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Location of 27 March 1975 Earthquake

Abstract

This investigation used three seismograms to triangulate the location of this earthquake from the time-delay between P- and S-wave arrivals. The average origin time was obtained from the three seismograms and the earthquake magnitude was calculated from the maximum amplitude and epicentral distance. The values and associated uncertainties were 34 $\pm$ 2 ˚N, 58 $\pm$ 3 ˚E for the location of the earthquake epicenter, with an origin time of 5:17 $\pm$ 3 and a magnitude of 7.1 $\pm$ 2.

Introduction

Seismogram triangulation is the best method for precisely locating the epicenter of an earthquake, which helps to identify the likely locations of future earthquakes. Examining the seismograms reveals the origin time and magnitude of the earthquake as well. Identifying seismic wave phases from seismograms also reveals information about structure of the deep earth. This investigation will identify the P- and S-wave arrivals on three seismograms and use the delay between the arrivals to calculate the epicentral distance for each seismic station. Once the epicentral distance has been calculated, the P-wave arrival time can be used to calculate the earthquake origin time, and the maximum amplitude can be used to calculate the magnitude.

Method

First the epicentral distance and origin time for each seismic station was calculated by determining the arrival times of the P and S waves and comparing them to the supplied graph, as in the described procedure (Naylor, 2020, p. 1). Matplotlib was used to plot circles of the determined radius around each seismic station to triangulate the epicenter of the earthquake. Next the direction of the epicenter from the BUL station was determined by examining the polarity of the Rayleigh waves. Finally, the magnitude of the earthquake was calculated with the provided formula (Naylor, 2020, p. 2).

Results

The arrivals as read off the seismograms are shown in the following table:

Station	Inst	Hr:min	mm	time (s)	delay (min:sec)	Phase
BUL	LP Vert	05:25	8	18	0	P
BUL	LP Vert	05:33	14	31	07:13	S
BUL	LP Vert	05:44	4	9	08:51	
BUL	LP North	05:33	14	31	07:13	S
BUL	LP North	05:44	0	0	18:42	

BUL	LP North	05:47	4	9	21:51	
BUL	LP East	05:33	14	31	07:13	S
BUL	LP East	05:41	10	22	16:04	
BUL	LP East	05:44	16	35	19:17	
COL	LP Vert	05:26	24	53.3	00:00	P
COL	LP Vert	05:36	18	40	09:47	S
COL	LP Vert	05:45	0	0	18:07	
COL	SP Vert	05:26	89	50	00:00	P
SHL	LP Vert	05:24	19	42	00:00	P
SHL	LP Vert	05:27	0	0	02:18	
SHL	LP Vert	05:28	9	20	03:38	
SHL	LP Vert	05:32	16	35	07:53	
SHL	LP North	05:24	22	49	00:00	P
SHL	LP North	05:27	0	0	02:11	
SHL	LP North	05:28	8	18	03:29	
SHL	LP North	05:32	16	35	07:46	
SHL	SP Horiz	05:29	62	34	04:44	
SHL	SP Vert	05:24	90	50	0	P

Table 1.

From the above table, the delay times for BUL, SHL and COL are 7:13 $\pm$ 15, 4:44 $\pm$ 15, and 9:47 $\pm$ 15, respectively. The epicentral distances are 51 $\pm$ 2°, 19 $\pm$ 2°, and 78 $\pm$ 2°.

When plotted as below, the epicentral distances enclose a triangle centered around 34 $\pm$ 2° N, 58 $\pm$ 3° E.

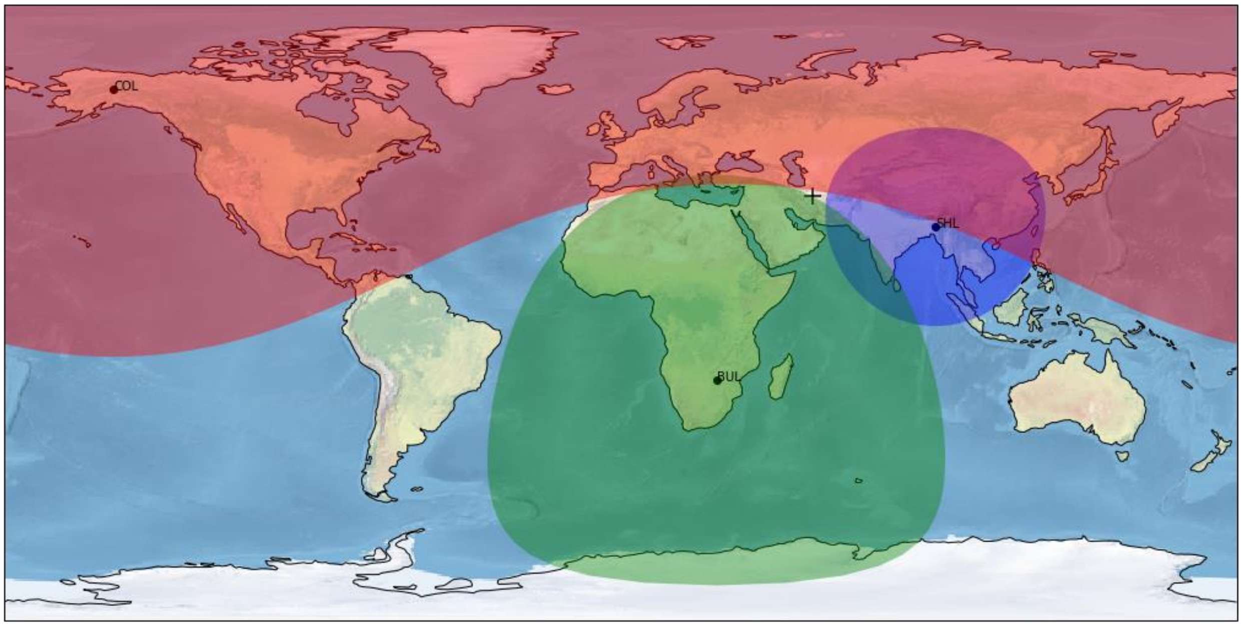

Figure 1.

The long period BUL seismograms show the first arrival Rayleigh wave spiking in the N and E directions, which confirms the direction of the epicenter as roughly northeast of the BUL station.

The calculated origin times for BUL, SHL and COL are 5:16 ± 2, 5:20 ± 2, and 5:14 ± 2, respectively. The average arrival time is 5:17.

The earthquake magnitude was calculated as follows.

Max amplitude= 4. 9 ± 0.2 cm

4.9 ± 0.2 cm/1500 = 3300 ± 100 microns

Avg period = 7min/ 15 ± 1 waves= 0.47 ± 0.03 min = 28 ± 2 seconds

Magnitude= $\log_{10}(A/T)+\log_{10}\Delta+3.3$

= $\log_{10}$(3300 ± 100 microns /28 ± 2 seconds)+ $\log_{10}$ (51 ± 1°)+3.3

=2.07+1.71+3.3

=7.1 ± 2

Conclusion

In conclusion, the earthquake happened at 5:17 ± 3 minutes around 34 ± 2˚N, 58 ± 3˚E, with a magnitude of 7.1 ± 2.

Discussion

The sources of error in this investigation were both numerous and difficult to quantify. Most errors were estimated by eye from the map or seismograms and propagated through calculations. Estimating error by eye is not very accurate, especially considering the difficulty of reading old seismograms.

The error estimation of the arrival times for each phase assumes that the phase itself has been correctly identified on the seismogram, when in fact this is not at all certain. A more accurate error estimation might be expanded significantly to include all arrivals that could be that phase, as opposed to a bit of uncertainty around the arrival assumed to be the correct phase. However, this would lead to errors in the tens of minutes, which would be so large as to make the arrival times useless for conveying any information about the earthquake.

This investigation made one consider the relative strengths and weaknesses of doing the earthquake location process by hand and with computers. While this process was tedious in the extreme, it also required enough human judgment that it would seem complicated to teach a computer to do. Judging which changes in amplitude and period constitute a new phase and which are just random seems like a task the brain is still better suited for than computers. The necessarily iterative nature of this process would seem to be challenging for computers as well. Judging whether an error is inherent to the process or is large enough to indicate that the assumed phase is incorrect and a new one needs to be used is an arbitrary decision of the kind that humans are still better at. Computer decisions are, however, at least never influenced by laziness or boredom.

Human laziness does ensure that the interpretation of data does not have a falsely high degree of accuracy. Judging whether an interpretation is too accurate relative to the inherent inaccuracy of the data is a similarly arbitrary decision; one where the human desire to leave the lab helps to prevent overfitting the interpretation to the data.

The accuracy of this investigation could as always be improved with readings from more seismic stations. While the location of the earthquake was reasonably well constrained by these data, the disparity in calculated origin times does suggest the need for more data. More modern seismograms that can be filtered for frequency would of course help to pick out S-wave arrivals and calculate the origin time as well.

References

Naylor, M. (2020) ‘Earthquake Location from Teleseismic Records.’ University of Edinburgh.