Youngstown Earthquake on 24 December 2011 at 01:24 (EST)

Summary

The location of the December 24th, 2011 Youngstown, Ohio earthquake was determined by using *P*- and *S*-wave arrival times at four seismographic stations deployed around the Youngstown since December 1st, 2011 (Table 1). The epicenter is fairly well determined by the data with the nearest station located at 1.9 km and the station coverage with an azimuthal gap of 120º. The epicenter and the seismographic stations used are plotted in Figure 1.

The focal depth is about 3.55 km with its 95% confidence error ellipsoid extending 0.86 km of major axis in vertical direction. The epicentral distances of the two nearest stations are less than the vertical extent of the hypocenter, and hence the solution from the location program is reliable. Additional uncertainty in the focal depth might be due to the velocity model used to locate the event. We used virtually two-layered crustal model that consists of the top layer with *P*-wave velocity of 4.5 km/s and thickness of 2.7 km, and a 7.3 km thick crystalline rock layer with *P*-wave velocity of 6.12 km/s. The *S*-wave velocity is considered to be Vp/√3.

The epicenter is also determined by adding *P*- and *S*-wave arrival times from permanent seismographic stations in Ohio and Pennsylvania. The second epicenter is very close to the first one with a slightly deeper focal depth (4.4 km), but it has larger error ellipse than the first one (Figure 1). The error ellipse around the epicenter indicates that the ellipse has a 95% chance of containing the ***true*** epicenter.

The duration magnitude, Mc, of the event is also determined by measuring signal durations from six stations. The duration magnitude, Mc, is 2.7. The details of the event location is given below.

Table 1. Source parameters of the December 24th, 2011 Youngstown, Ohio earthquake

Date (year-mo-dy)	Time (UTC) (hh:mm:sec)	Latitude (ºN)	Longitude (ºW)	Depth (km)	Magnitude (Mc)	RMS (s)	Erh (km)	Erz (km)
2011-12-24	06:24:57.98	41.1186	80.6936	3.55	2.7	0.012	0.43	0.86

December 28, 2011

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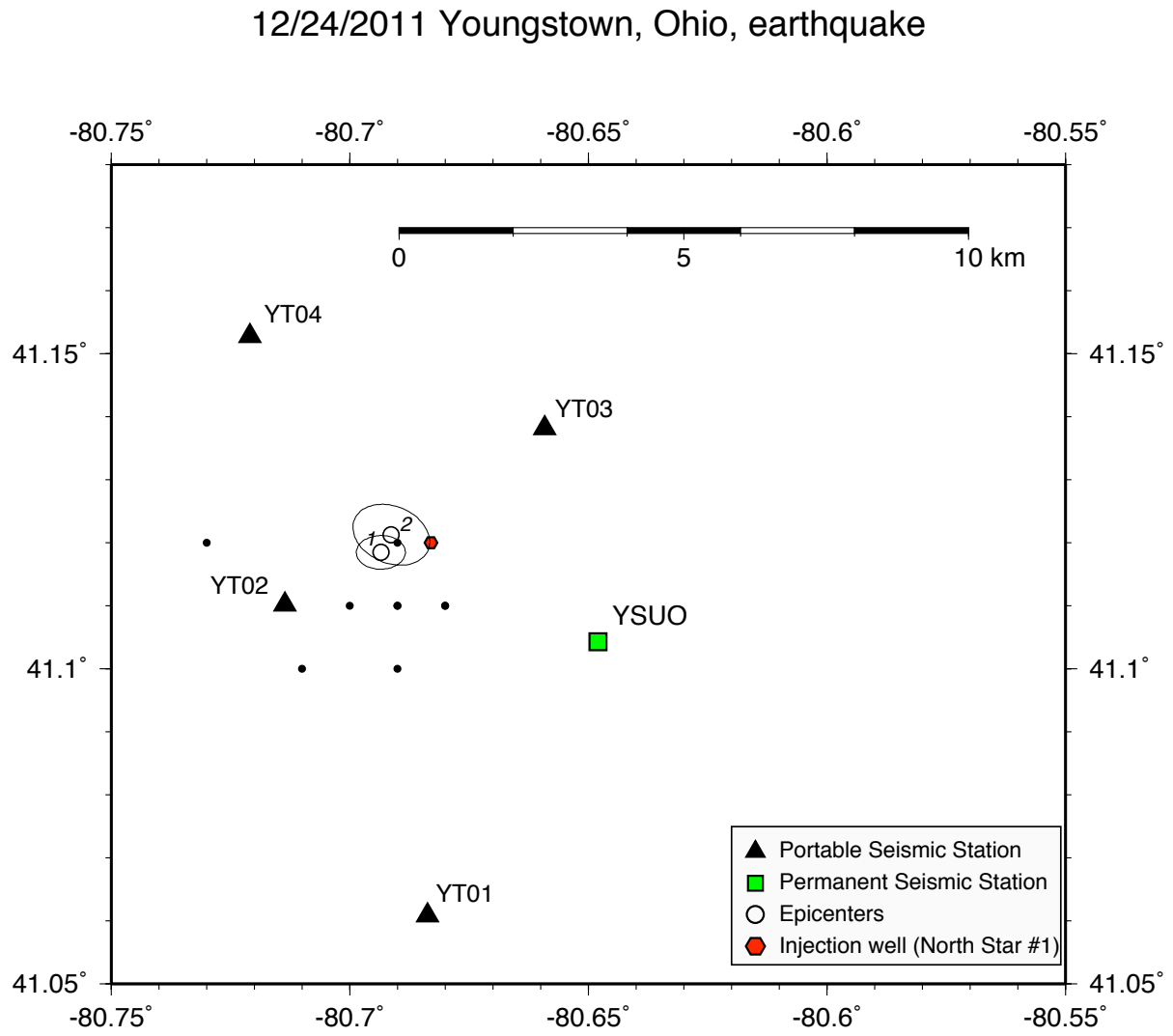

Figure 1. Location of the Mc 2.7, 12/24/2011 Youngstown, Ohio earthquake and seismographic stations around the region. Epicenter #1 is determined by using *P*- and *S*-wave readings from four portable seismographic stations, whereas the epicenter #2 is determined with additional data from regional seismographic stations in Ohio and Pennsylvania. Locations of the four portable seismographs deployed since 12/01/2011 and a permanent seismographic station YSUO (Youngstown State University) of the Ohio Seismic Network, as well as an injection well (North Star #1) are plotted for reference. The ellipse around the epicenter is the 95% confidence error ellipse indicating that the ellipse has a 95% chance of containing the ***true*** epicenter.

```
PROGRAM HYPINV (version 1.3 - JUNE 1978) run on 28 Dec  2011 at 01:23:43
stations
   center 41. 07.45  80. 40.60  dlyaz=  999.00 dlywd=  0.00
  i  name ---lat---- ----lon---- pdly1 sdly1 pdly2 sdly2 fmc xmc wt mdl cal per typ
  1 YT01  41. 03.65  80. 41.03w  0.00  0.00  0.00  0.00 0.0 0.0 1  1    0.0 0.2  0 0.0
  2 YT02  41. 06.61  80. 42.82w  0.00  0.00  0.00  0.00 0.0 0.0 1  1    0.0 0.2  0 0.0
  3 YT03  41. 08.29  80. 39.55w  0.00  0.00  0.00  0.00 0.0 0.0 1  1    0.0 0.2  0 0.0
  4 YT04  41. 09.17  80. 43.25w  0.00  0.00  0.00  0.00 0.0 0.0 1  1    0.0 0.2  0 0.0
  5 YSUO  41. 06.26  80. 38.88w  0.00  0.00  0.00  0.00 0.0 0.0 1  1    0.0 0.2  0 0.0

 crust
 model:        1                       2                       3
 layer vel   depth  thick     vel   depth  thick     vel   depth  thick
   1  4.500  0.000  2.700    3.700  0.000  1.000    5.980  0.000  7.000
   2  6.120  2.700  7.300    5.400  1.000  2.100    6.620  7.000 28.000
   3  6.620 10.000 31.000    6.100  3.100 11.900    8.100 35.000999.000
   4  8.250 41.000999.000    6.700 15.000999.000    0.000  0.000  0.000

 test parameters
-iteration and convergence- -weighting, errors, trial depth- -duration mag constants-
   20=itrlim    0.90=damp    50.00=discut   0.50=rmscut  -1.70=fma1    -1.27=fma2
0.005=dquit   0.0001=drqt     1.00=disw1    2.00=rmsw1    2.21=fmb1     2.00=fmb2
 7.00=dxfix    0.012=eigtol   3.00=disw2    8.00=rmsw2    0.00=fmz1     0.00=fmz2
 7.00=dzmax     0.02=rback    1.00=swt      0.05=rderr    0.00=fmd1     0.00=fmd2
 0.50=dzair     0.60=bacfac   2.50=ztr      1.00=ercof   500.0=fmbrk    1.73=pos

1 24 dec 11,  6:24  event no.   1
                                                      adjustments (km)
  i origin   lat n    lon w     z  nwr  rms   dt    dlat   dlon    dz    rr nf
  1 177.86 41  7.28  80 41.48  4.41  8 0.06 0.017 -0.236  0.276  0.000 0.363 3
 focal depth freed
  2 177.88 41  7.15  80 41.68  4.41  8 0.05 0.104 -0.087 -0.079 -0.803 0.811 4
  3 177.98 41  7.11  80 41.62  3.61  8 0.02-0.004  0.012 -0.009 -0.061 0.063 4
  4 177.98 41  7.11  80 41.61  3.55  8 0.01 0.001  0.002 -0.005 -0.006 0.008 4
  5 177.98 41  7.11  80 41.61  3.54  8 0.01-0.001 -0.009 -0.002 -0.004 0.010 4
  6 177.98 41  7.11  80 41.61  3.54  8 0.01-0.001  0.009  0.005  0.016 0.020 4
  7 177.98 41  7.11  80 41.61  3.55  8 0.01 0.000 -0.007 -0.005  0.000 0.008 4

          eigenvalues
    (2.8720.4210.3050.141)                                          #error ellipse
  eigenvectors of adjustment        covariance           errors #  serr az dip
 ot (-.995-.0110.0270.097)(  0.002 -0.001 -0.002 -0.013)  0.040 #  0.36 289 78
 lat(0.003-.997-.030-.067)( -0.001  0.015  0.001  0.008)  0.124 #  0.17  89 10
 lon(0.009-.0170.982-.188)( -0.002  0.001  0.032  0.019)  0.179 #  0.12 180  4
 z  (-.1010.070-.184-.975)( -0.013  0.008  0.019  0.128)  0.358 #
--------------------------------------------------------------------------------
year mo da origin time lat n     lon w    depth  rms   erh   erz gap xmag fmag
2011-12-24 06:24:57.98 41 07.11  80 41.61  3.55  0.012 0.17  0.36 119      2.7

 rmswt dmin itr nfm nwr nws remk tq sq dq    lat    lon
  0.01  1.9   7   4   8   4  aa  b  a  b     41.1186 -80.6936

  sta dist azm  an p/s w   sec+ccor  (tobs -tcal -dly  =res)  wt  xmg fmg  info

YT02   1.9 242 144 ipd   58.826 0.00 0.850 0.837 0.00  0.013 1.14         0.293
                    s  1 59.423 0.00 1.447 1.448 0.00 -0.001 0.86         0.719
YT03   3.6  53 121 ipd 1 59.031 0.00 1.055 1.040 0.00  0.015 1.14         0.418
                    s  1 59.760 0.00 1.784 1.799 0.00 -0.015 0.86         0.668
YSUO   4.1 112 116 ipu 4 58.116 0.00 0.140 1.115 0.00 -0.975 0.00         0.000
YT04   4.4 329 113 ipu   59.132 0.00 1.156 1.159 0.00 -0.003 1.14         0.521
                    s  1 59.971 0.00 1.995 2.006 0.00 -0.010 0.86         0.427
YT01   6.5 172 102 ipu   59.460 0.00 1.484 1.482 0.00  0.002 1.14         0.520
                    s  1 60.517 0.00 2.541 2.564 0.00 -0.023 0.86         0.430
```