SOURCE CHARACTERIZATION OF A LARGE ROCK BURST, COEUR D'ALENE MINING DISTRICT, IDAHO

Alan C. Rohay, Battelle Memorial Institute, Pacific Northwest Division
Kenneth F. Sprenke, University of Idaho, College of Mines
Michael C. Stickney, Montana Tech, Earthquake Studies Office

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ABSTRACT

Characterization of mining-related seismic events is critical to the implementation of the Comprehensive Nuclear-Test-Ban-Treaty monitoring system. Mine seismicity from uncontrolled sources is particularly troublesome, with magnitudes up to 4 or 5, producing signal strengths comparable to 1- to 10- kiloton contained nuclear explosions. In this study, ground motions from four surface stations and one underground station were inverted to determine the complete moment tensor of a relatively large rock burst in the Coeur d'Alene Mining District in northern Idaho. Many rock bursts, induced by the mining process, show implosional source mechanisms, a feature that should be useful to discriminate mining-related events from underground explosions. The rock burst analyzed in this study yielded seismograms with a moment tensor solution involving a significant volumetric component. The moment tensor was decomposed into isotropic and deviatoric components from which the volumetric closure and total shear deformation were estimated for comparison with in-mine co-seismic damage. The magnitude 3.1 burst occurred 7.5 hours after routine daily blasting in the mine. The event represented the result of deep underground mining combined with sliding on nearby bedding planes or faults. The implosional characteristic may prove to be a useful parameter for fingerprinting seismic events from deep hard rock mines.

Key Words: moment tensor, rock burst

OBJECTIVE

Mining activities world-wide produce seismic events, some of which may be visible to monitoring for the Comprehensive Test Ban Treaty (CTBT). Mine seismicity from uncontrolled sources are particularly troublesome, with magnitudes as high as 4 to 5, producing signals equivalent to 1-10 kiloton contained nuclear explosions. Rock bursts in deep underground mines are in this latter category. These events, however, may have characteristics unlike either explosions or earthquakes that might be used to "fingerprint" specific mines for discrimination purposes. In this light, we are investigating seismic signals from one of the most rock burst-prone hard rock mining areas in the world: the Coeur d'Alene Mining District of northern Idaho.

In a review of mining-induced seismicity, Gibowicz and Kijko (1994) note that such events generally fall into two types: those directly associated with mining operations and those associated with movement on major geological discontinuities. Rock bursts in the Coeur d'Alene District are not so easily categorized. While the events clearly are associated with mining rate (Sprenke and others, 1991) and stope geometry (Jung et al., 1995), they have long been known to be the result of failure on faults and bedding planes (Scott, 1990). These structures are associated with the Osburn Fault, part of the Lewis and Clark Line megashear that strikes north-northwest through the district. An underhand-longwall system of mining, implemented in the late 1980s at the Lucky Friday Mine, has greatly reduced rock burst problems at that mine, illustrating the influence of mining geometry on rock bursts. A district-wide network operated in the early 1990s (Jung et al., 1995) showed that those shear events that could be fit by a double couple solution were consistent with a regional tectonic stress with a northwesterly oriented seismic P-axis and a northeasterly seismic T-axis. This is an orientation particularly deleterious for slip on the north-northwesterly oriented vertical faults and steeply dipping bedding parallel to the Osburn Fault. Apparently, mining operations in the Coeur d'Alene district are releasing pent-up strain, strongly affected by local geology and tectonics. Not unlike deep mines world-wide, the seismicity in this district are affected by depth of mining, production rate, mining geometry, geologic structure, and geologic discontinuities.

Although blasting often triggers rock bursts instantaneously, many rock bursts, particularly large damaging events in deep underground mines, occur spontaneously and unexpectedly, despite the fact that they are caused by stress changes associated with the mining process. This interaction of mine geometry and geological structure suggests that rock bursts in deep underground mines may often be of a shear-implosional nature, involving both co-seismic opening closure and shear failure in the surrounding strata (e.g. McGarr, 1992). Seismograph networks (Stickney and Sprenke, 1992; Jung et al., 1995) demonstrated that well-constrained all-dilatational P-wave first motions for about half of the events in the Lucky Friday Mine indicated a significant implosional component.

RESEARCH ACCOMPLISHED

For this project, we have investigated the seismic signals from a damaging rock burst in the Lucky Friday Mine that occurred at 6:09 August 29, 1998 UTC (11:09 p.m. August 28 PDT). The local magnitude of the event was 3.1 as measured at Butte, Montana. It was recorded on the Montana and Washington regional networks. Predominantly dilatational first motions for this event from our five local stations and several regional stations suggested that this event had an implosional component. To test this hypothesis, we are performing a moment tensor inversion using the signals from five strong motion accelerometers that were deployed in the immediate area of the mine (Figure 1).

The seismic signals used in this experiment were collected as part of a local network deployment of five strong motion accelerometers and one broadband seismometer from May 6 to September 2, 1998 in the immediate vicinity of the Lucky Friday Mine (Rohay et al., 1998). The August 28 rock burst was the largest seismic event recorded in that period. One accelerometer was located in an abandoned adit; the remaining stations were surface stations. The source location was provided by the in-mine geophone array operated by the mine.

The quality of the strong motion accelerometer data was found excellent by comparison with the broadband seismograph record. Both instruments produced virtually identical records of ground motion (Figure 2). The broadband had a GPS time receiver; however the strong motions did not record absolute time. However, because an independent source location was provided by the in-mine geophone array, the lack of absolute timing was not a problem.

The horizontal ground motion signals from the five triaxial accelerometers were rotated to a north and east orientation conforming to a vertical, north, and east coordinate system. Polarities were confirmed to correspond to positive amplitudes for ground motion in the up, north, and east directions. These signals are then again rotated to a radial-transverse-vertical system with radial axis away from the source toward the respective receiver. The seismograms showed reasonably clear P, SH, and SV pulses plus oscillations, particularly on the horizontal components that decay with time, perhaps representing trapped waves in the strata. The oscillations were not the same on all the stations, indicating some degree of heterogeneity about the mine area. The underground station, closest to the workings, shows considerable more high frequency than the others, indicating potential attenuation and near-surface effects.

The moment tensor of the rock burst is estimated in the far field using a linear inversion method in the time domain:

$$\mathbf{U} = \mathbf{G}\ \mathbf{m} \qquad (1)$$

where **U** consists the n sampled observations of ground displacement at the various stations, **G** is an n x 6 matrix containing the Green's functions calculated by the appropriate algorithm and earth model, and **m** = (M11, M12, M22, M13, M23, M33), a vector containing the six moment tensor elements to be determined (Gibowicz and Kijko, 1994).

The data we are using are the maximum displacement amplitudes of the P, SV, and SH waves as recorded at the five three-component strong motion stations surrounding the site. Low frequency noise was removed by filtering below 1 Hz before integrating the time series from acceleration to velocity and displacement. The amplitudes of the P, SH, and SV phases were measured at each of the five stations, and corrected for the free surface effect. These become the 15 observations we will use to estimate the 6 unknowns in the moment tensor.

Green's functions have been formulated in a simple manner using the displacement vectors for far field P, SV, and SH wave radiation (Pujol and Herrmann, 1990) at each of the five stations. A synchronous source in the form of a step function was used to estimate displacements. Based on observations by Stickney and Sprenke (1993), we assumed an isotropic and homogeneous velocity model with a P-wave velocity of 5.74 km/s, and S-wave velocity of 3.47 km/s. A density of 2.7 was assumed for the metasedimentary rocks in the mine area. To estimate the moment tensor elements, we are following a least squares procedure outlined by McGarr (1992).

CONCLUSIONS

We expect that the moment tensor estimates for the M3.1 Coeur d'Alene Mining District rock burst of August 29, 1998 will be dominated by negative diagonal components, indicating a dominantly implosional source. We will use the same procedures for the many smaller events recorded on the acceleromter array and determine whether there are several characteristic types of events that can be classified. We also expect that our results will be similar to those obtained for a group of events studied by McGarr (1992) from deep hard rock mining districts in South Africa. This could indicate that implosional events may be characteristic of a type of event that may fingerprint such mines for CTBT purposes. We will also evaluate regional seismic signals for a catalog of large rock bursts from the Couer d'Alene mining district to evaluate the effect of such implosional events at distances useful for treaty verification monitoring.

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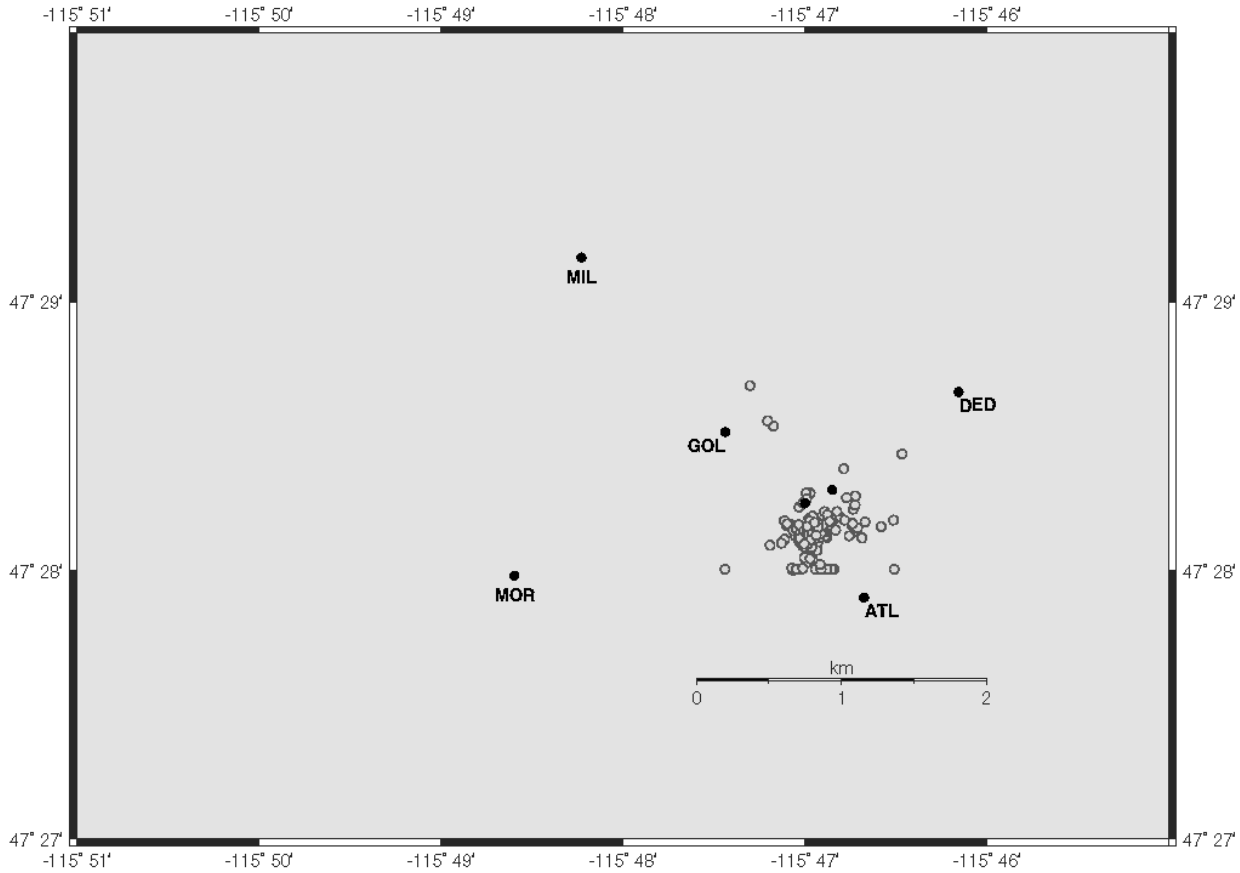


Figure 1. Rockburst locations from the Hecla Mining Company's Lucky Friday mine, and the location of the strong motion accelerometers. The two unlabeled black dots show the locations of the Silver shaft and Number 2 shaft.

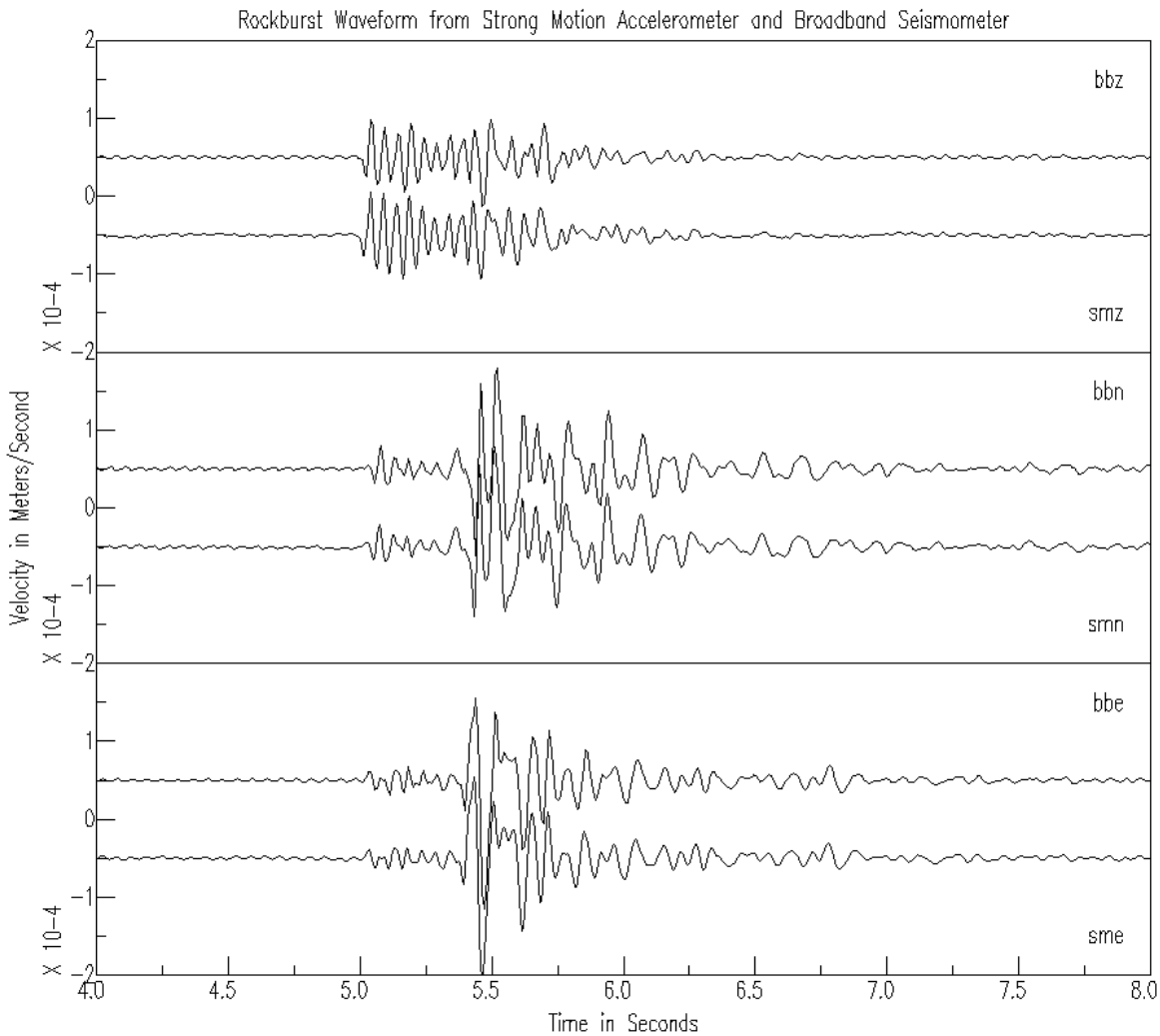


Figure 2. Comparison between three-component broadband velocity records from CMG 40 system (bbz, bbn, bbe) and the result of integrating the strong motion accelerometer records to velocity (smz, smn, sme). The comparison is made at station MOR where the two systems were co-located. This record is for a smaller event than shown in Figure 3 because the magnitude 3.1 event clipped the recording system for the broadband instrument.

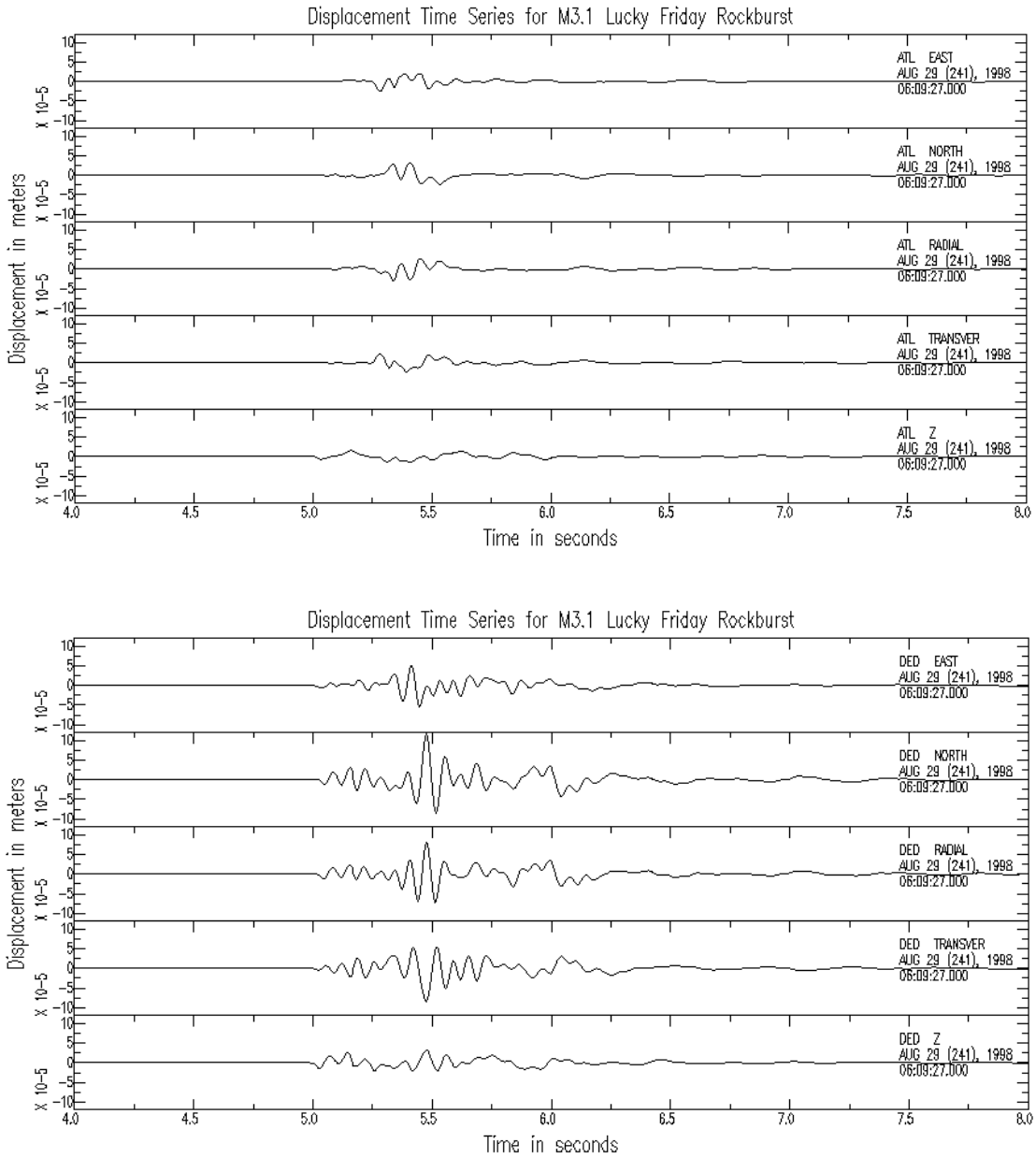
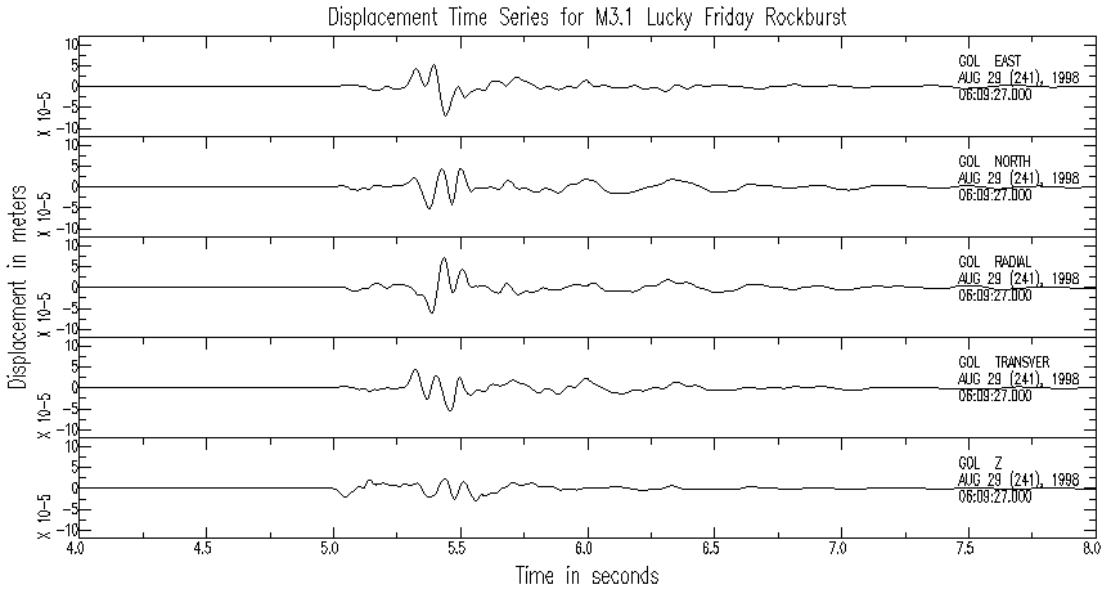


Figure 3. Displacement time series for the five strong motion accelerometers, having the north, east, and up positive convention and the radial (positive outward) and transverse (90 degrees clockwise) convention. Note that the polarity of the first motion is negative on the radial and vertical components (towards the source) at five all stations.



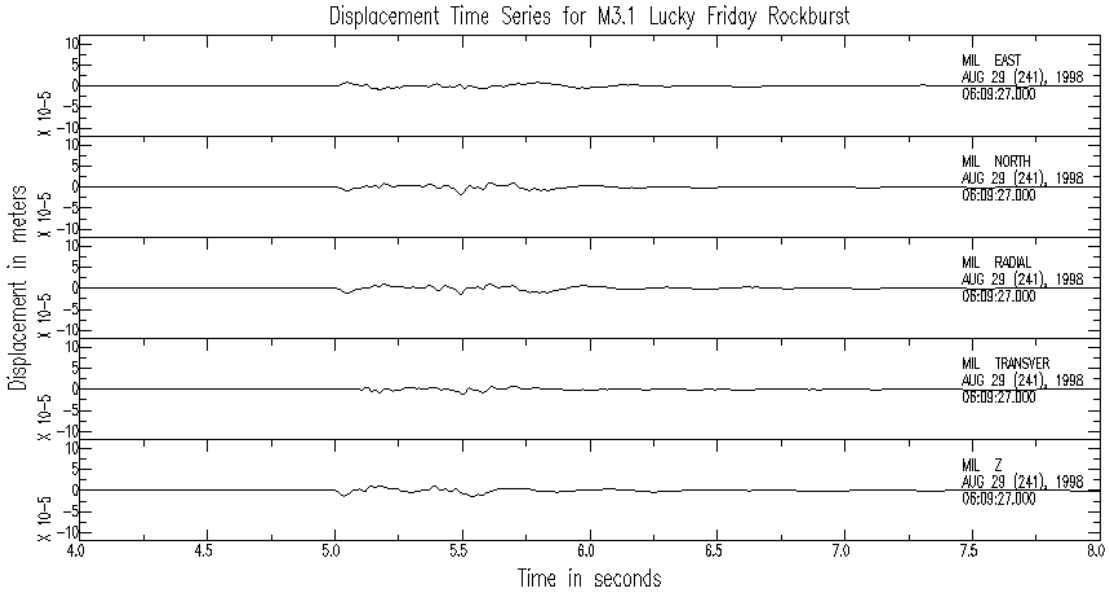


Figure 3 (continued).

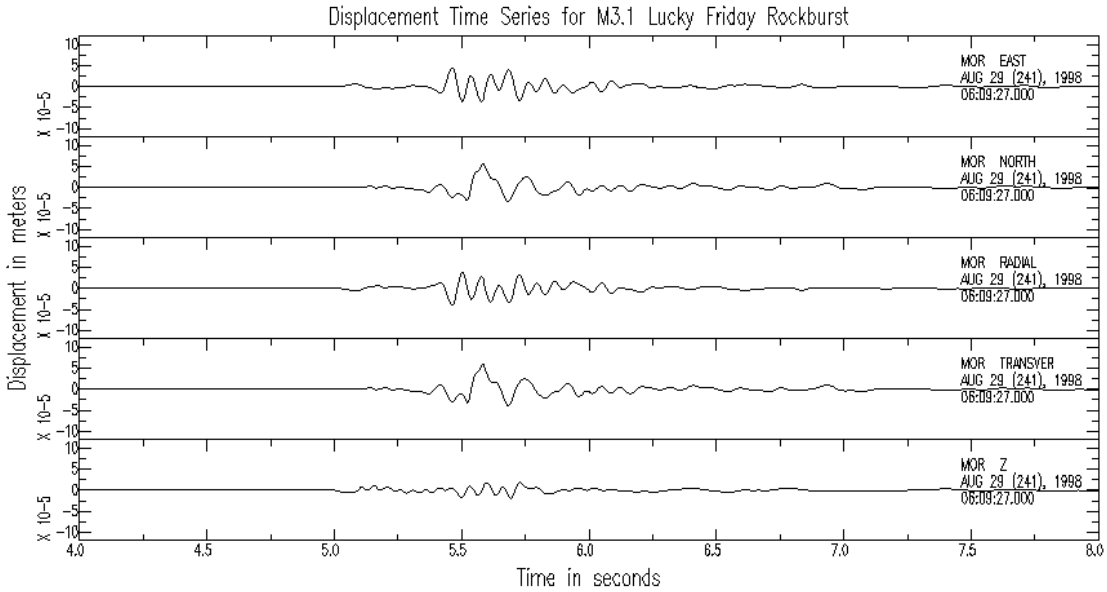


Figure 3 (continued).