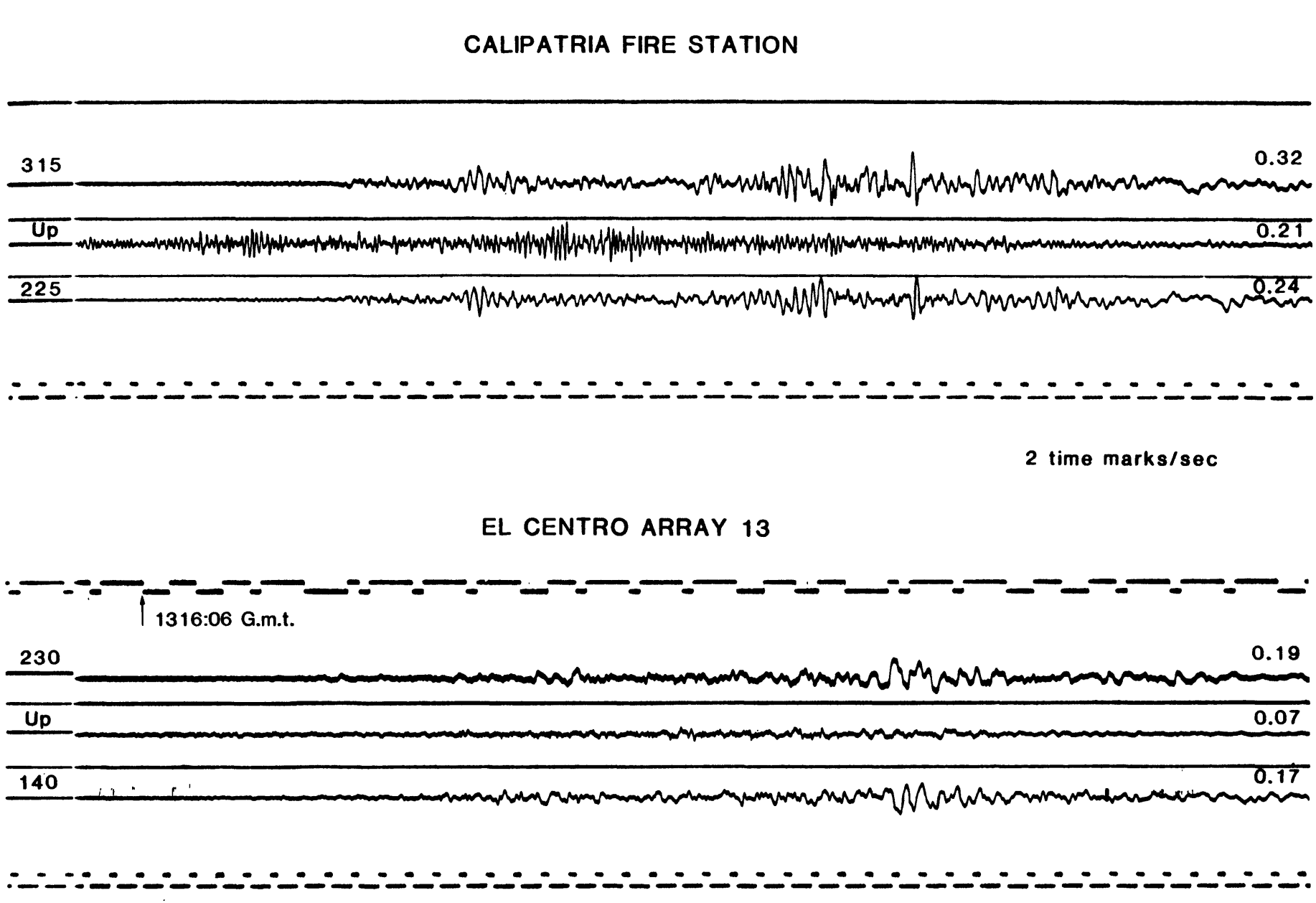

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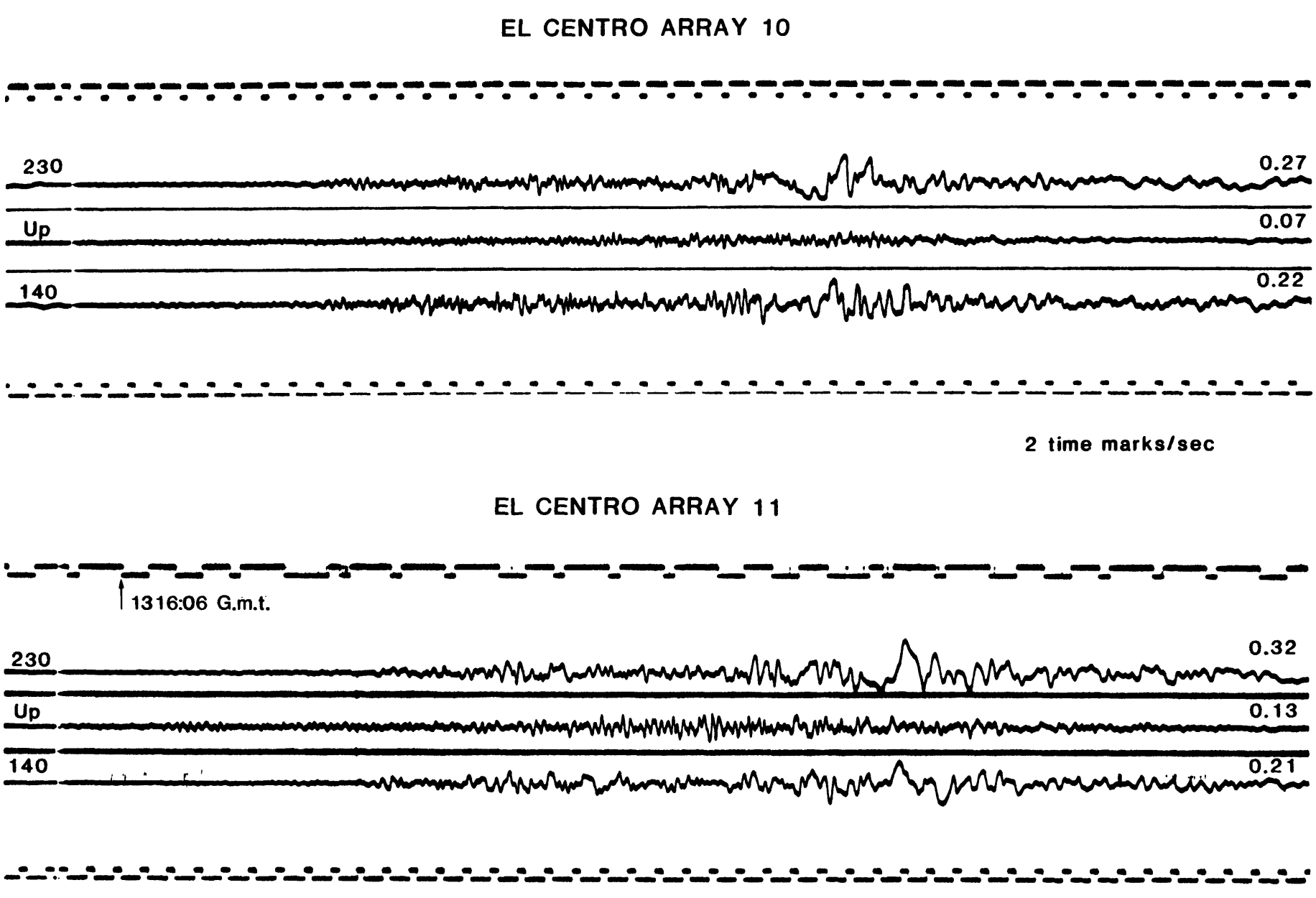

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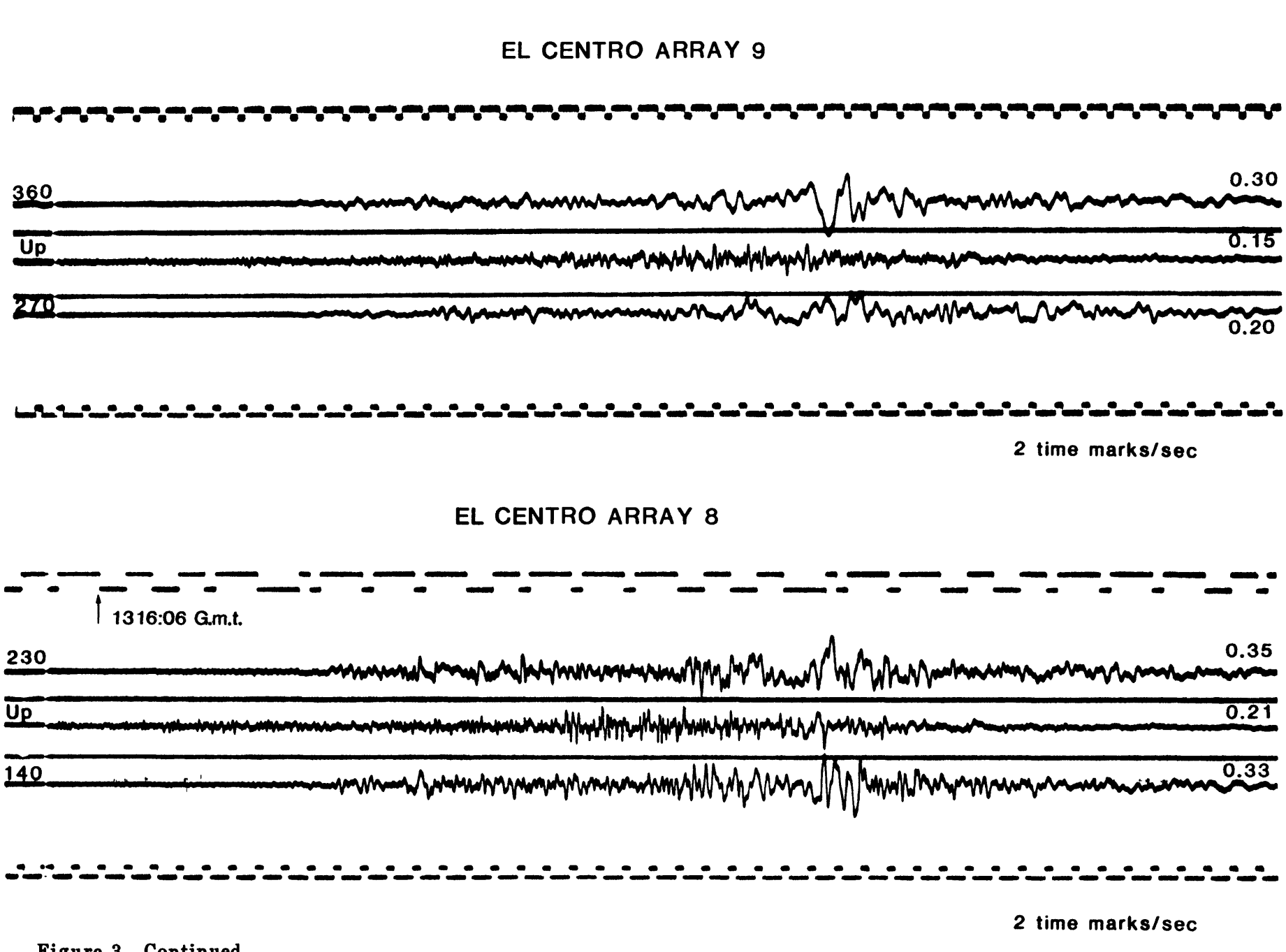
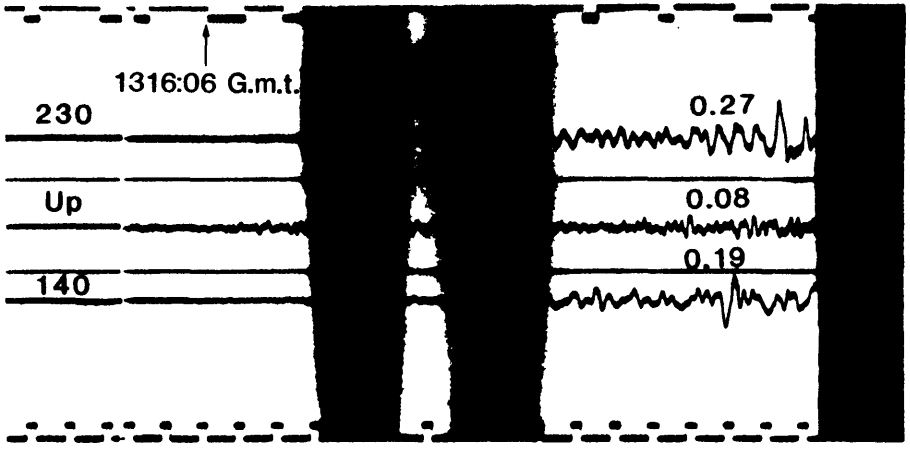


Figure 3. Continued.

EL CENTRO ARRAY 12



2 time marks/sec

EL CENTRO ARRAY 7

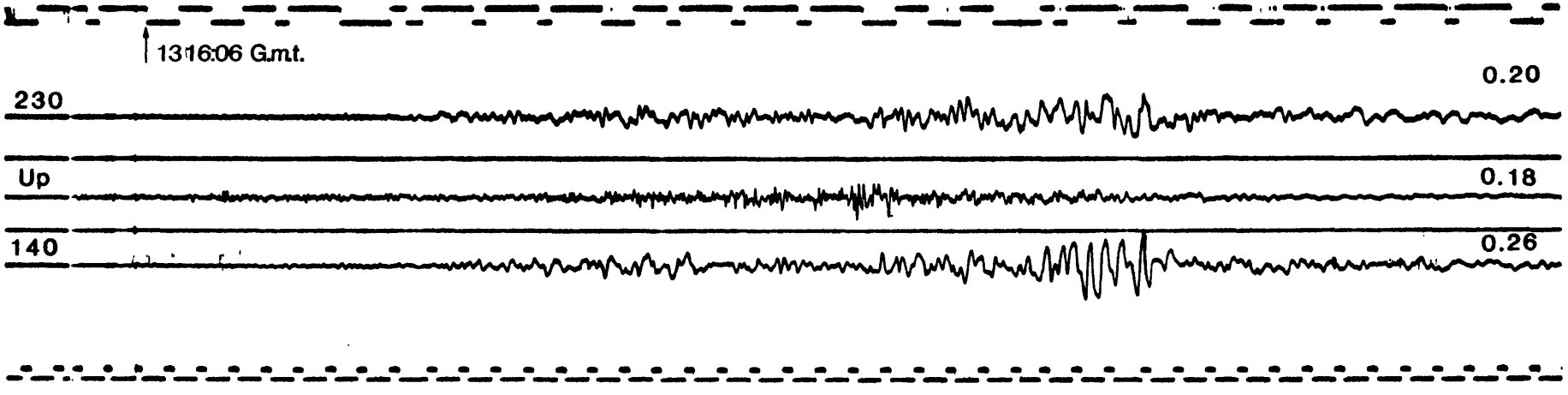
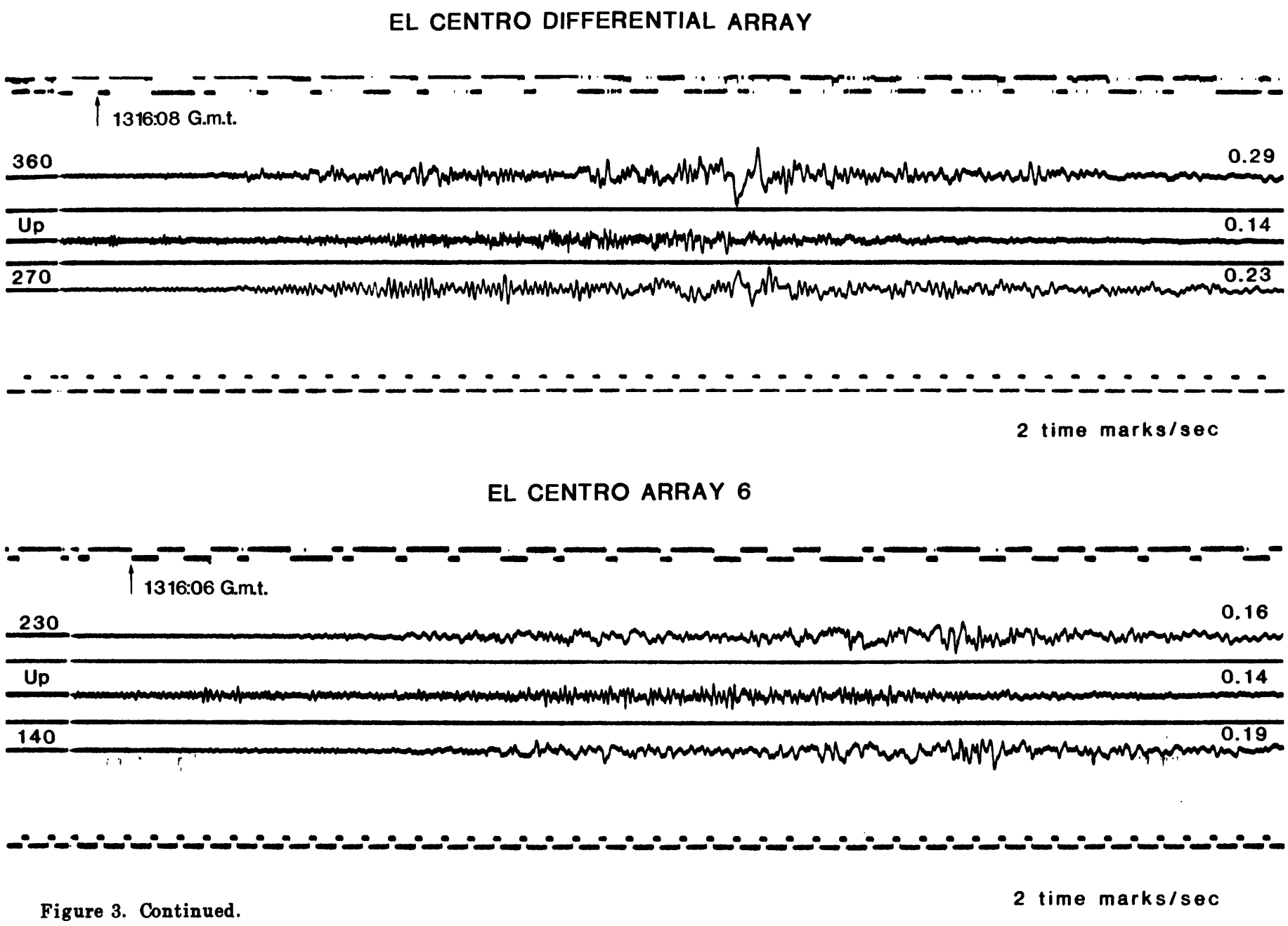


Figure 3. Continued.

2 time marks/sec



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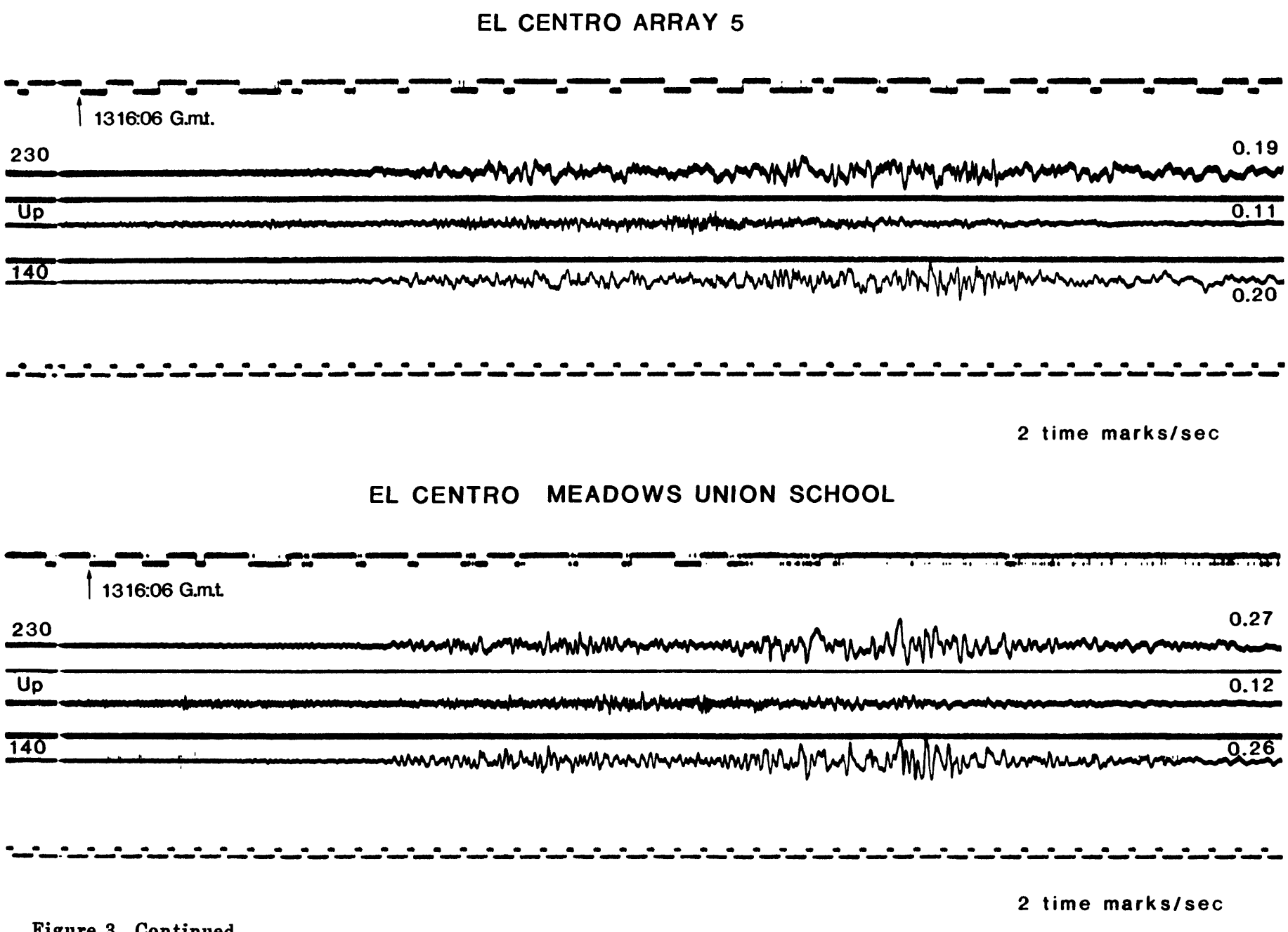

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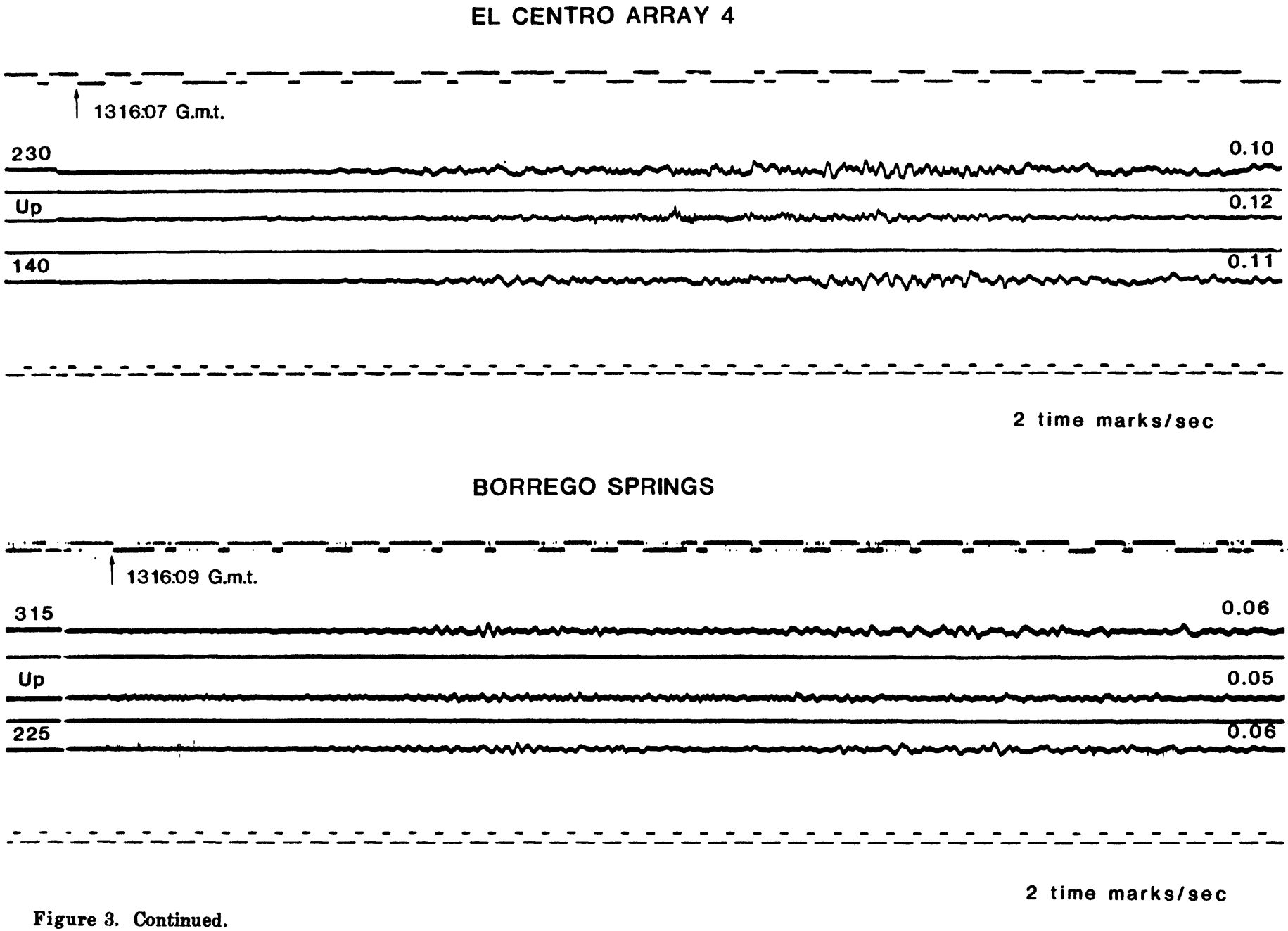

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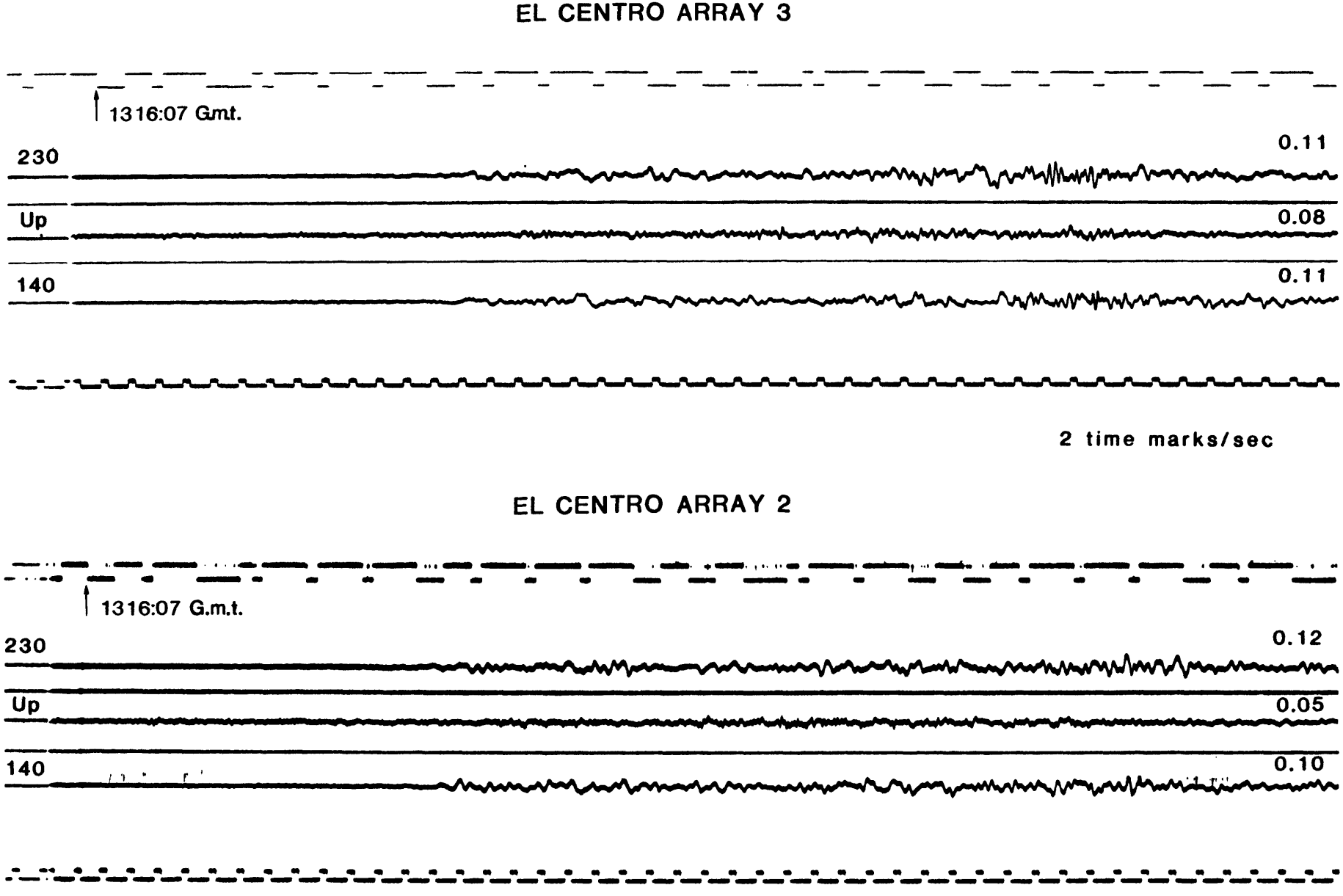

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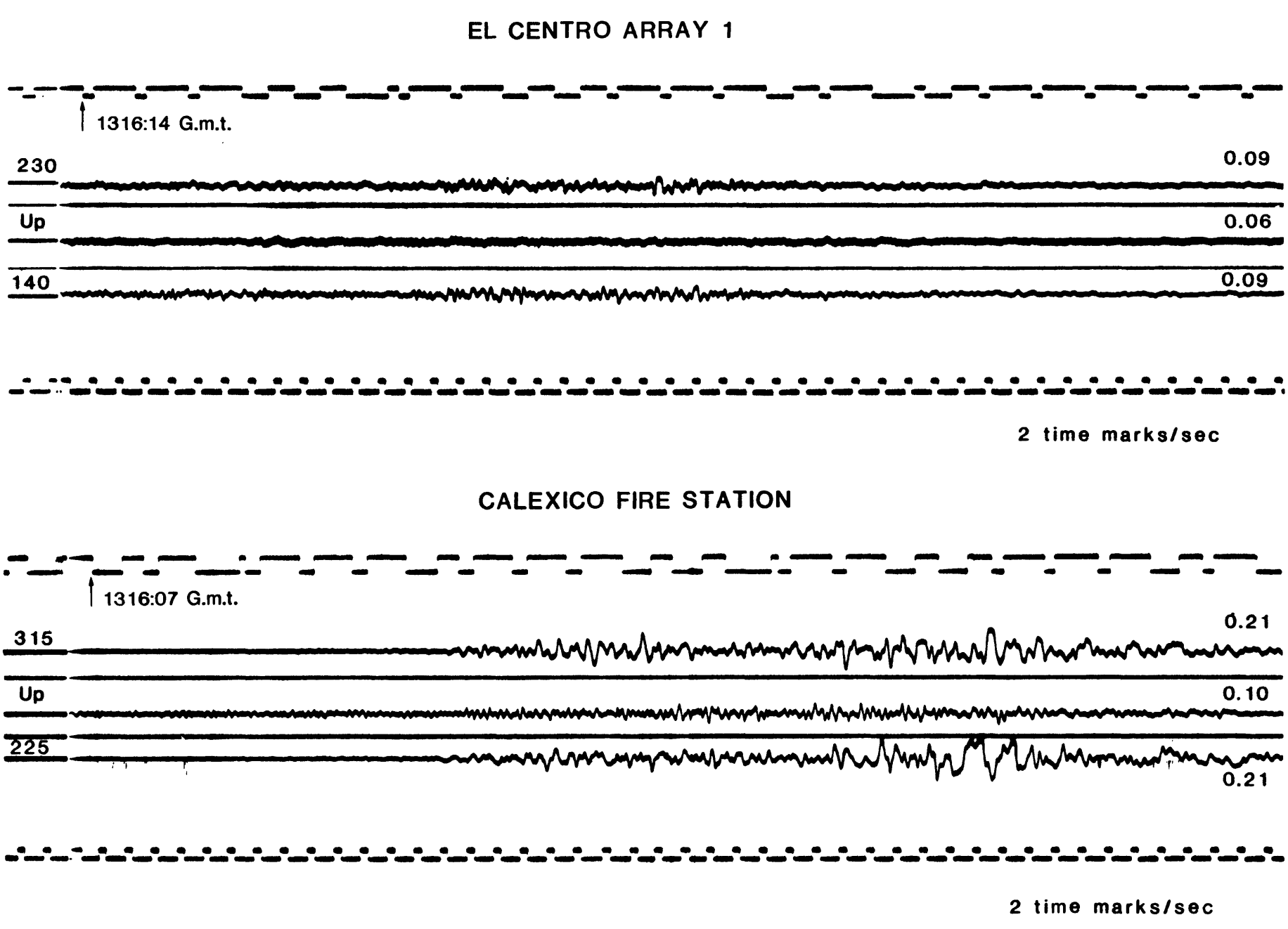

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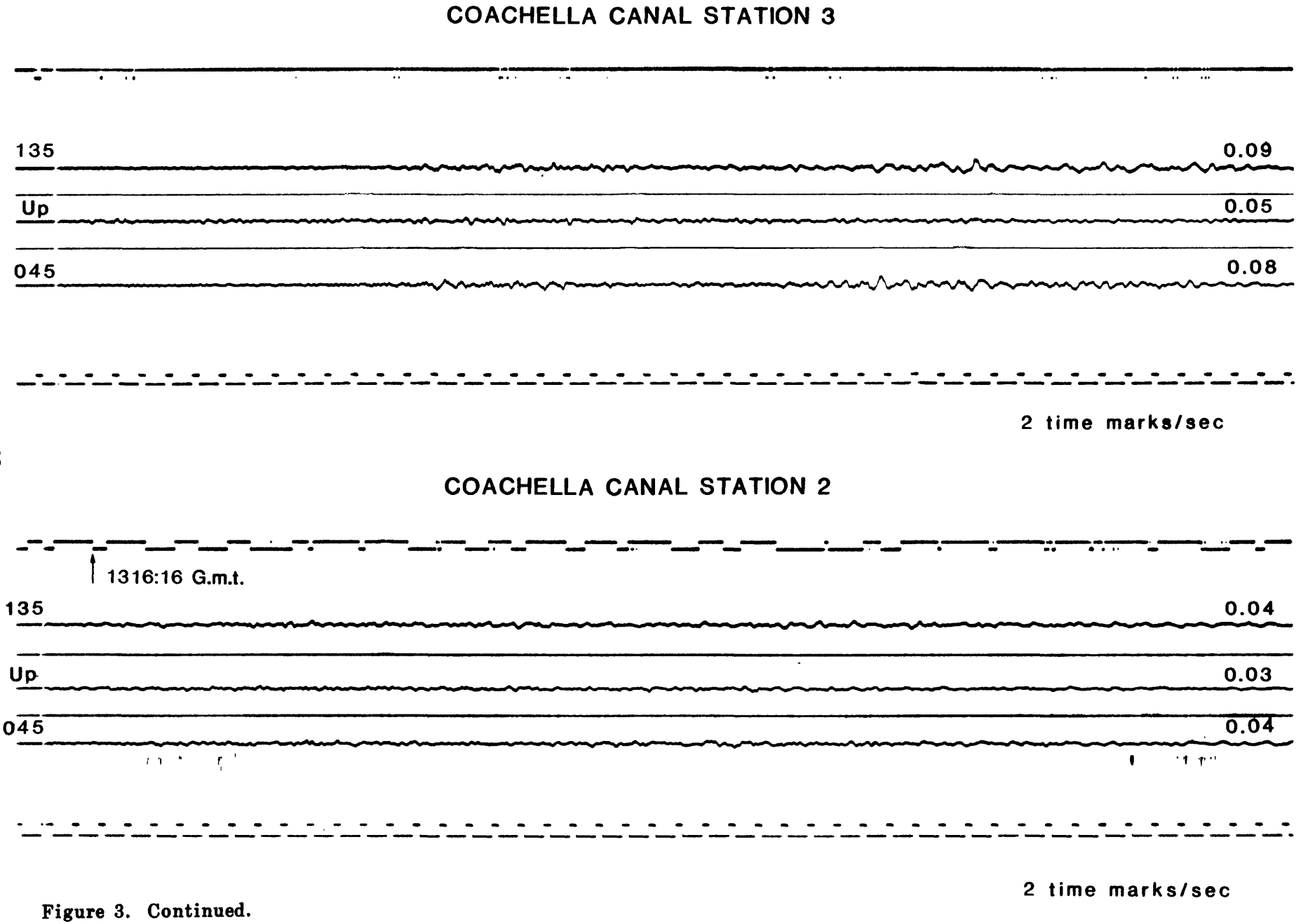

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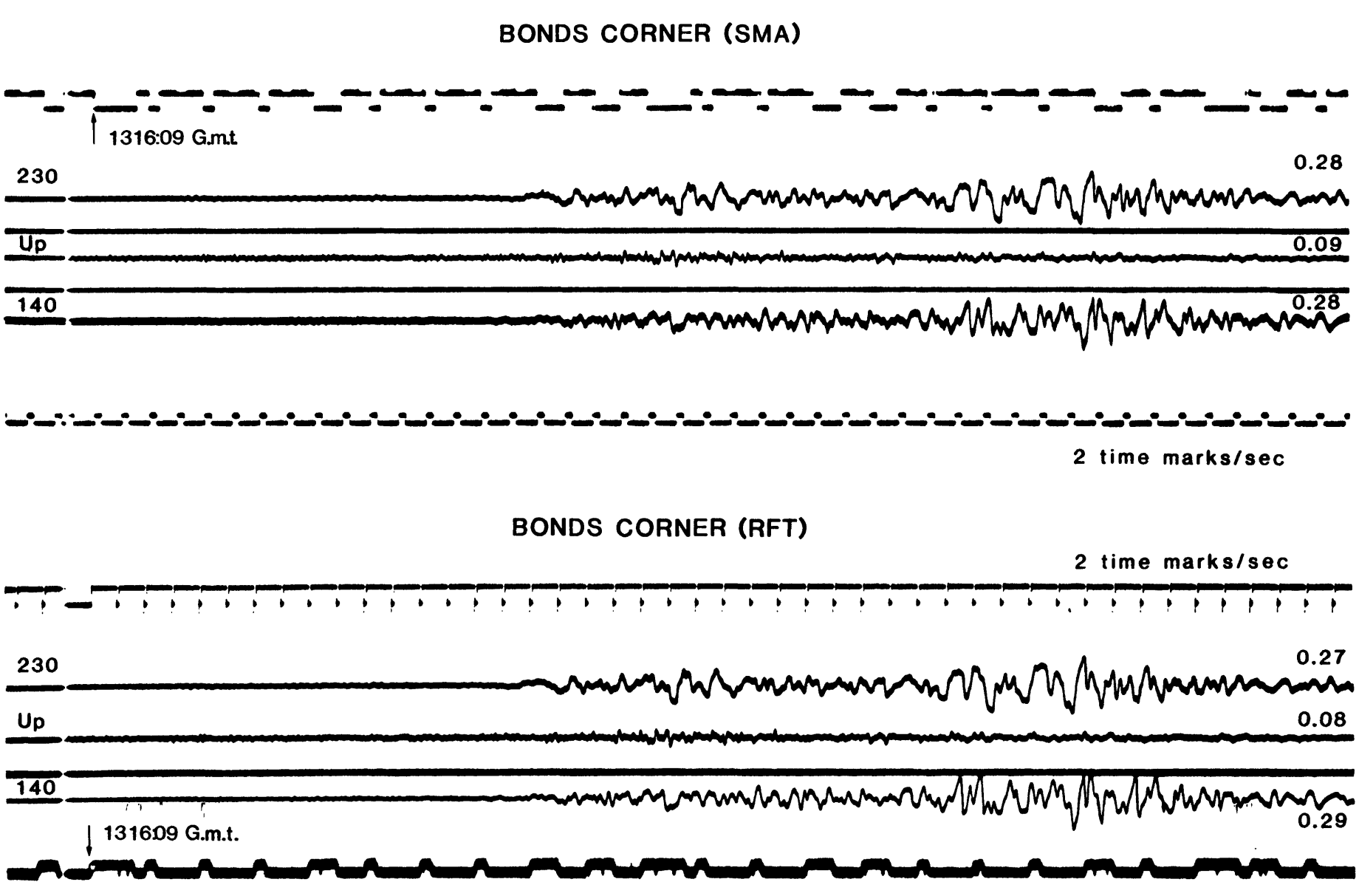

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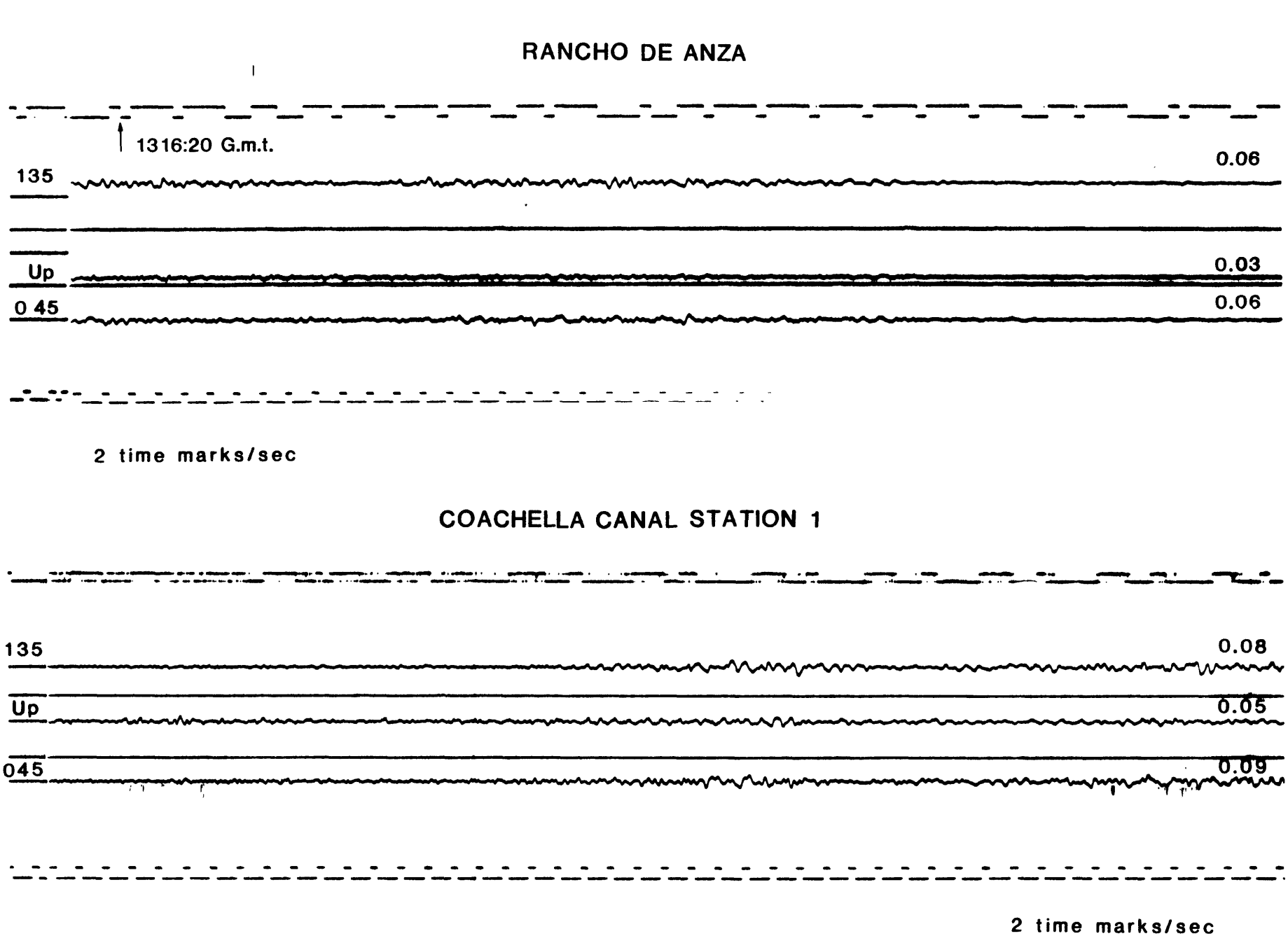

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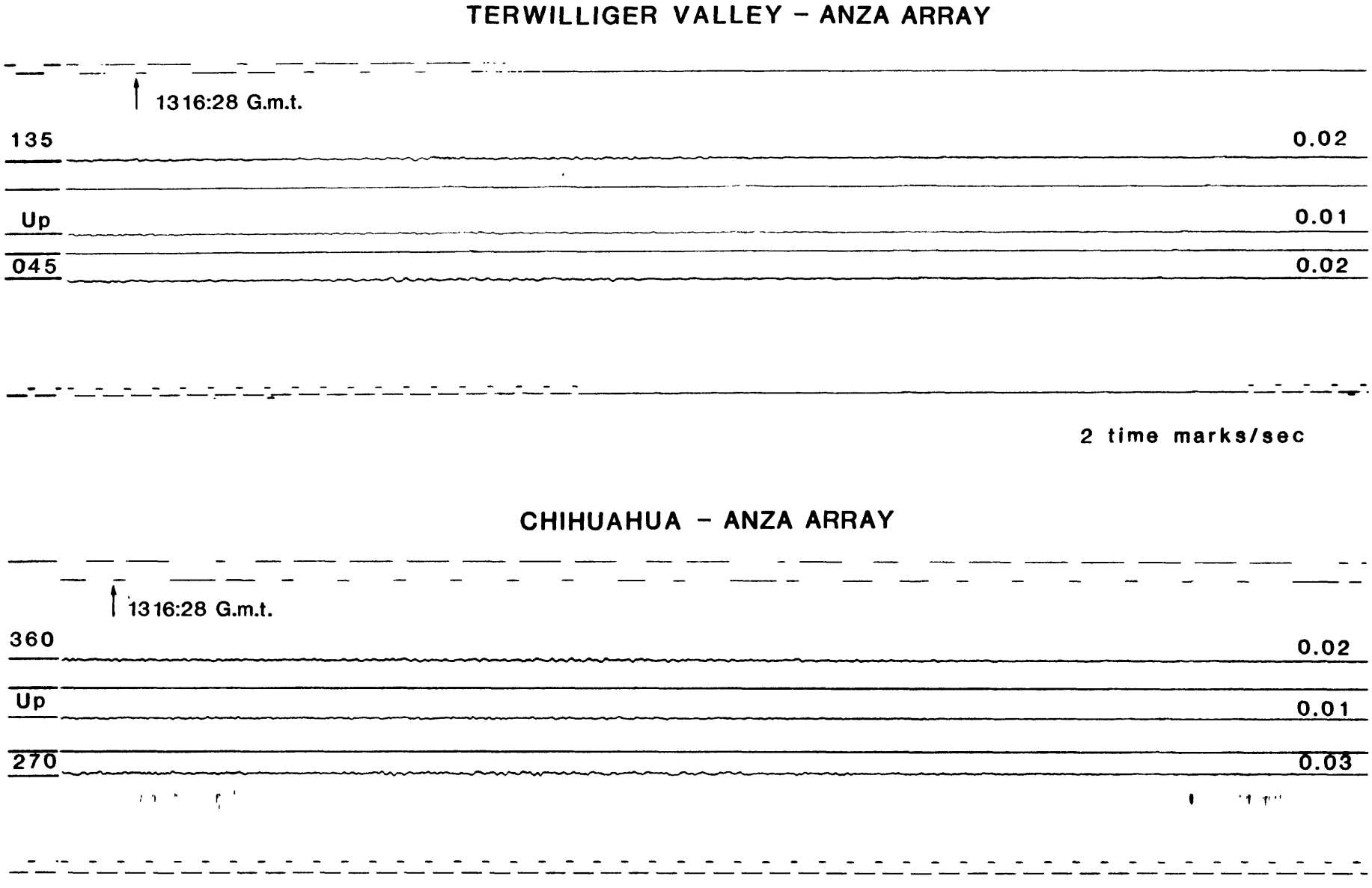

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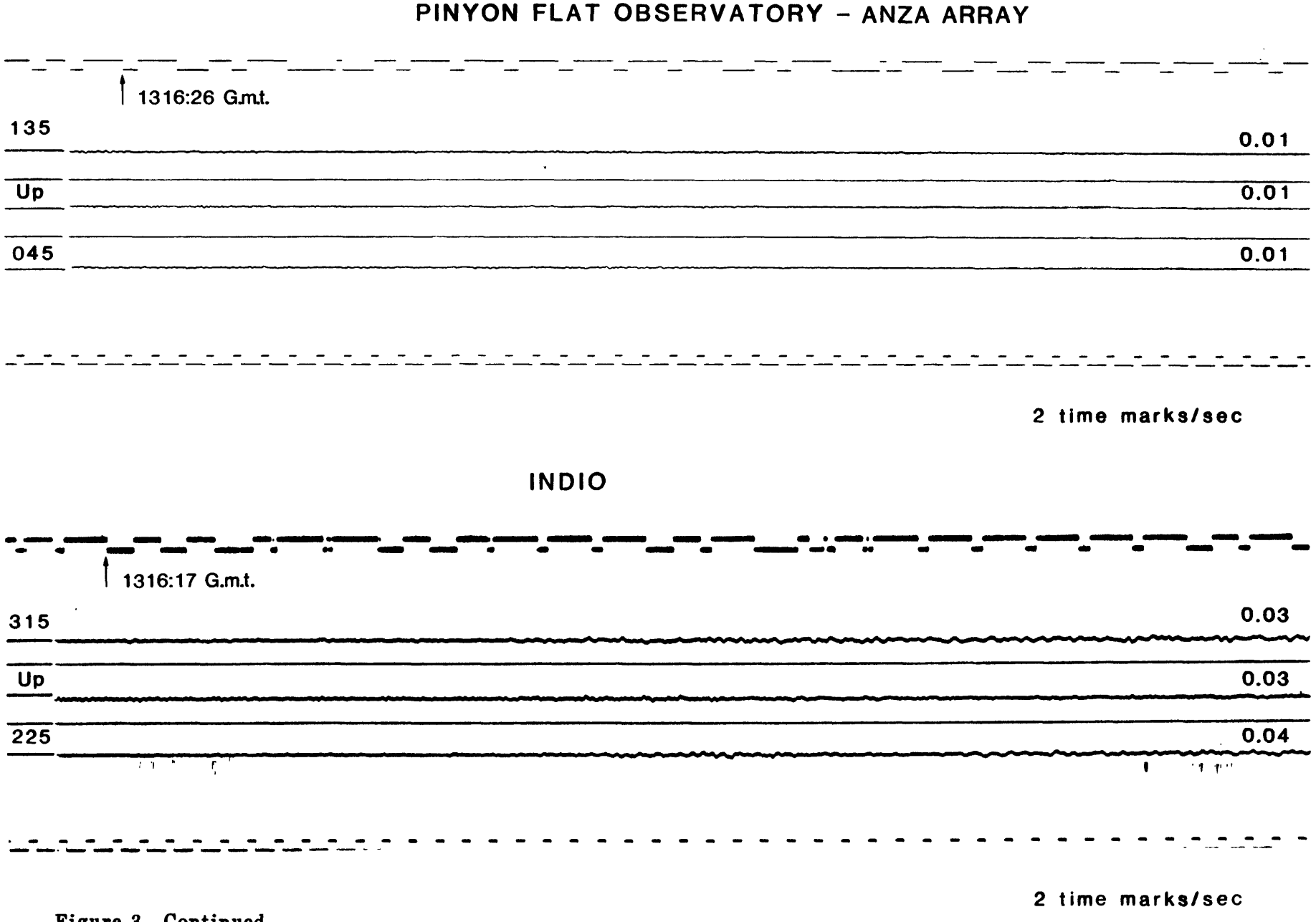

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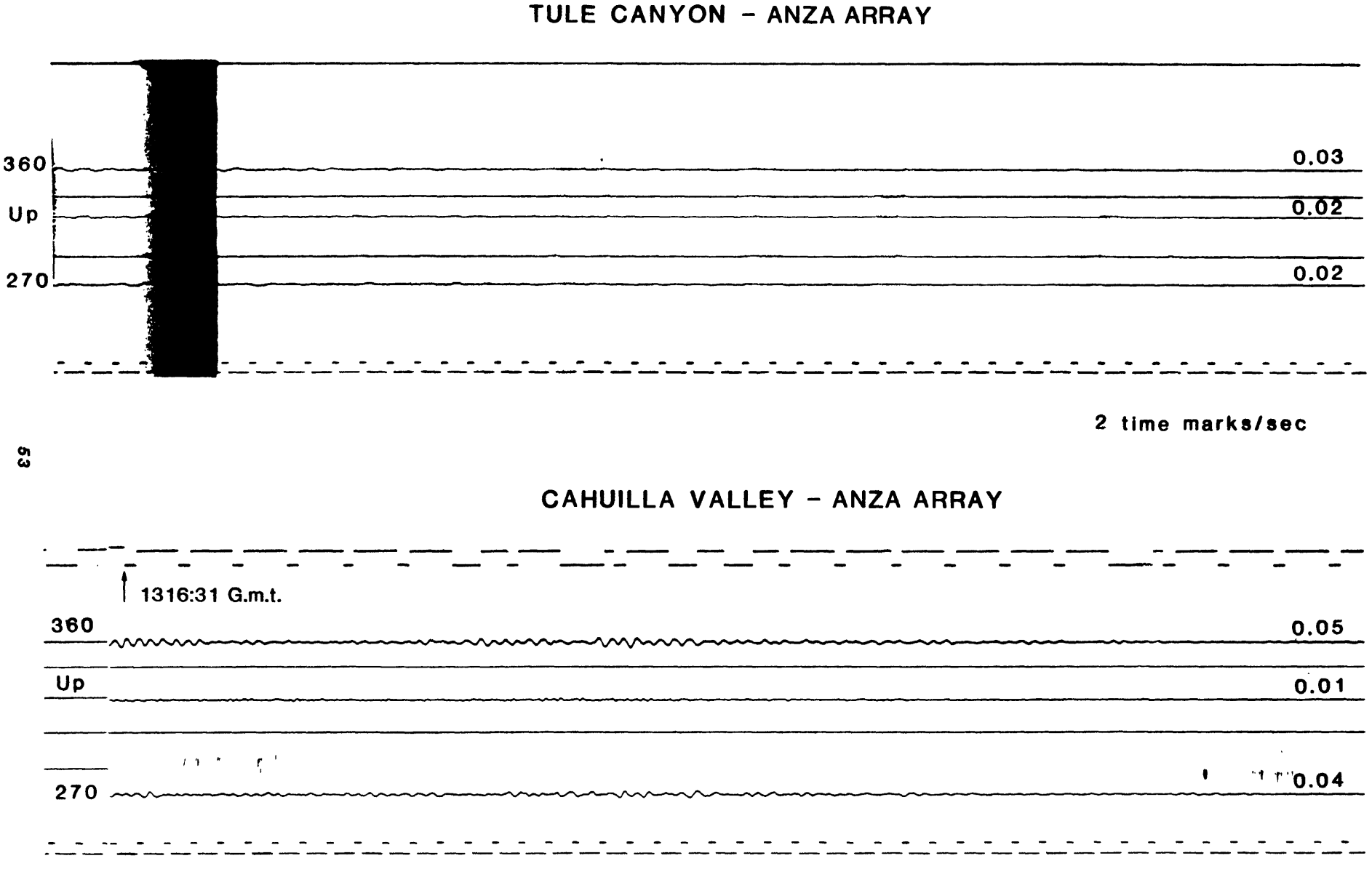

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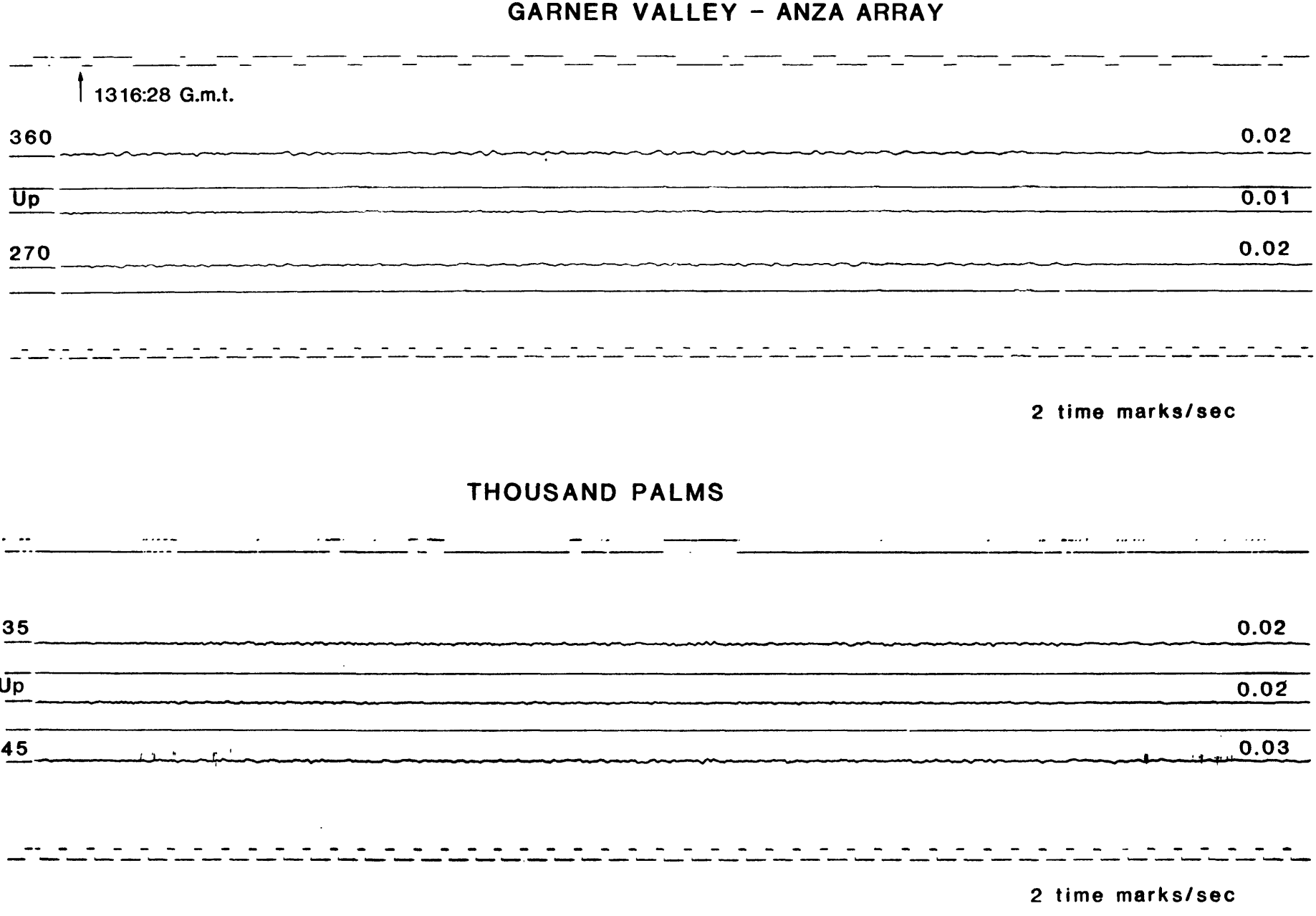

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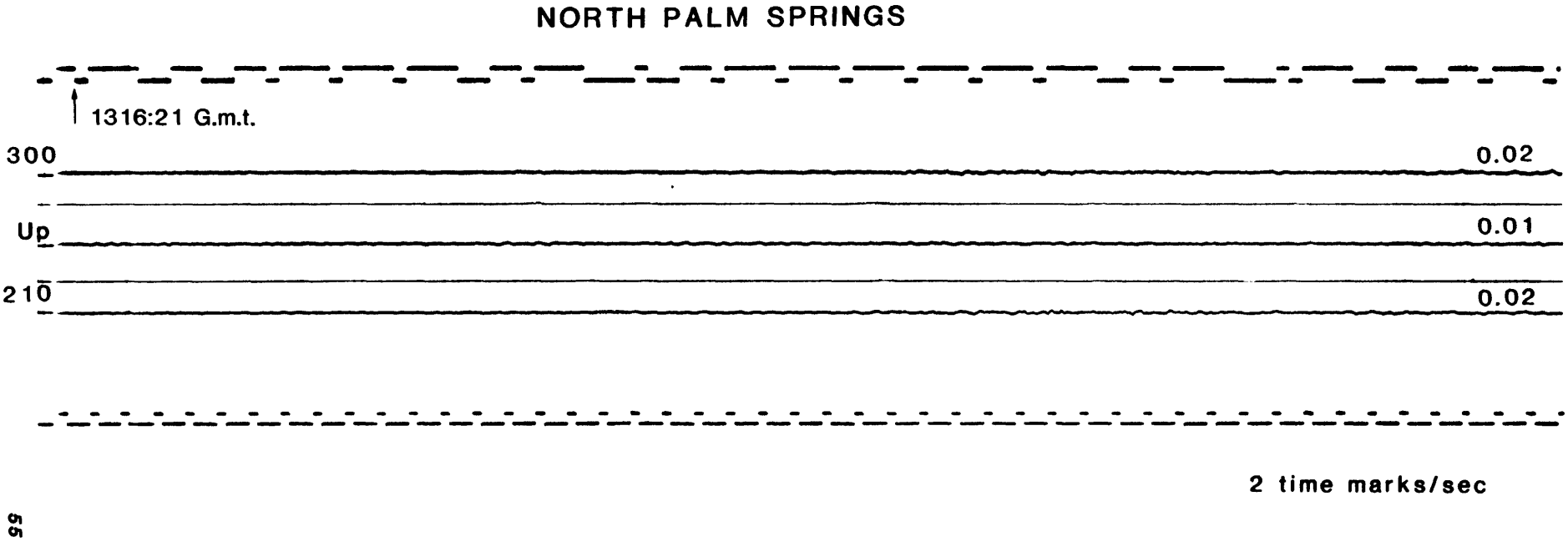

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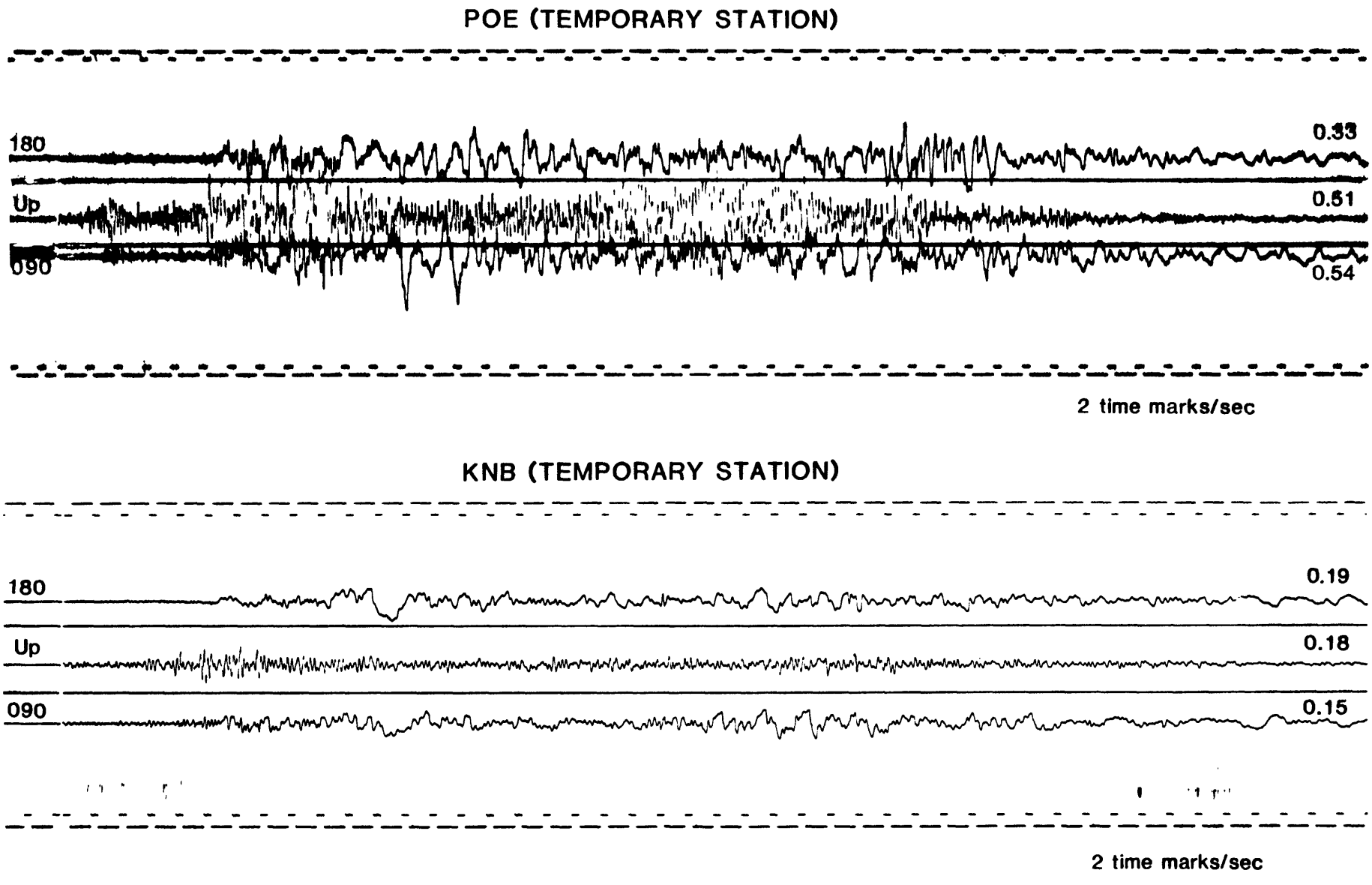

Figure 3. Continued.