

EARTH PHYSICS BRANCH OPERATIONS

IN

THE WINDSOR-LASALLE AREA

1975-1976

by

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1975 Operations

Commencing in February of 1975 a series of felt tremors was experienced in the area south of Windsor, Ontario. See Figure 1 for location map and Table 1 for a summary of these events. The area concerned includes the southern boundary of the city of Windsor and the Township of Sandwich West, and lies immediately across the Detroit River from the heavily industrialized area of southern Detroit. Sandwich West Township is a suburban-rural area with many market farms. The geology is paleozoic with shale and limestone formations predominating. It is everywhere covered by a thick layer of overburden averaging about 25 meters in depth. Salt is mined commercially in the area by the Canadian Rock Salt Co. with a major operation at the Ojibway Mine located on the boundary of Windsor and Sandwich West on the Detroit River.

After each reported tremor, the Earth Physics Branch (EPB) has searched its seismogram records at the appropriate times for evidence of seismic activity. No seismic signal from any of the tremors has been found, but the closest Canadian seismograph station is SUD at a distance of about 525 km so that it would take an event of magnitude 3 in the Windsor area to be recorded. Further, inquiries were sent following each tremor to the University of Michigan at Ann Arbor which operates the World-Wide Standard Station AAM. This station is located approximately 60 km west of the Windsor area - again, none of the felt tremors was detected at AAM.

Historically, the Windsor area has experienced few earthquakes. It lies within Zone I of the Canadian Seismic Zoning Map (1970) which typifies areas with few and minor earthquakes. Those earthquakes which have been felt from time to time in the Windsor area have been the larger events located in adjacent more seismic areas such as eastern Ohio. The recent series of

tremors, however, are of local origin. The felt area for each one has included roughly the same area, the southern edge of Windsor and the northwestern portion of Sandwich West Township, particularly the small urban area known as LaSalle which lies immediately along the Detroit River. Typically the tremors have been described as sharp explosions or jolts lasting a few seconds which are of sufficient strength to rattle windows and awaken people. Often the tremors have been reported heard as a low rumble. No felt report from the Detroit side of the river have ever been noted for any of these tremors, but the American side of the river is heavily industrialized. The fact that none of the tremors have ever been recorded at AAM places the upper bound on their magnitude in the range M_L 1.5 to 2.0.

Speculation as to the source of these recent tremors has centred on two possibilities. This first source suggested has been the steel milling operations on the Detroit side of the river. These operations are 24 hours a day and are known to have "bumps" caused by explosions of steam pockets in the hot slag byproducts. Such "bumps" are known to break windows locally. However, no correlation has been established between such "bumps" and the felt reports in LaSalle. The second source which has been suggested is the operation of the Canadian Rock Salt Co.; at the Ojibway Mine in Windsor, either by the explosions used in the process of mining salt or by induced earthquakes. The company typically blasts a series of holes, each consisting of several hundred pounds of explosives, between 07^h and 08^h GMT. The typical explosion can be felt mildly at the surface immediately over the working area, but would not be responsible for the stronger tremors over the wider areas which have been noted.

Induced earthquakes at the salt mine would also seem to be an unlikely source for the felt tremors. As has been noted, the tremors are often accom-

panied by an audible rumble, which is more the characteristic of a surface explosion than an earthquake. Also, the fact that none of the tremors has exceeded magnitude 2 in size would suggest a definite upper bound to the energy released. If the tremors were the product of induced seismic activity it is unlikely that the upper bound on energy release would be as low as the magnitude 2 level. However, induced seismicity remains at least a theoretical possibility because of the large amount of salt which has been removed from the Ojibway Mine.

Because of the concern expressed by the municipal officials in the LaSalle-Windsor area and in order to try to shed some light on the source of these recent tremors, EPB agreed to operate a seismograph unit in the area for the summer of 1975. This project was undertaken with the cooperation of Dr. David Symons of the University of Windsor. Dr. Symons was responsible for finding a suitable site and operator. EPB supplied the equipment and paid for the routine daily servicing required. The seismograph was located on the farm of Mr. M. Langois at the southern end of LaSalle and within the area which had experienced the felt tremors. Two points should be noted concerning this operation. Firstly, the thick overburden, which is everywhere prevalent in the area, made it impossible to locate the seismometer on bedrock. It was instead placed on a compact clay layer at the bottom of a shallow hole dug in a field of Mr. Langois' farm. As a consequence the noise level was very high, and the equipment could only be operated at a minimal gain of around 10K magnification. This limited the amount of information which could be acquired. Secondly, and most unfortunately, the equipment was vandalized by persons unknown almost immediately, with a tent and car battery being stolen. This resulted in a small amount of lost recording time initially, but, perhaps, contributed to later electronic problems with equipment and more significant losses in recording time.

Two felt tremors were experienced while the seismograph was operating. One on June 21, 1975 occurred when the equipment was malfunctioning and no useful record was obtained. The second occurred on July 26, 1975 and was heard by both Dr. Symons and Mr. Langois as a "low rumble coming from the west". A short burst of energy is visible on the July 26 record at 20:29:51 GMT (Figure 2). This record is similar to the typical record of a surface explosion but is by no means conclusive. The distance to the source cannot be fixed accurately but certainly is less than 20 km. The magnitude of the event is in the range M_L 1.5 - 2.0. Subsequent investigations of possible sources for this event were inconclusive. No bumps were reported from the Detroit side of the river; no blasts were reported in the Ojibway Mine.

No other felt tremors were reported during the operation of the LaSalle seismograph. Scanning of all the records produced by this operation has, likewise, failed to identify any other possible tremors. However, the records are very noisy and at a minimal gain so that only the largest tremors would have been recorded.

The LaSalle seismograph stopped operation on August 14, 1975 and the equipment was returned to Ottawa.

1976 Operations

1. Ojibway Mine Seismograph

The occurrence of the February 14, 1976 tremor (Table 1) in the Windsor-LaSalle area, rekindled public concern about these events. On March 30, 1976 the author met with municipal representatives of Windsor, Detroit and Sandwich West Township and other concerned officials to discuss the series of tremors. In this meeting at the Windsor City Hall both Mayor Weeks of Windsor and Reeve Menard of Sandwich West, strongly requested the deployment of three seismo-

graph units in their area to provide the capability to locate the source of any subsequent tremors. It was obvious at this meeting that the tremors were considered a real menace by the people of Windsor-LaSalle. In light of the inherent siting problems as a consequence of lack of bedrock and the urban nature of the area, I suggested that the deployment of more units in a similar manner as was done previously would be of little value.

The LaSalle seismograph in 1975 was vandalized, operated at minimum gain at a noisy site and provided little information. Two more such systems would offer little chance of improvement at the cost of much effort and money. EPB did offer, however, to operate one seismograph in the Ojibway Mine of the Canadian Rock Salt Co. in order to see if a bedrock site within the mine would result in some more useful information being obtained. This only partially satisfied the local officials who indicated that they would approach their local Members of Parliament for support in the matter of acquiring additional equipment.

Both the local M.P.'s, the Hon. E. Whelan and the Hon. H. Gray, subsequently have written to our minister requesting further assistance in determining the source of tremors in the area.

A seismograph was installed in the Ojibway Mine of the Canadian Rock Salt Mine Co. on April 21, 1976. Coordinates of the site are $42^{\circ}15'30''N$ and $83^{\circ}06'20''W$ with an elevation of -122 meters. Location of the station (OM) is shown in Figure 1. The equipment is attended by the personnel of the Canadian Rock Salt Co. and records are mailed to Ottawa in weekly batches for interpretation. To date (July 05) records covering the period April 21 through June 24 have been received.

The equipment has operated satisfactorially with no major loss of recording time. Servicing of the equipment, record changes, time corrections,

etc., has been well done by personnel of the Ojibway Mine. Some problems in recording time signals have been encountered, but these have now been resolved. Initially, the equipment was set to run at a peak magnification of over 200K. This proved to be too high for the local noise conditions and the magnification was lowered on May 05 to a peak of about 120K at 0.1 sec. This reduction has improved the overall quality of the records produced while still retaining sufficient sensitivity to record very small tremors in the immediate Windsor-LaSalle area. (A peak gain of 120K compares favourably with the magnification levels of any other seismographs operated in urban areas by EPB and is a factor of ten higher than was possible with the similar equipment operated in LaSalle in 1975). The present calibration curve for the present system is shown in Figure 3. Also, the equipment was initially set to run with a time scale of 60 mm/min. This was increased on May 20 to 90 mm/min to provide increased resolution.

As currently operated, the Ojibway Mine seismograph represents a first class seismic monitor for the Windsor area. It is sensitive to more distant earthquakes as well as the local tremors. Energy produced by the destructive earthquake in northeastern Italy on May 06 and the record of a large blast in eastern Ohio on May 08 are shown (Figures 4 and 5). Location of this last event is confirmed by Dr. Henry Pollack of the University of Michigan who is presently investigating the area near Zanesville, Ohio for a responsible source.

Of tremors in the immediate Windsor area, two distinct classes of events have been noted, those originating inside the Ojibway Mine and those originating outside the mine. One of the internal mine blasts, set off in the Ojibway Mine for the purpose of extracting salt, is shown on the record of May 07 (Figure 6). These events have a distinctive character with a high

frequency impulsive start followed by a tail of longer period more subdued energy. This tail probably represents "air blast" within the mine and serves to uniquely identify those blasts occurring in the mine.

Few local events which can be classified as having occurred outside the mine have been recorded to date. One such event is shown in Figure 7. This is the record of an explosion of 6,000 lbs of dynamite at the Allied Chemicals Quarry about 15 km southeast of the station in Sandwich West Township. This explosion was witnessed by the author and was timed to occur at $19^{\text{h}}:24^{\text{m}}:33.20^{\text{s}} \pm 0.05^{\text{s}}$ GMT. On the OM record of the blast, a clear S phase is visible at $19^{\text{h}}24^{\text{m}}38.0^{\text{s}}$ giving an apparent velocity of 3.1 km/sec. A poorly-defined P phase is also visible on the same record at $19^{\text{h}}24^{\text{m}}:36.0^{\text{s}}$. This gives an apparent P velocity of 5.4 km/sec. These values for P and S velocities are in the range of velocities observed for limestone areas elsewhere. They will be subsequently used for evaluating the performance of various proposed arrays in the Windsor area.

The record character of the May 27, 1976 Allied Chemicals Quarry blast should be compared to the record character of the July 26, 1975 tremor (Figure 2 and Table 1). Note that these records are from similar equipment, but at different locations and operating at slightly different time scales and much different gains. The 1975 equipment was located on the surface, off the southern end of the map area in Figure 1 and operated at a gain one-tenth of that of the present OM station. The similarity of the records, however, suggests that the July 26, 1975 tremor was also the product of a surface explosion larger than the May 27 Allied Chemicals Quarry blast; that this blast occurred within 20 km of the 1975 seismograph but not necessarily at the Allied Chemicals Quarry. The Allied Chemicals Quarry is outside the felt area of the tremors in Table 1.

2. Site Testing, May 26 to 28, 1976

For the period May 26 through 28, 1976 the author and Mr. F. Lombardo tested sites in the Windsor-LaSalle area for possible installation of additional seismograph units. This was done to gain familiarity with the area, so that, in the event of the recurrence of felt tremors EPB would be in the position to quickly deploy additional units if required. Location of the sites tested is shown on Figure 1 and pertinent information on each is given in Table 2. In general, it was found that most sites on the surface were extremely noisy. The two sites which were somewhat less noisy were the Fighting Island site (FI) and the Allied Quarry (AQ), but other difficulties make these sites less suitable. Access to Fighting Island is only by water. The site used for the test was on a new piling driven to bedrock; this would not be available after the present construction is finished. No bedrock is available elsewhere on the island. The AQ site is outside the general felt area of the tremors and is quiet only when the main crusher is not in operation, otherwise it is very noisy. This crusher is presently operated for one shift of 8 hours per day.

As a contrast, the site T5 which is underground in the Ojibway Mine only a few tens of meters from a crushing station was as quiet or quieter than surface site tested.

(It should be noted here that the two MEQ-800 "smoker" units which were used for the site testing operated efficiently and reliably and allowed six sites to be adequately tested in two days).

3. Estimations of Possible Ojibway Mine Arrays

In light of the superiority of sites for seismograph units within the Ojibway Mine even close to the operation of heavy equipment over any sites

available on the surface and the excellent cooperation and support of the Canadian Rock Salt Co. in the operation of the present system, the most feasible place to install more equipment would seem to be in the Ojibway Mine. The Canadian Rock Salt Co. is agreeable in principle to assist in the installation and operation of additional equipment as long as it does not seriously disrupt their own operations. EPB plans to deploy a 4-component slow speed tape recording seismograph array. This equipment which is normally used in EPB field programs is currently being modified for installation in the mine and necessary additional equipment is being purchased by EPB. A target date of late August, 1976 for installation would now seem reasonable. The equipment will be installed by EPB and operated by the personnel of the Canadian Rock Salt Co. in much the same manner as the present station is operated. The present station will be kept as a monitor.

The Ojibway Mine property will allow for an array with maximum dimensions of about 2 km north-south and east-west. In order to assess the feasibility of using such an array to locate any subsequent felt tremors, I have investigated the potential resolving capability of possible arrays.

I have assumed that the four sites OM, NW, NE, and SE (Figure 1) would form the basis of the array in the Ojibway Mine. Slight variations in the positions of any of these components will not affect its overall ability to locate sources in the immediate area. The feasibility of operating equipment at each of the sites has been checked with the Canadian Rock Salt Co. I have further assumed that phases P and S can be read at each site and that these phases have velocities of 5.4 and 3.1 km/sec respectively. I have then calculated the resolving ability of the array to locate surface sources in three possible locations: the Canadian Rock Salt Co. property within the array, Zug Island on the Detroit side of the river and Ecorse also on the

west side of the river (Figure 1). I have considered four variations of the basic array data set;

- 1) P and S phase read at all four sites. This represents the maximum amount of information available.
- 2) P read at 4 sites and S at one site, OM.
- 3) P read at 3 site and S at one site, OM (Site NE is not used).
- 4) P read at 4 site and no S available.

A summary of the results of this study is presented in Table 3. For this table I have assumed a mean time residual of 0.05 sec. which is reasonable for the type of equipment being used for the array. Table 3 suggests that the proposed array in the Ojibway mine should be able to locate surface sources with a accuracy of 600 m provided that at least three stations operate and both P and S phases can be resolved at least one. In the event that no S phase can be resolved the ability of the array to locate sources outside the mine property is seriously affected. Some care must be taken in applying Table 3. It is generally found that the tabulated standard deviations of the calculated positions are minimum values. This is because the estimates are based on the assumption of normal random errors which is not usually satisfied in practice. Thus the actual accuracy with which the Ojibway Mine array can locate nearby sources may be worse than indicated by a factor of two or more. It is not likely to be better than Table 3 indicates. Table 3 does, however, indicate the relative resolving powers of the various arrays.

The Ojibway Mine array should be installed and operating by September, 1976. Its usefulness as a seismic monitor should be evaluated after the occurrence of the next felt tremor or, failing that, after a six month period. If past experience is any guide, two or three felt tremors can be expected during the winter period 1976/77. If data from the array is not successful

in uncovering the source of any subsequent felt tremors then the operation should be stopped. Given the lack of suitable sites in the Windsor-LaSalle area the proposed Ojibway Mine array is the best seismic monitor that can be obtained. The only significant improvement that could be made in its coverage of the immediate area would be to introduce suitable sites from the Detroit side of the river so as to enclose potential sources from that side within an enlarged array. This is clearly impractical.

If there are no subsequent felt tremors, the array may still be able to determine the source(s) of repeating smaller tremors and thereby shed some light on the problem. As has been noted, few events of external origin have been recorded to date on OM. They may, however, be a seasonal phenomena that will re-occur during the coming winter.

TABLE 1

FELT TREMORS IN WINDSOR, 1975/76

<u>Date</u>	<u>Time (GMT)</u>	<u>Comments</u>
1975 Feb 11	03 ^h to 05 ^h	Like explosion, rumbling sound, windows rattled & numerous calls to police.
1975 Mar 29	23 ^h	Windows rattled. Several calls to police.
1975 Apr 13	05 ^h to 08 ^h	Two shocks, many awakened.
1975 May 15		LaSalle seismograph installed.
1975 June 21	07 ^h to 08 ^h	Series of tremors heard and felt. Duration about 20 sec. for strongest.
1975 July 26	20:29:51	Heard as low rumble coming from West. Recorded, see Figure 7.
1975 Aug 14		LaSalle seismograph stopped.
1975 Sept 15	04 ^h	Explosion, over in few seconds. Felt widely. People awakened, pictures moved.
1976 Feb 14	04 ^h	Numerous calls to police.
1976 Apr 21		Ojibway mine seismograph installed.

TABLE 2

SITES TESTED FOR SEISMOGRAPHS, MAY 26/28, 1976

<u>CODE</u>	<u>ON/OFF (GMT)</u>	<u>SETTING</u>	<u>COMMENTS</u>
MA	May 26, 00:55 May 26, 12:29	60 db 5-10 Hz	LaSalle Municipal Arena: In visitors locker room, on concrete floor (floating). Minimum setting, early morning traffic evident.
GP	May 26, 13:39 May 27, 13:19	60 db 5-10 Hz	Clark Keith Generating Plant: In coal crusher (unused) on concrete floor (pilings to bedrock). Directly across river from Great West Steel. Plant does not generate power, but does transform power with turbines. Turbines stopped during night. Minimal setting, noisy records.
SS	May 27, 14:34 May 27, 19:02	60 db 5-10 Hz	Sandwich West Secondary School: In book storage room, on concrete tiled floor with pilings to bedrock. Minimal setting, very noisy. Vehicles on local road cause strong vibrations.
T5	May 26, 16:00 May 26, 19:30	78 db 5-10 Hz	T5 Crusher, Ojibway Mine: About 40m from salt crusher Quiet trace, operation of crusher not apparent.
FI	May 26, 20:12 May 27, 12:25	60 db 5-10 Hz	Fighting Island, LaSalle: On piling to bedrock for continuing construction of building. No bedrock on island.
AQ	May 27, 15:17 May 27, 19:33	60 db	Allied Chemical Quarry: On bedrock in unused part of Quarry. About 600m from working face. Possible to operate at 78 db if crusher not operating.

TABLE 3

Approximate resolution in meters of location of surface sources, assuming a time resolution on phases of 0.05 sec

		<u>ARRAY</u>			
		<u>#1</u>	<u>#2</u>	<u>#3</u>	<u>#4</u>
Source	Ojibway Mine	105	163	174	206
	Zug Island	314	566	573	4943
	Ecorse	303	544	599	6914

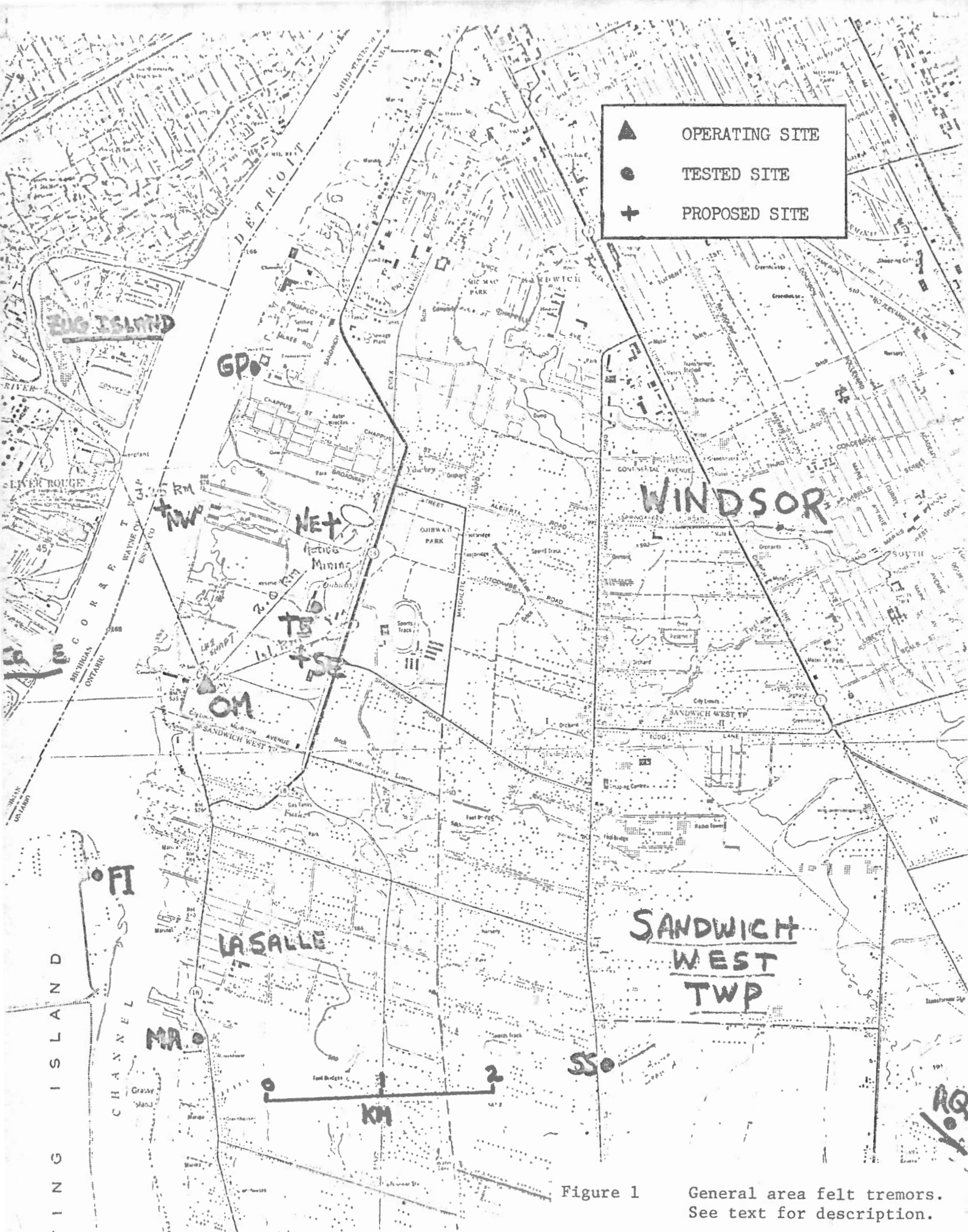


Figure 1 General area felt tremors. See text for description.

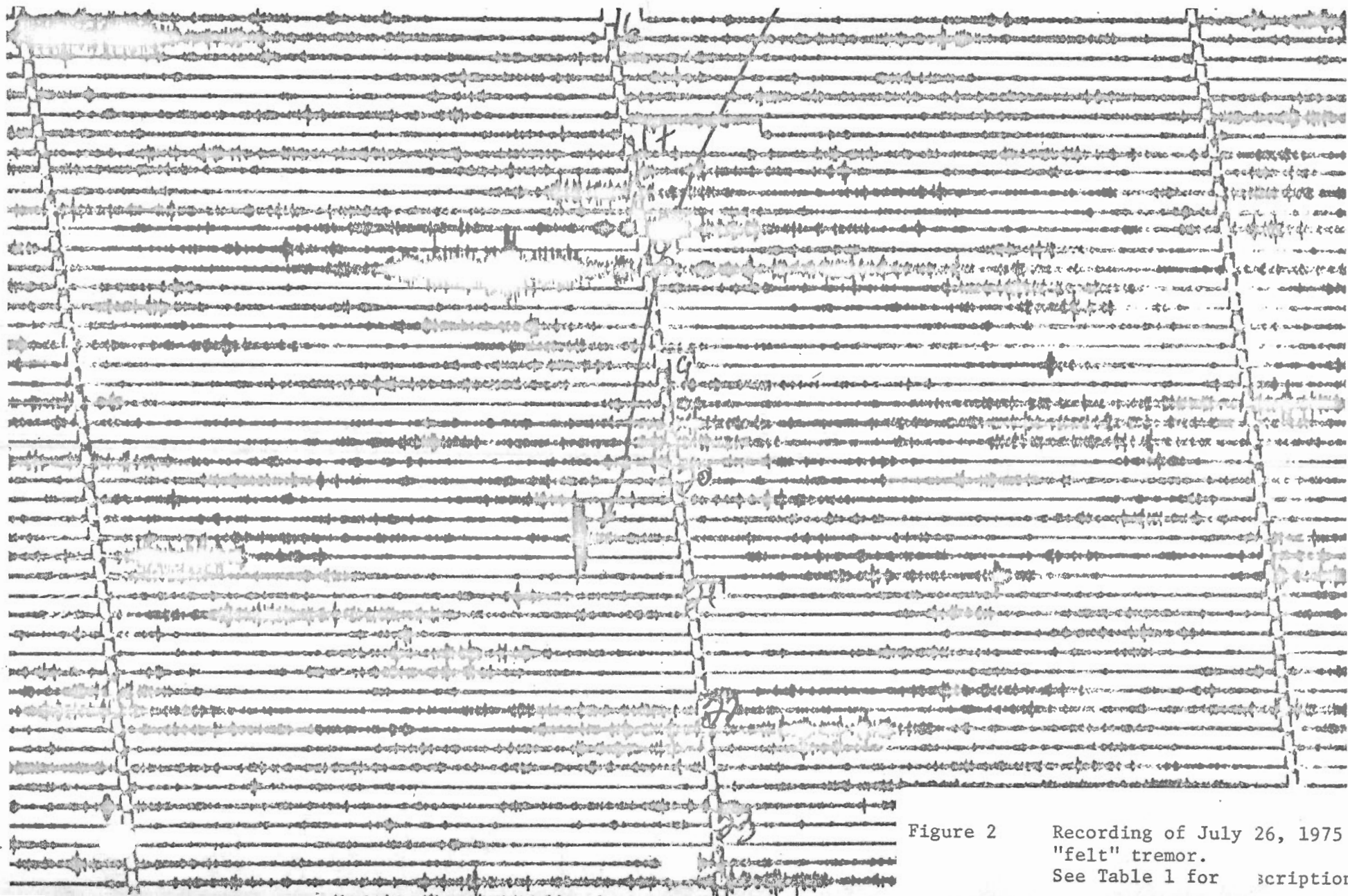


Figure 2 Recording of July 26, 1975
"felt" tremor.
See Table 1 for description.

STATION:

OTTAWA

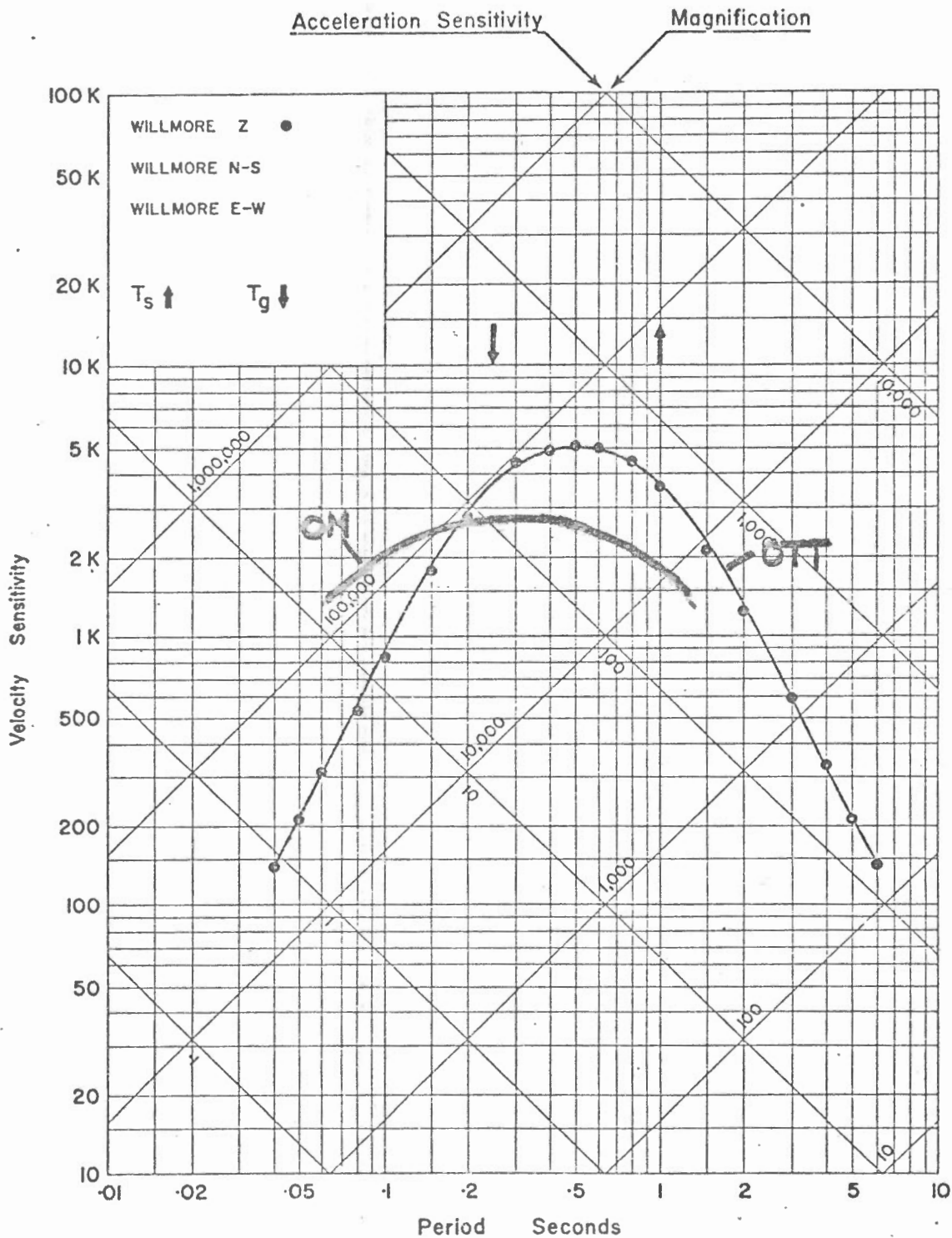
(OTT)

$\phi = 45^{\circ}23'38''N$

$\lambda = 75^{\circ}42'57''W$

Altitude 83 M

Foundation: Boulder clay on limestone



Dates of Calibration:

WILLMORE Z ● 19 Se
 WILLMORE N-S
 WILLMORE E-W

Figure 3

Calibration curves of seismograph stations OM and OTT

ON. ONTARIO 1976
P. 24 03 BEN DR AMP 1CM/V
7-15/76 H 11 M 02.0 0.0
Alabid

CPZ/SPZ \uparrow C

May 06/76

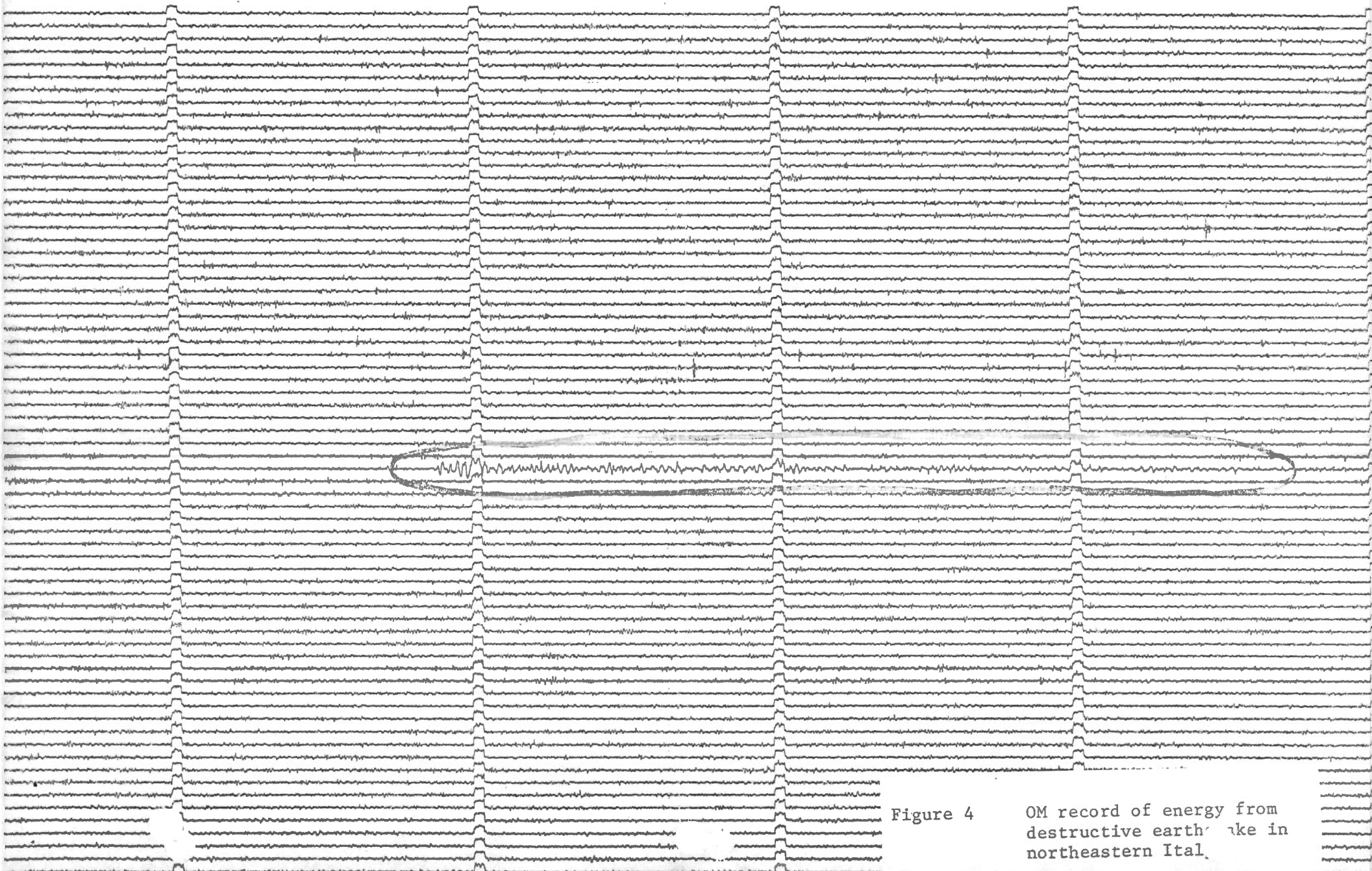


Figure 4

OM record of energy from destructive earthquake in northeastern Ital.

MAY 8 - 1976

May 8

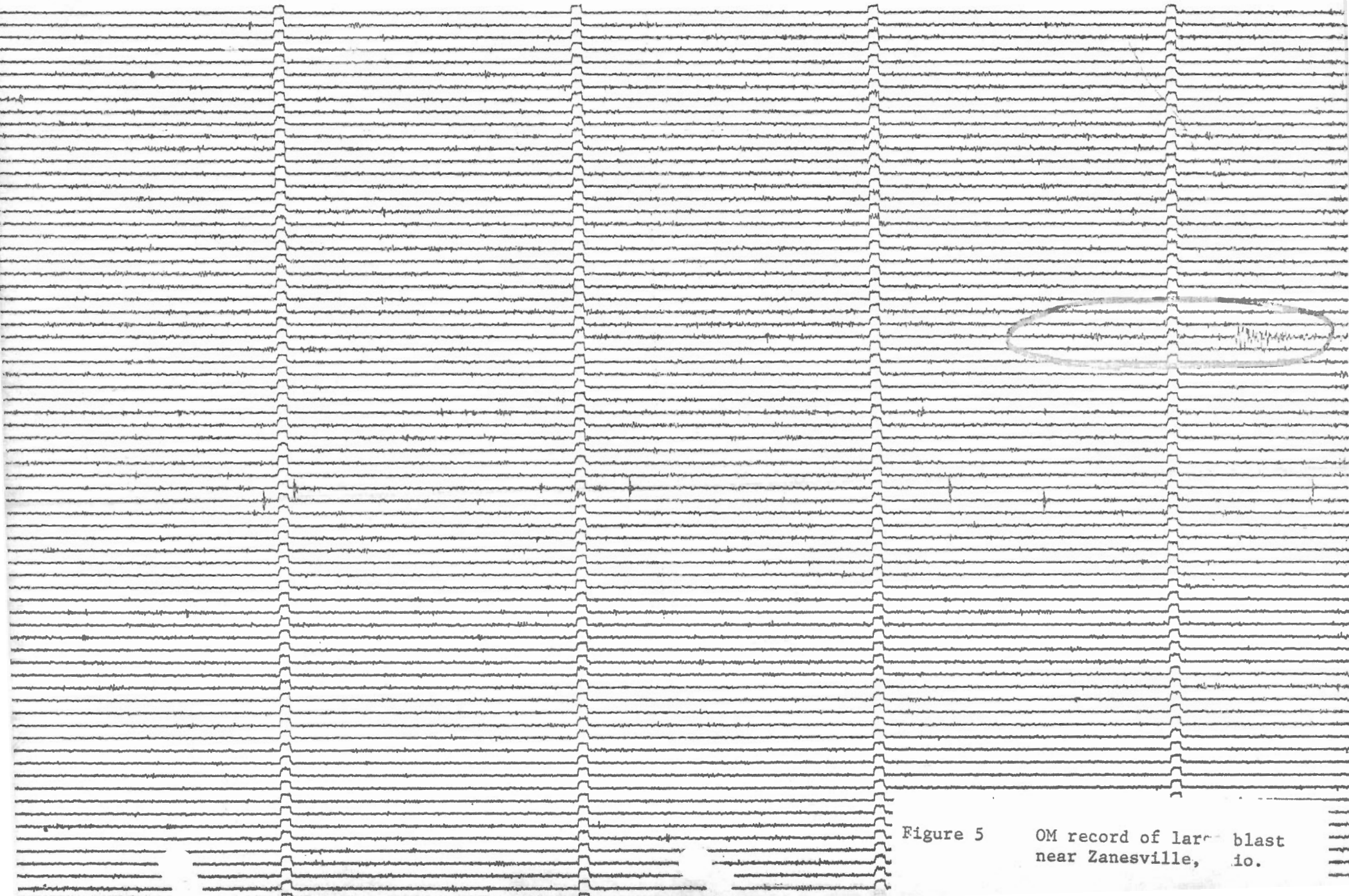


Figure 5

OM record of large blast
near Zanesville, io.

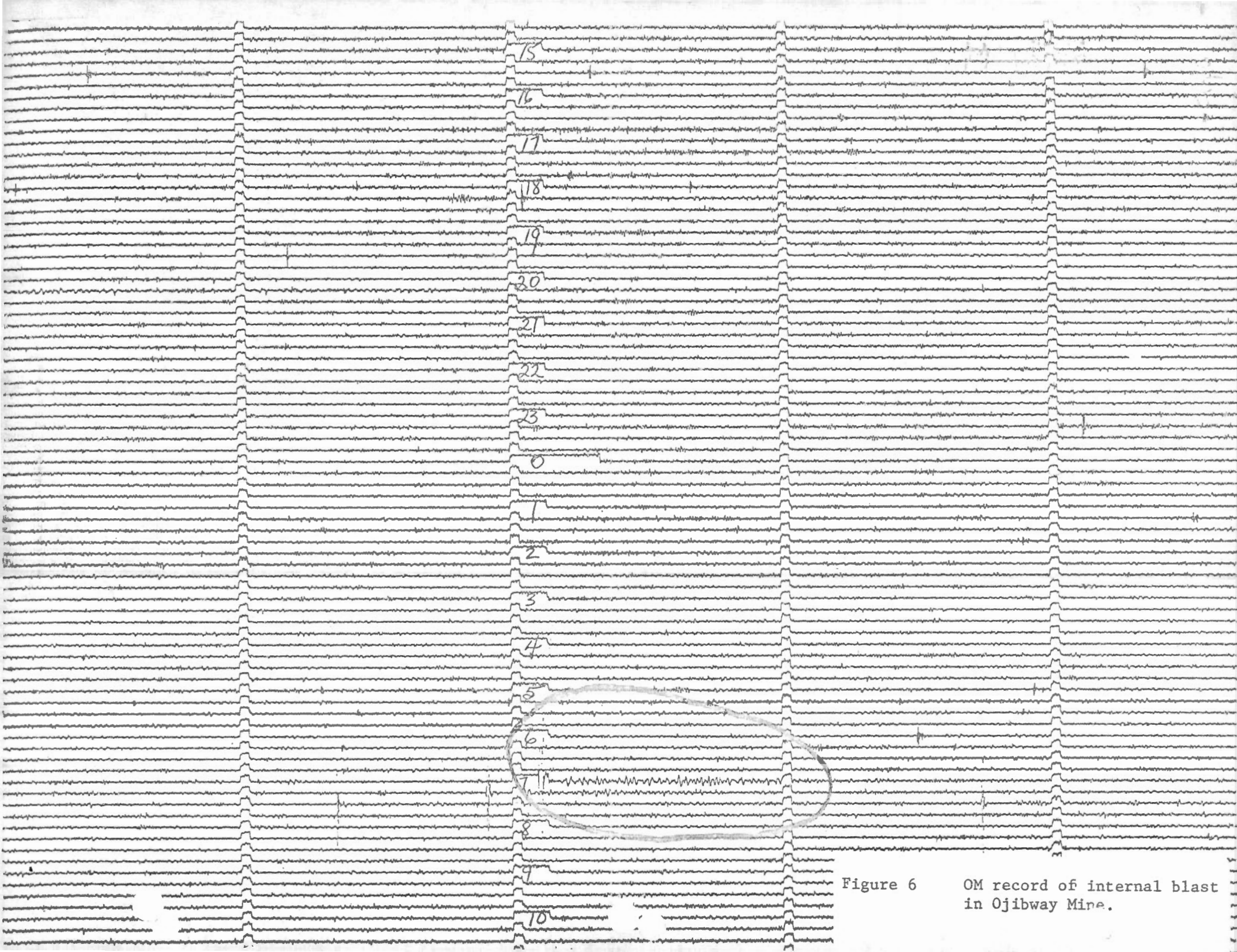


Figure 6 OM record of internal blast in Ojibway Mine.

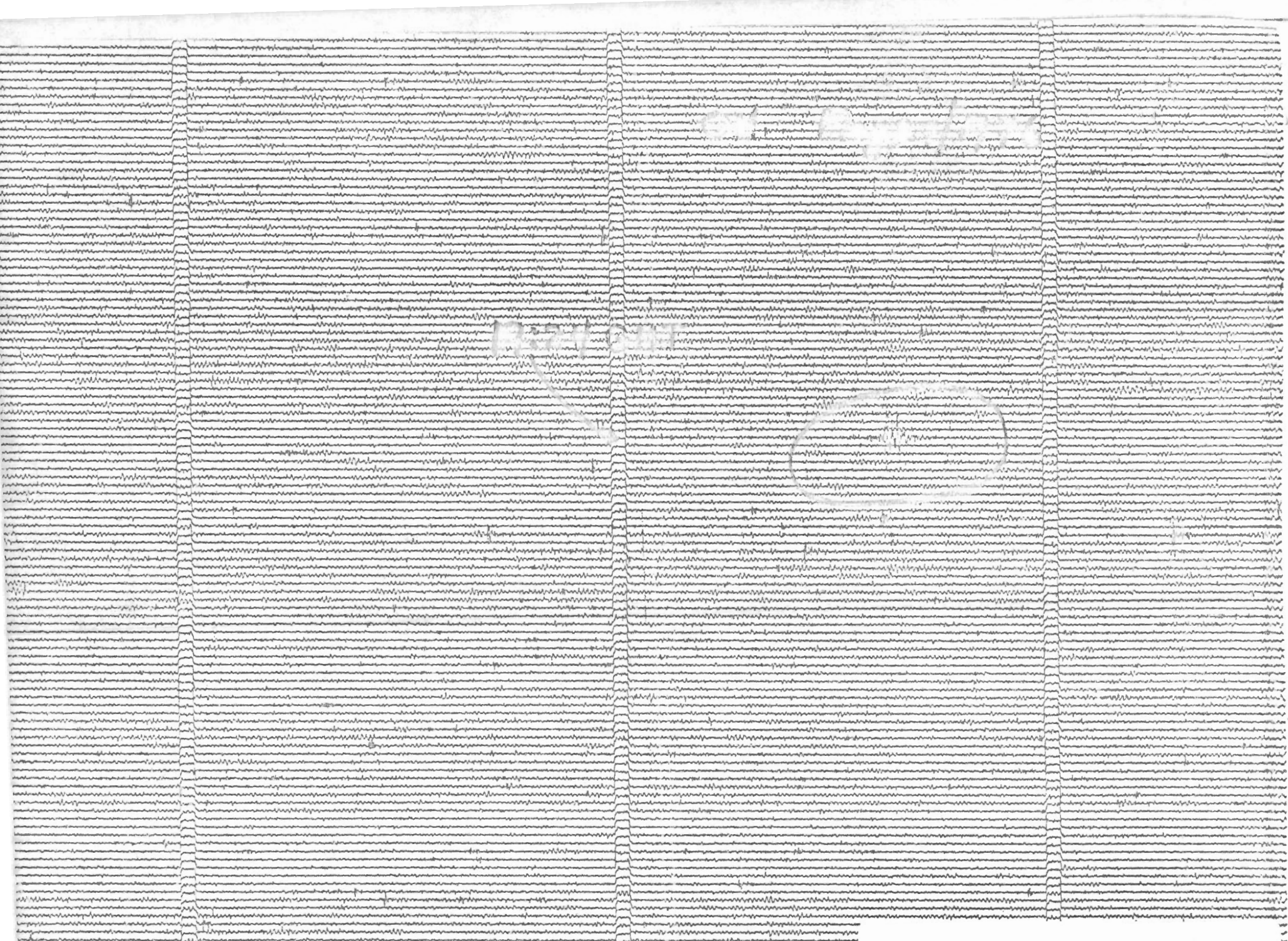


Figure 7 OM record of Allie Chemical Quarry blast of 6, 1 lbs. at a distance of 15 1/2 m