A Preliminary Engineering Report on the
Bingöl Earthquake of May 1, 2003

Polat Gülkan, Sinan Akkar and Ufuk Yazgan

Middle East Technical University
Department of Civil Engineering and
Disaster Management Research Center

Introduction

A M_w6.4 magnitude earthquake struck the city of Bingöl on May 1, 2003 at 3:27 am local time. Middle East Technical University responded to the developing situation by dispatching a team consisting of staff from Civil Engineering and Geological Engineering on the same day. Other teams have since been to the area to do building damage surveys and geotechnical observations as well as additional investigations of geology and tectonics.

This report is based on observations of the first two of the authors listed above, and will subsequently be supplemented by the report on geology. It is intended as an early report to provide readers with a preliminary impression for the event.

Bingöl Statistics

Bingöl is situated in the upper Murat River plateau of Eastern Turkey. The city marked on Figure 1 is 900 km due east by road from Ankara, and the straight line distance from Ankara is 650 km. In addition to the administrative provincial center at Bingöl itself there exist 7 sub-provinces and 9 districts to which 329 villages have been linked. Results from the 1990 ve 2000 nation-wide censuses are summarized in Table 1.

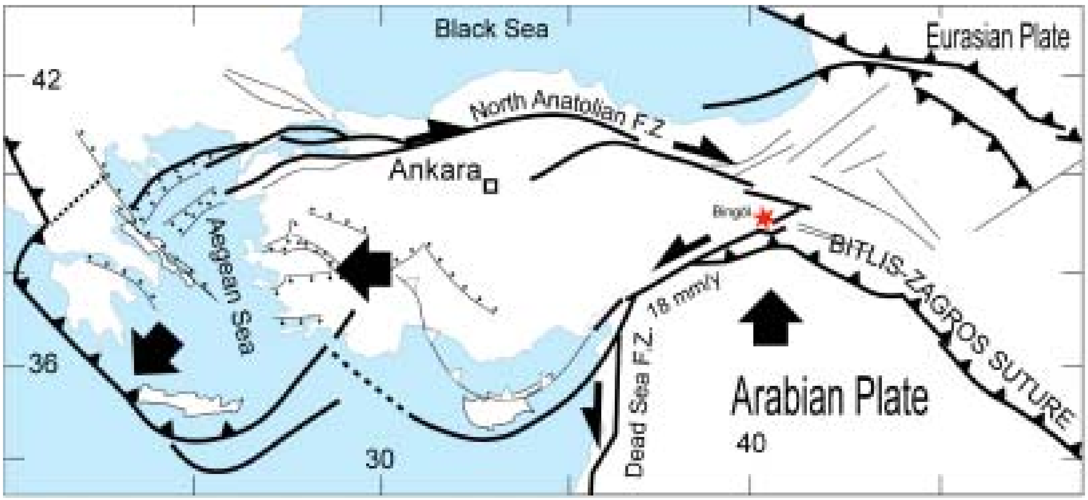


Figure 1. Location of Bingöl (Source: Dr. N. Kaymakçı)

Table 1. Bingöl Population

Sub-Province	1990 Census			2000 Census		
	Total	**Urban**	**Rural**	**Total**	**Urban**	**Rural**
Bingöl Center	95 445	41 590	53 855	116 411	68 876	47 535
Adaklı	19 519	4 548	14 971	10 856	3 370	7 486
Genç	42 263	11 545	30 718	45 994	18 345	27 649
Karlıova	34 956	8 504	26 452	32 421	8 761	23 660
Kiğı	11 438	4 544	6 894	6 780	4 684	2 096
Solhan	35 292	12 191	23 101	33 604	14 325	19 279
Yayladere	3 607	1 294	2 313	4 050	3 136	914
Yedisu	6 554	2 432	4 122	3 623	1 973	1 650
Total	**249 074**	**86 648**	**162 426**	**253 739**	**123 470**	**130 269**

What these numbers reveal is that the degree of urbanization, defined as people dwelling in centers where a municipality has been formed, and the population density are both very low in comparison with the national averages. Most people live in villages or hamlets at or near valley elevations where winter is less harsh. The economy is driven by cattle and other livestock breeding. The rate of population growth is very slow because young persons emigrate either to the west of the country in search of jobs, or to countries in Europe where earlier generations have settled. Bingöl city itself, the provincial center has become more populous, especially following the 1971 earthquake.

Results from the 1984 and 2000 Building Censuses have been summarized in Table 2.

Table 2. Building Statistics

Year	Total Bldg.	Resid.	Mostly Resid.	Mostly Non-Resid.	Wholly Comm.	Edu. Cultur	Health	Inst.	Rel.	Mixed Non-Res.	Other
1984	9,815	7,976	358	192	1,062	79	13	61	34	38	2
2000	17,209	14,348	763	165	1,481	140	26	127	76	40	43

Bingöl has an extremely rough terrain with mountains in the 2 500-3 000 m elevation range, connected by plateaus of tectonic origin and deep valleys. The drainage to the river Murat is through two streams called Göynük and Perisuyu, respectively. A typical land climate is effective in the province where the average January temperature is –1.4 Deg. C, and dips to below –20 degree are frequent. Summers are brief but warm. The common flora consists of grass and similar herbage. Forests of oak have been depleted through felling and animal intrusion. Annual rainfall in Bingöl is 900 mm.

Bingöl Earthquake Statistics

A list of $M \geq 5.5$ earthquakes within and close to the province has been compiled from Gencoglu et al. (1990) in Table 3, with later events substituted from other sources.

Table 3. Earthquakes within Bingöl and Vicinity

Date dd.mm.yy	Lat. (N)	Long. (E)	Depth (km)	Magnitude (Local)	Notes
--.03.01	39.92	41.30	-	5.7	
28.04.03	39.10	42.50	-	6.3	Bulanık-Muş
--.--.05	38.30	38.60	-	5.7	
04.12.05	39.00	39.00	-	6.8	Akçapınar
04.12.05	39.00	39.00	-	5.8	
04.12.05	39.00	39.00	-	5.6	
--.--.06	39.92	41.30	-	5.7	
27.01.07	39.10	42.50	-	6.3	Malazgirt
05.03.09	39.70	40.50	-	5.5	
14.02.15	38.80	42.50	-	5.6	
13.09.24	39.96	41.94	10	6.8	Pasinler
10.12.30	39.72	39.24	30	5.6	
12.11.34	38.54	41.00	50	5.9	Yenibaşak
27.11.34	37.90	40.20	-	6.2	Diyarbakır
15.12.34	38.90	40.50	-	5.8	
21.11.39	39.82	39.71	80	5.9	Tercan
26.12.39	39.80	39.51	20	7.9	Erzincan
18.10.40	39.60	42.20	15	5.6	
08.11.41	39.70	39.70	-	5.5	
12.11.41	39.74	39.43	70	5.9	Erzincan
31.05.46	39.29	41.21	60	5.9	Varto-Hınıs
14.12.47	39.90	42.50	-	5.5	
17.08.49	39.57	40.62	40	6.7	Karlıova
03.01.52	39.95	41.67	40	5.8	
25.10.59	39.47	41.70	-	5.8	
02.03.60	37.90	41.10	-	5.5	
01.03.61	38.40	39.30	-	5.5	
12.02.62	39.00	41.60	-	5.5	
17.02.62	38.70	41.50	-	5.5	
31.08.65	39.36	40.79	11	5.6	
07.03.66	39.20	41.60	26	5.6	
19.08.66	39.17	41.56	26	6.9	Varto
20.08.66	39.42	40.98	14	6.2	Varto
20.08.66	39.16	40.70	33	6.1	Varto
26.07.67	39.54	40.38	30	5.9	Pülümür
22.05.71	38.85	40.52	3	6.8	Bingöl*
06.09.75	38.51	40.77	32	6.6	Lice
13.03.92	39.71	39.61	27	6.8	Erzincan
15.03.92	39.60	39.60	17	6.1	Pülümür
27.01.03	39.52	39.78	10	5.8	Pülümür

* This earthquake caused 900 deaths.

The entire province is situated within the highest hazard zone of the Hazard Zones Map for Turkey that went into effect in 1996 (Figure 2).

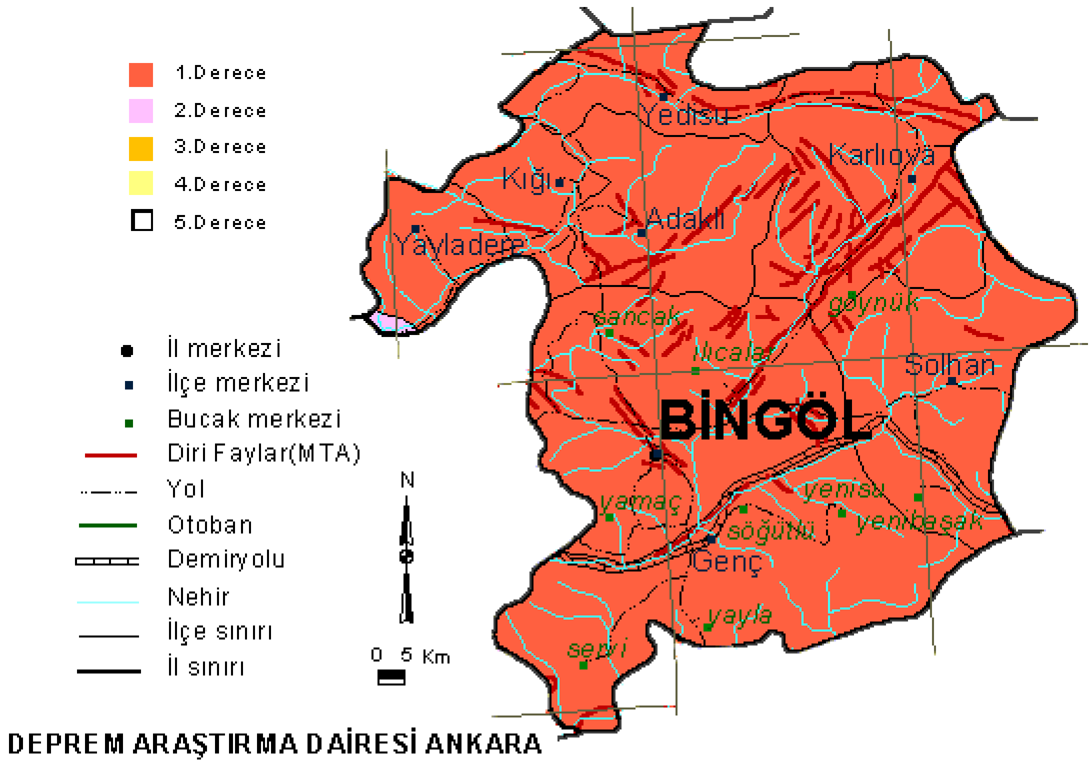


Figure 2. Major Faults in Bingöl (Source: Earthquake Research Division, General Directorate of Disaster Affairs, Ankara)

Material Losses during the May 1, 2003 Earthquake

Definitive statistics were not at hand at the time of writing this report. According to official sources, some 174 people lost their lives, and 520 injuries were reported. The most tragic concentration of deaths took place in the Çeltiksuyu Regional Primary Education Boarding School when its dormitory block collapsed with some 200 children and at least one teacher were asleep inside. The death toll in the instance alone was 84 children plus the teacher. 114 of the students could be rescued through timely intervention of the Civil Defense teams. The city itself reported some 60 deaths and 370 injuries.

Other deaths and injuries are as follows:

Ortancaçanak: 2 deaths, 15 injured,
Göltepesi: 2 deaths, 4 injured,
Çimenli: 13 deaths, 10 injured,
Haziran: 1 death, 1 injured,
Beyaztoprak: 2 deaths,
Çiris: 7 deaths, 1 injured
Yesilova: 2 injured,
Çanakçı: 2 injured,
Solhan: 1 injured

It is traditional in Turkey to report building damages on the basis of dwelling numbers, and not building numbers. We have been able to account for 12 total collapses within the Bingöl city proper (other sources have cited 18), and 3 total collapses in Genç sub-province. Rural home damages are as yet not known. The total number of urban dwellings that would require repair is in the range of 3 000.

Magnitude and Epicenter Coordinates

Many seismological centers have reported the earthquake. Epicentral coordinates marked in Figure 3 have been summarized in Table 4.

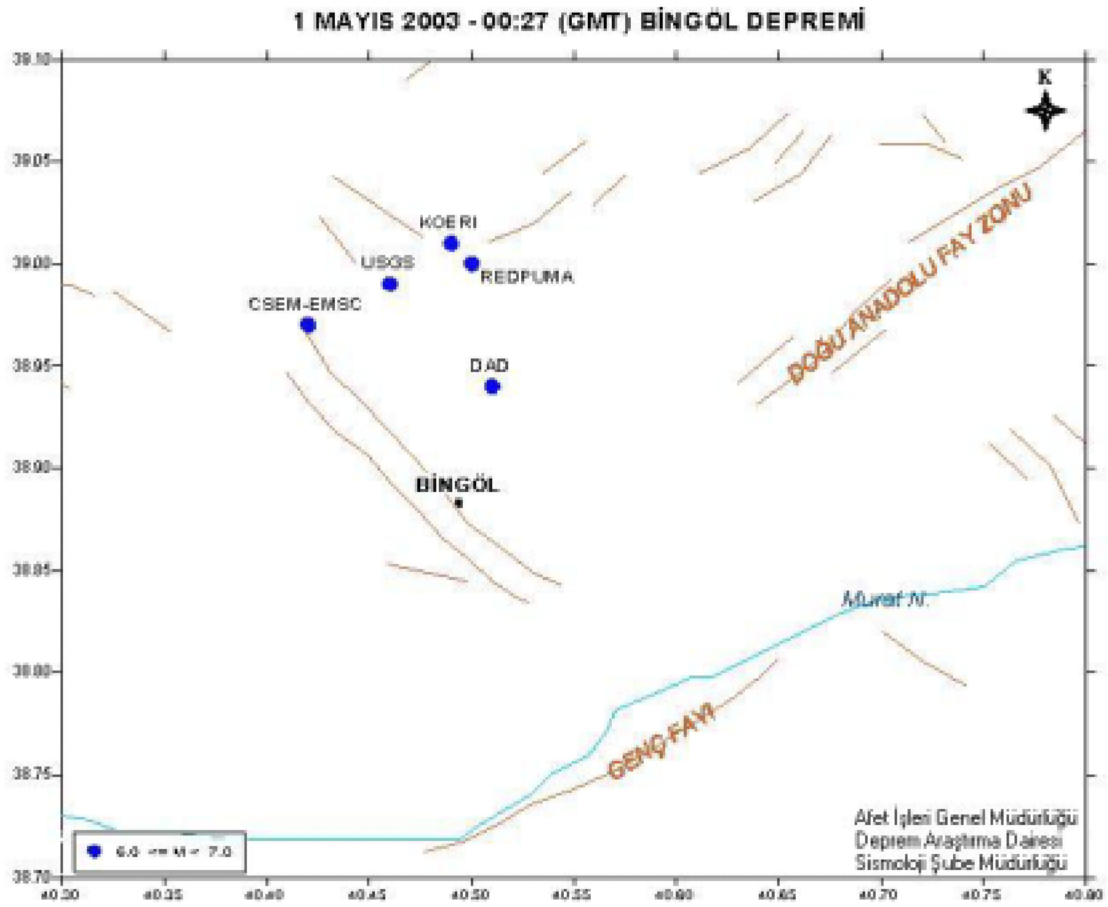


Figure 3. Reported Epicentral Coordinates

General observations suggest that the epicenter is located on a right-lateral transform fault, not part of the East Anatolian system to the south of a district center called Sancak, which is located 17 km to the north-west of Bingöl. Our preliminary observations support the idea that for the building stock in Bingöl this was a near-field experience.

Table 4. Preliminary Epicentral Coordinates and Magnitudes

Station	Lat. (N)	Lon. (E)	Depth (km)	Magnitude
GDDA	38.94	40.51	6	6.1(M_d)
Kandilli Observatory	39.01	39.99	10	6.4 (M_s)
USGS	39.00	40.44	10	6.4 (M_w)
CSEM	38.97	40.42	10	6.6 (M_w)
REDPUMA	39.00	40.50	10	6.1 (M_s)

Strong Motion Record

A digital instrument situated in a low-rise appurtenant building adjacent to the local office of the Ministry of Public Works and Settlement recorded the main shock. The main service building built according to a template design experienced what appeared to be moderate damage. (An identical building in Bolu was subjected to the November 12, 1999 earthquake that centered near Düzce, and was damaged more severely. Interestingly, an identical instrument in Bolu had then recorded a peak of about 0.79 g.) The new settlement area of the city situated in the north-east and shown in Figure 4 is built upon recent (Holocene) river terraces consisting of loose material with cobbles. The four-story Ministry of Public Works and Settlement building is shown in Figure 5.

Figure 4. Recent Development in Bingöl, View toward North-East
(Çapakçur River Valley in Foreground Bisects the City.)

Figure 5. Ministry of Public Works and Settlement Regional Office in Bingöl
(The recording instrument was in the back of the adjacent building.)

The instrument had been set upon a support in the back of the appurtenant building. The Earthquake Research Division of the General Directorate of Disaster Affairs, an agency with a mission similar to that of FEMA, released the digital record on their website (www.deprem.gov.tr) on the day the earthquake had occurred. The three components of the acceleration trace are given in Figure 6. We have calculated the preliminary velocity and displacement traces that are displayed in Figures 7 and 8, respectively. These diagrams are of course preliminary, and may require subsequent corrections.

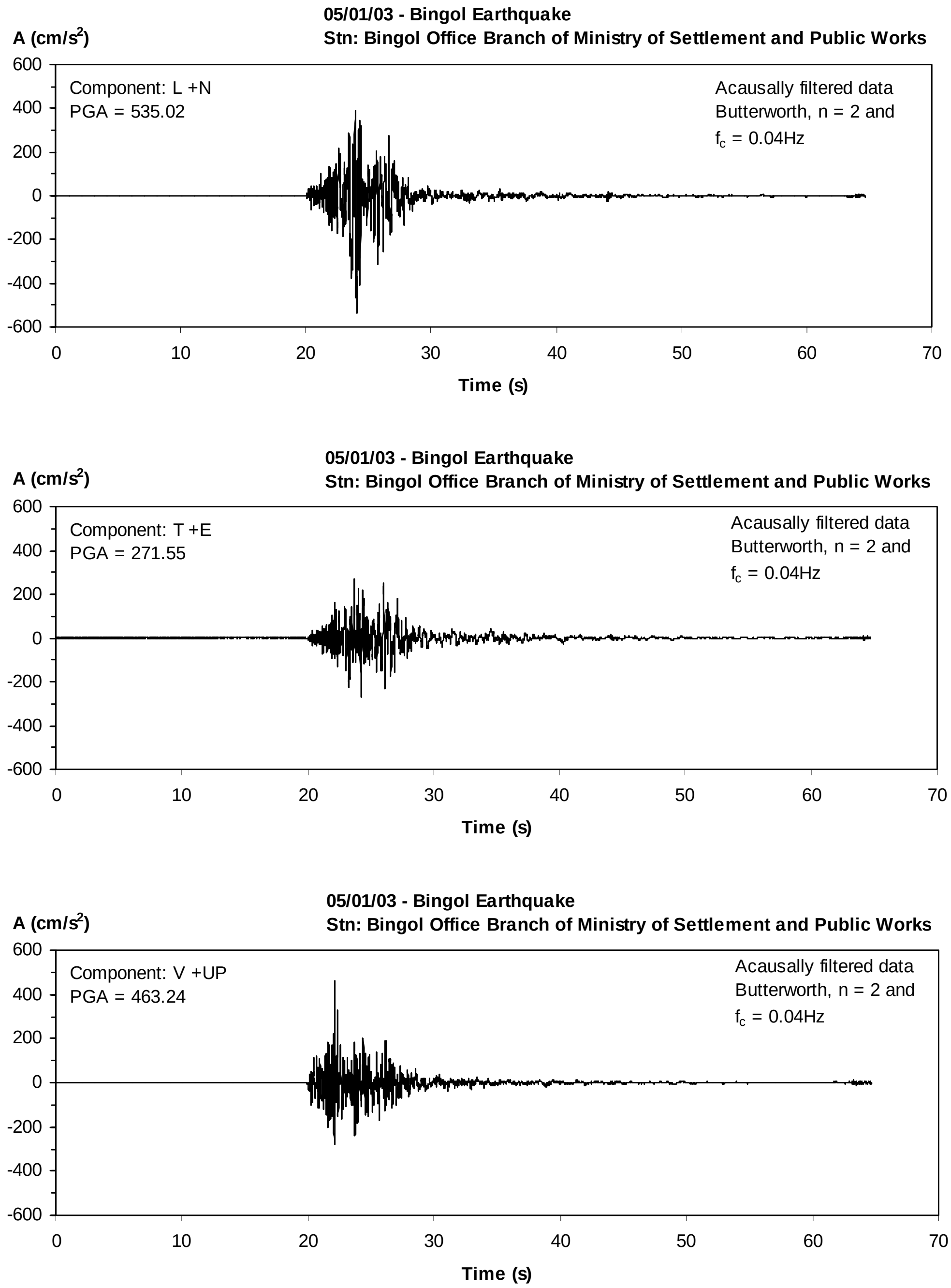


Figure 6. Acceleration Components

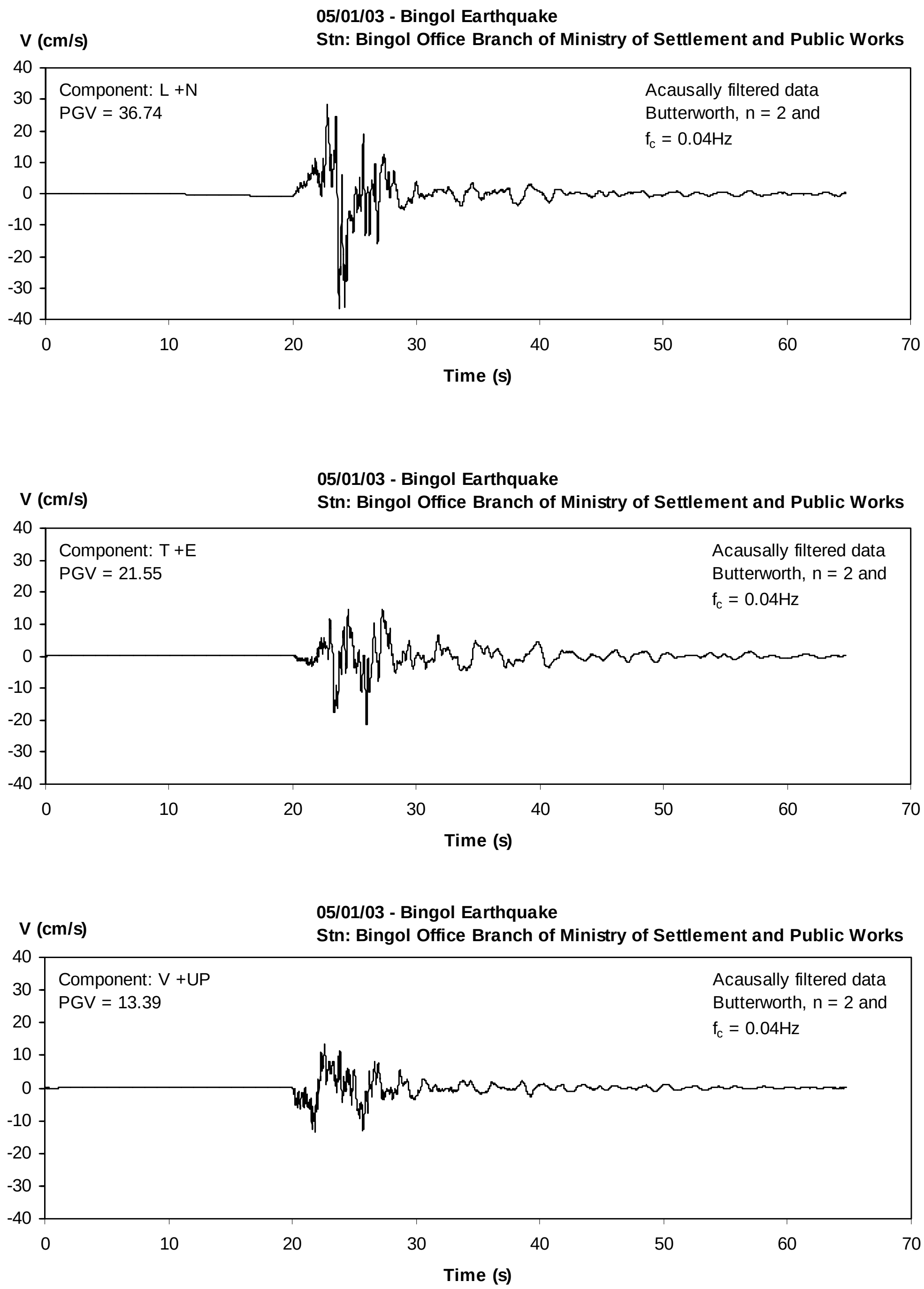
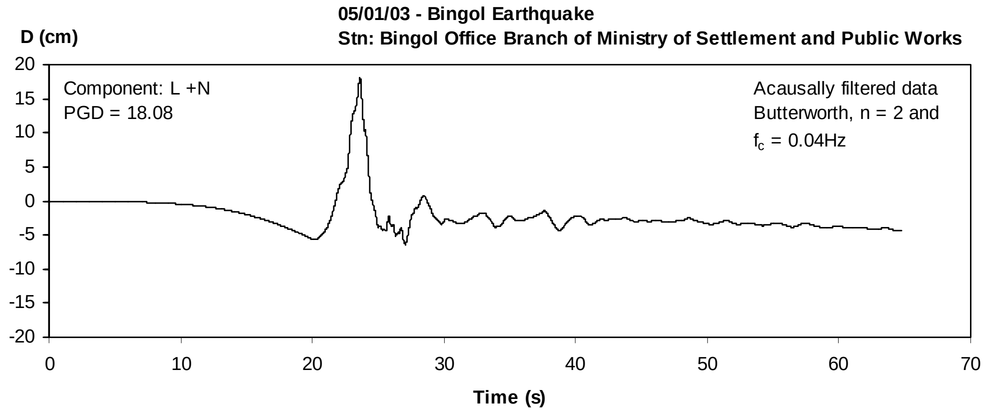
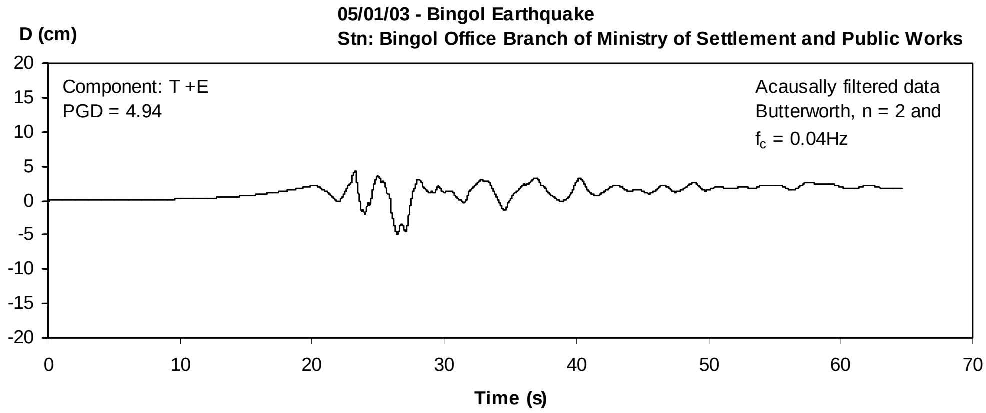


Figure 7. Velocity Components





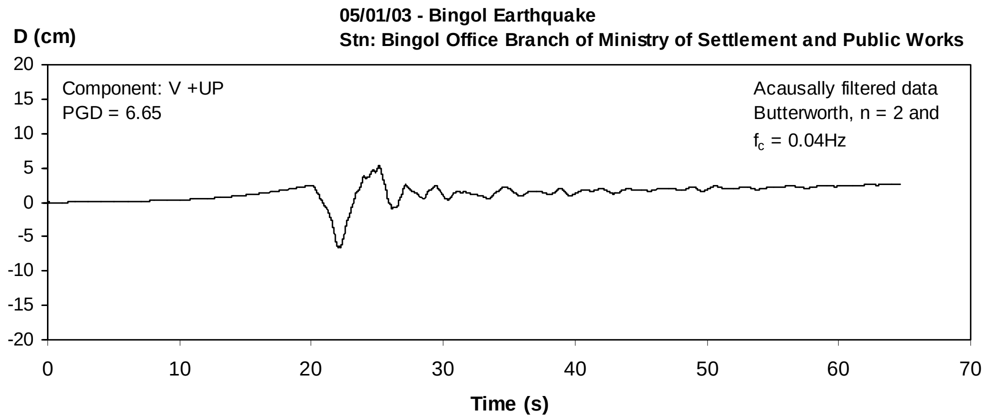
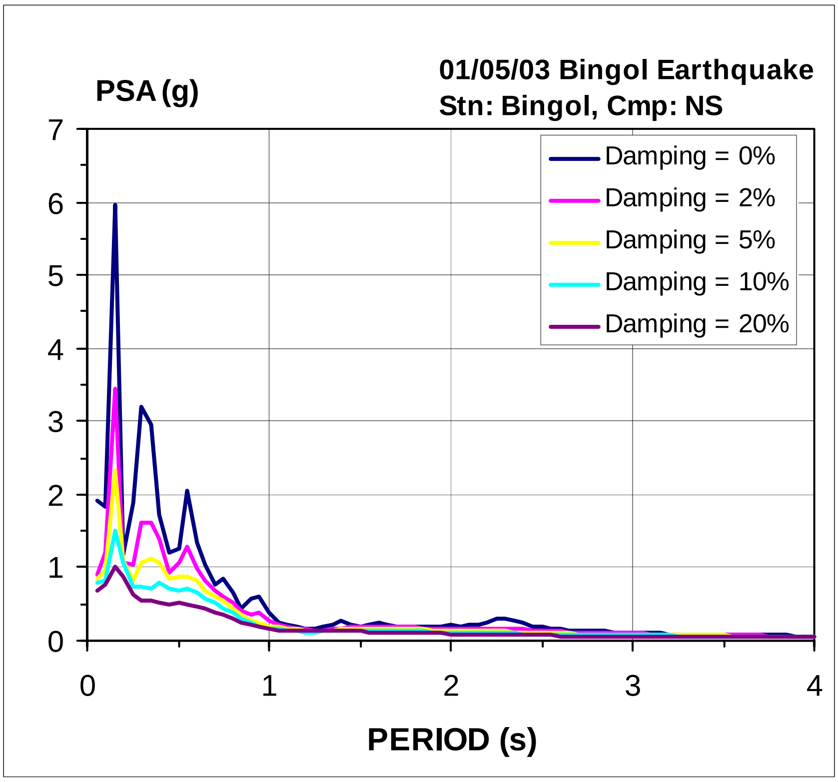
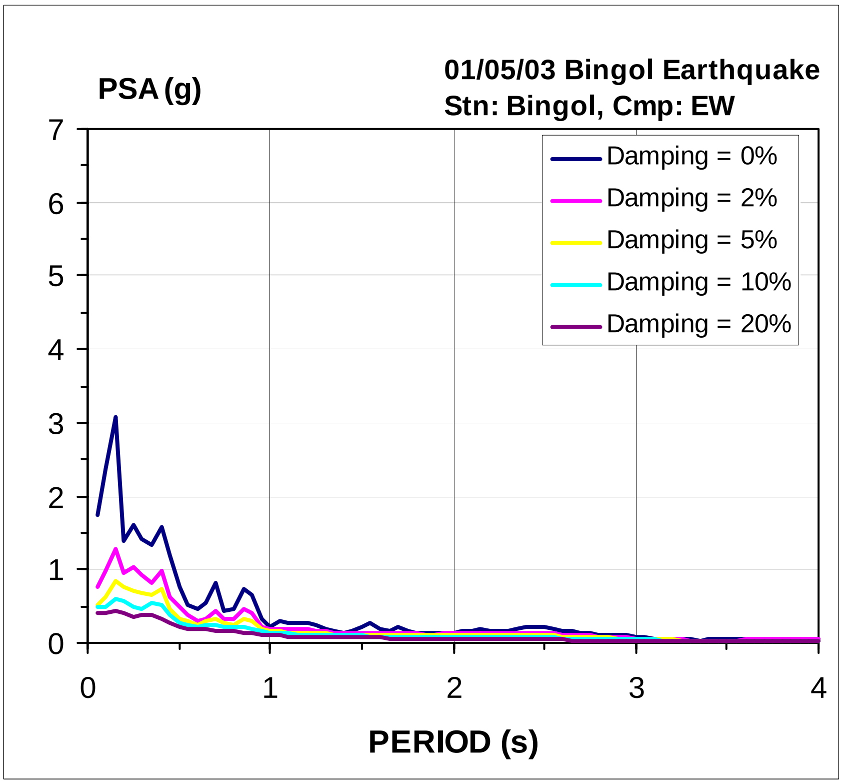


Figure 8. Displacement Components

We also have calculated response and drift spectra from the information contained in these figures, and display these in Figures 9-12. The peak at about 2.2 s for the velocity and displacement spectra would seem to merit close examination in terms of any basin effects or particular soil column responses.


01/05/03 Bingol Earthquake
Stn: Bingol, Cmp: NS
PSA (g)
7
6
5
4
3
2
1
0
0
1
2
3
4
PERIOD (s)
Damping = 0%
Damping = 2%
Damping = 5%
Damping = 10%
Damping = 20%


01/05/03 Bingol Earthquake
Stn: Bingol, Cmp: EW
PSA (g)
7
6
5
4
3
2
1
0
0
1
2
3
4
PERIOD (s)
Damping = 0%
Damping = 2%
Damping = 5%
Damping = 10%
Damping = 20%

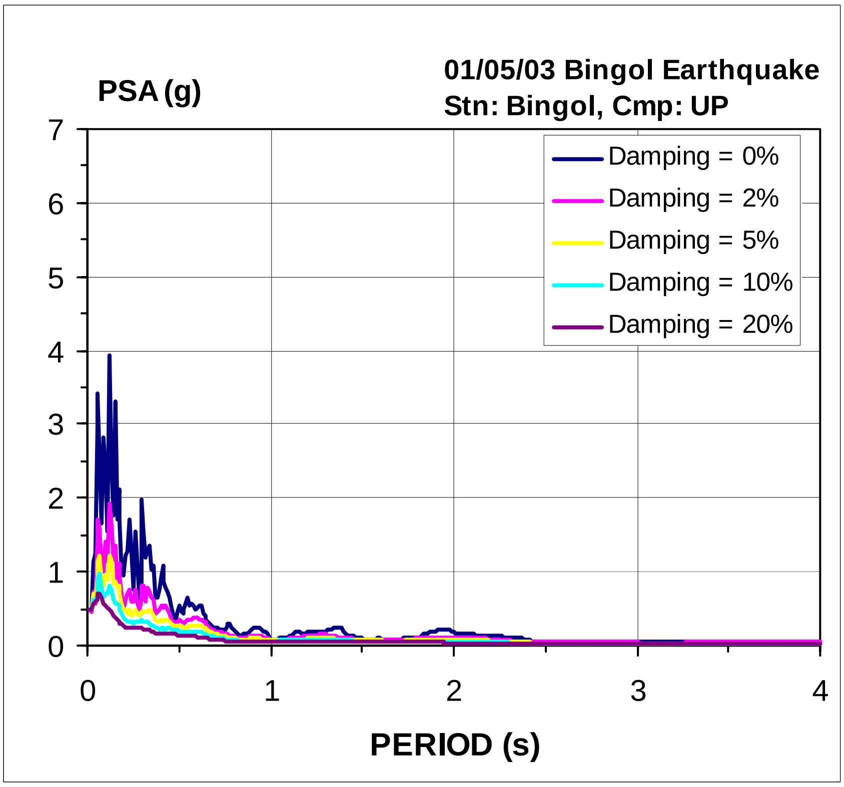
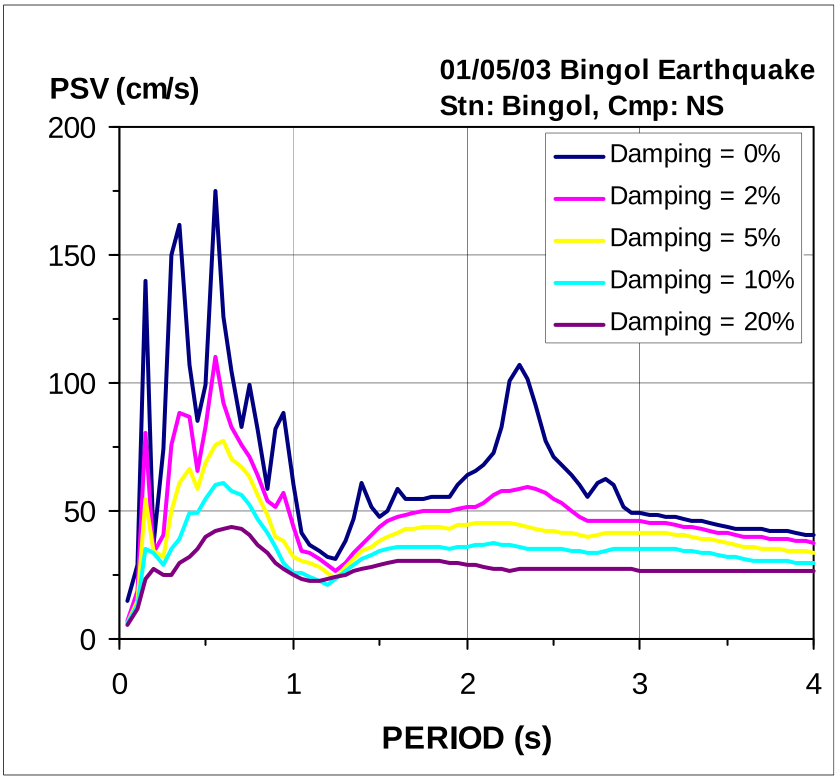
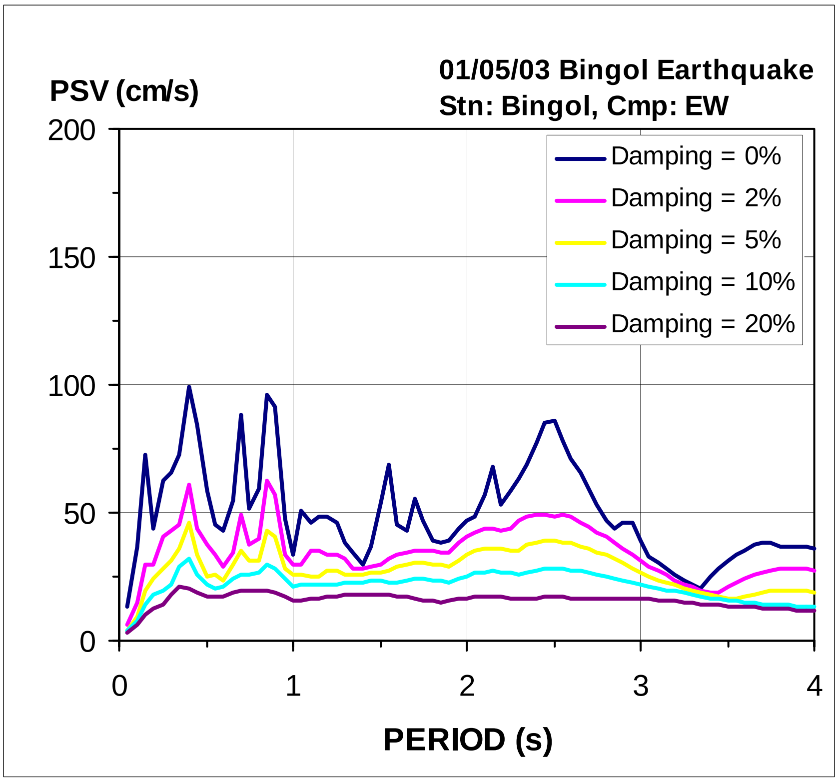


Figure 9. Spectral Acceleration Diagrams





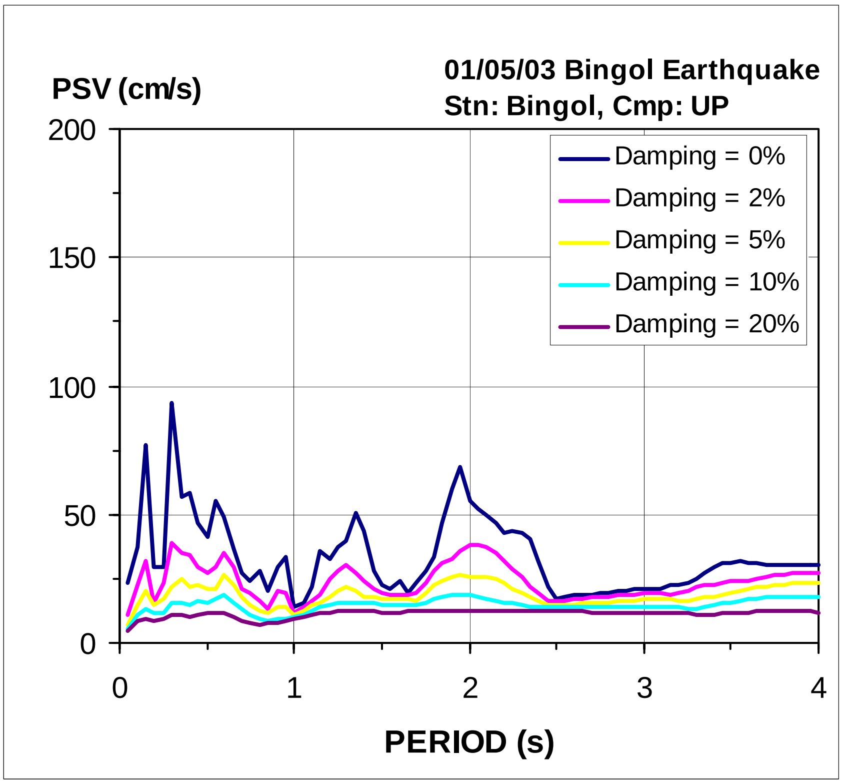
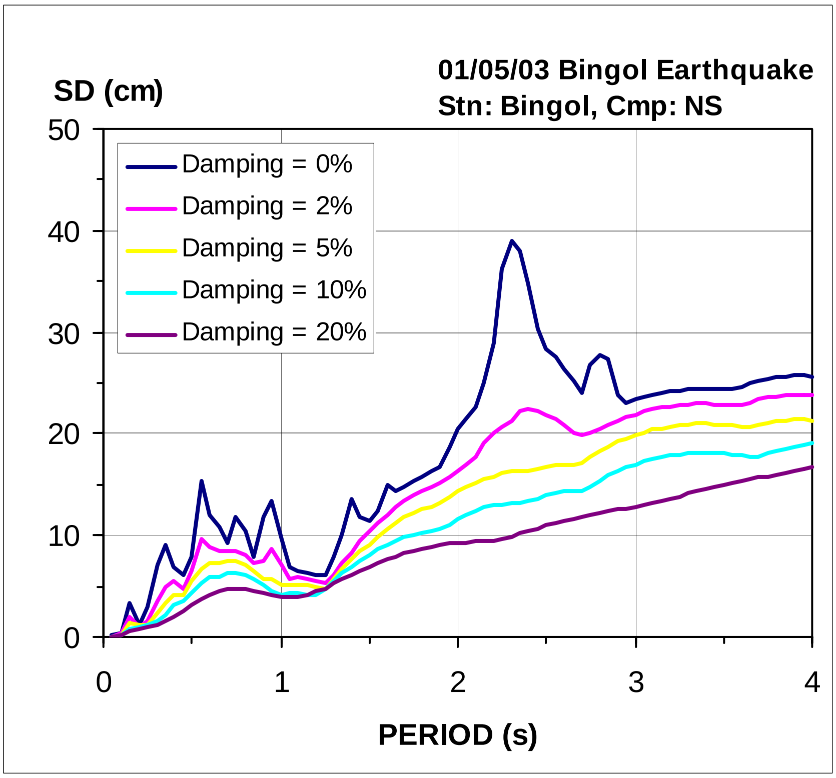
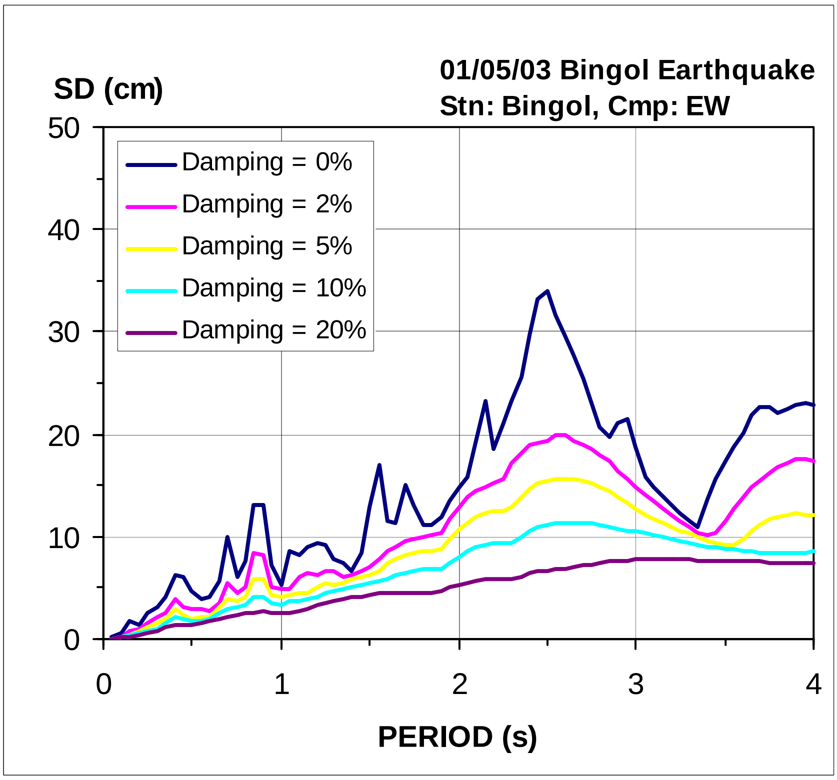


Figure 10. Spectral Velocity Diagrams


01/05/03 Bingol Earthquake
Stn: Bingol, Cmp: NS
SD (cm)
50
40
30
20
10
0
Damping = 0%
Damping = 2%
Damping = 5%
Damping = 10%
Damping = 20%
0
1
2
3
4
PERIOD (s)


01/05/03 Bingol Earthquake
Stn: Bingol, Cmp: EW
SD (cm)
50
40
30
20
10
0
Damping = 0%
Damping = 2%
Damping = 5%
Damping = 10%
Damping = 20%
0
1
2
3
4
PERIOD (s)

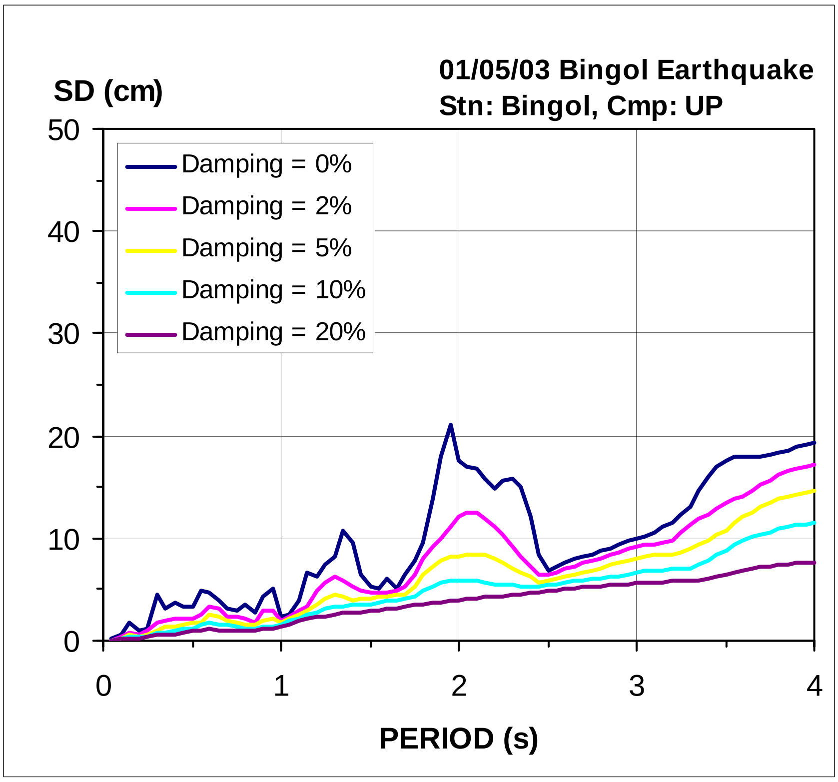
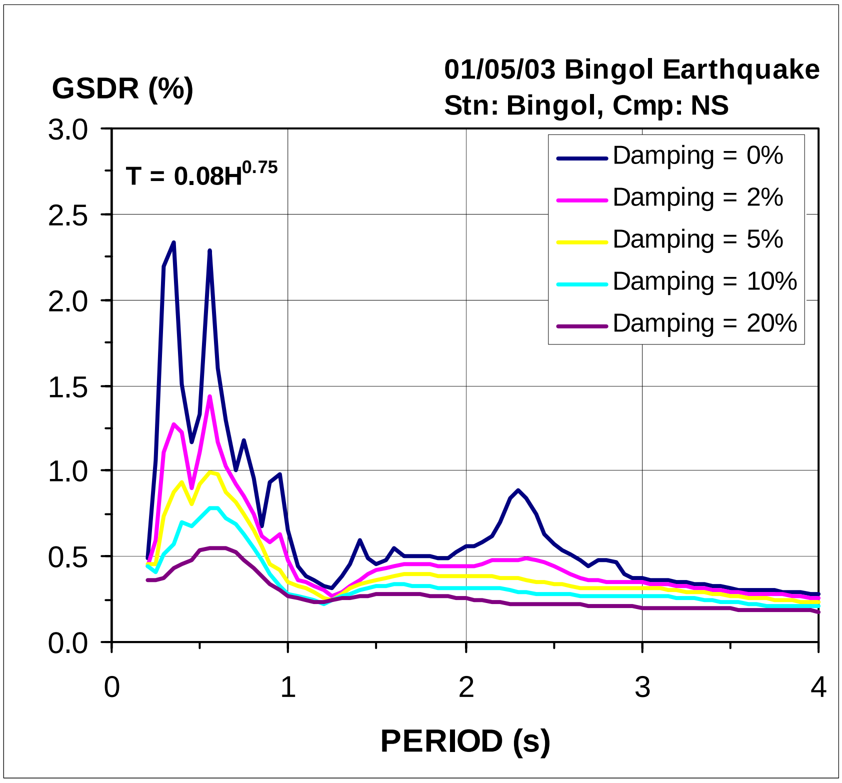


Figure 11. Spectral Displacement Diagrams



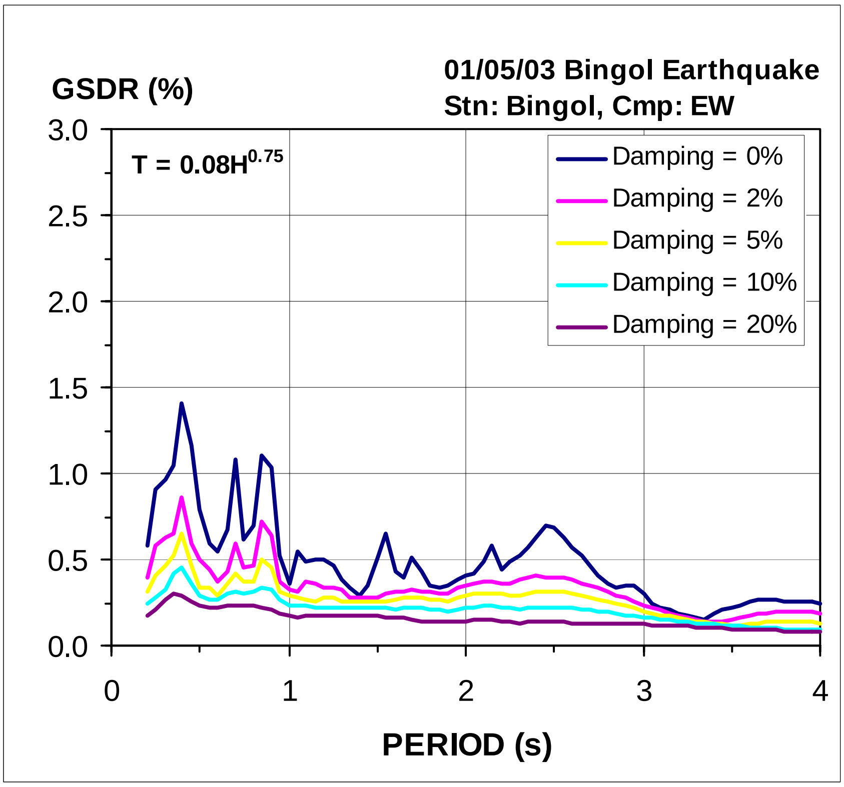


Figure 12. Drift Spectra for Horizontal Components

Preliminary Observations on Building Damage

Bingöl expanded rapidly following the far more devastating earthquake in 1971 when the government financed the reconstruction of several new districts in the city proper, and new land was converted for further development. The rolling hillside to the north shown in Figure 4 also developed quickly as institutional offices (hospital, the law enforcement units, ministry offices including Public Works) established their offices on either side of the road from Elazığ in the west. With a river in between, the city became in effect a two-winged settlement area with the older section reachable over a bridge. Compared with the state of the urban texture in 1971, the new Bingöl is virtually a rebuilt environment. In terms of site characteristics both halves appear to be similar, with loose cobbled river terraces inclined steeply toward the river forming much of the base materials. In no location in the city did we observe any instance of liquefaction or foundation settlement underneath buildings.

Building damage near the city center was similar to what we have observed in Turkey under similar conditions. Centrally located avenues and streets where many commercial establishments are at the ground story of otherwise residential buildings was strewn with shards of broken glass panels from the shops, likely signs of high drifts those buildings needed to sustain. Large-scale destruction such as was seen in the two 1999 earthquakes in the Sea of Marmara region did not now occur in Bingöl. The N-S component with the higher acceleration peak also displays a higher drift demand of about 1 percent at 0.6 s, which might be characteristic of buildings in the 4-6 story range after cracking has occurred in the vertical load-carrying members. The surprisingly high spectral acceleration for the same component at about 0.2 s requires subsequent examination.

The most tragic building collapse occurred at Çeltiksuyu Regional Primary Education School when both the dormitory building with about 200 children asleep inside and the adjacent school block were badly damaged. An identical school building (Kaleönü) closer to the city and some 7 km away from the collapsed dormitory block failed in identical fashion. Regional schools are the response of the Government of Turkey to fulfill its obligation to provide facilities for the mandatory 8-year primary education. Kids from the small villages and hamlets in the surrounding area are enabled to live in them as boarders. Some are for combined boarder-daily commuter students when they are close to cities, and others may serve regular attending children during the day with no adjacent dormitories. Other institutional buildings in Bingöl also suffered structural damage.

If a E-W section were taken (roughly parallel to the river ravine in the foreground of Figure 4) then the geology and topography of the city are described by the representative formations in Figure 13.

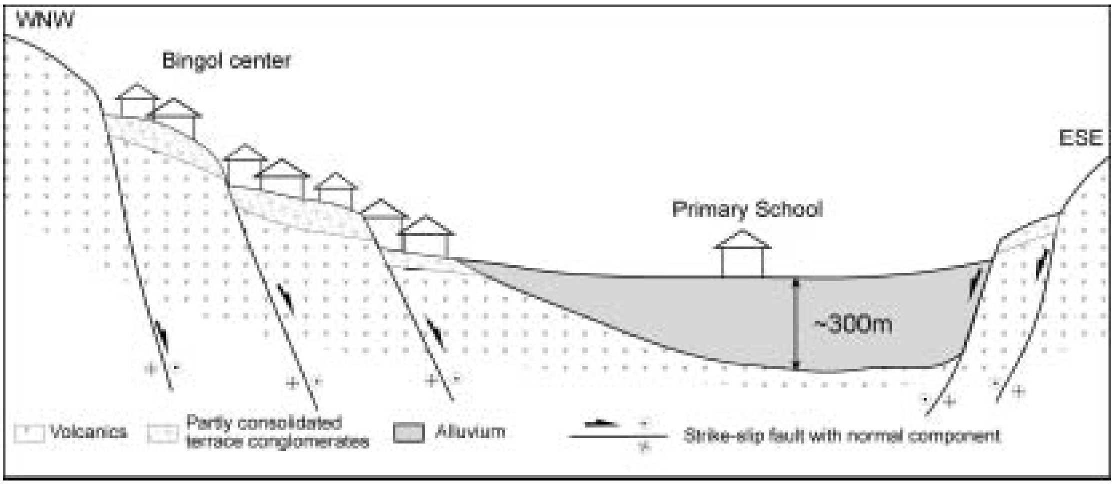


Figure 13. E-W Section for Bingöl ("School" denotes the Çeltiksuyu Regional Primary Education facility that is about 10 km from the town center. The sketch is not to scale. Source: Dr. N. Kaymakçı.)

Short notes on the modalities of building damage will be provided within the corresponding figure captions. We should note that the post-1971 earthquake government built housing (three story reinforced concrete frame structures without walls) performed well, and would be rated as fit for "immediate occupancy."

Figure 14. Kaleönü Primary Education School Building (This school is located 7 km to the west of the one in the next figure, but has an identical design. It is located at the city fringe. Note the canopied entrance that is now at the second story level. The story mechanism appeared to have been triggered by flexural action. Column reinforcement was plain bars, transverse confinement in columns negligible, and nonexistent within joints.)

Figure 15. Çeltiksuyu Regional Primary Education School Building (Note identical entrance canopy partially visible on left. Again, the ground story had collapsed fully in exactly the same way as that in Figure 14. This building had been completed in 1998.)

Figure 16. Dormitory Block on the west of the class room block at Çeltiksuyu Regional Primary Education School (All three stories appeared to have turned into mechanisms, resulting in complete pancake type collapse. Plain reinforcement was visible in broken columns.)

Figure 17. North Side of Building in Figure 15

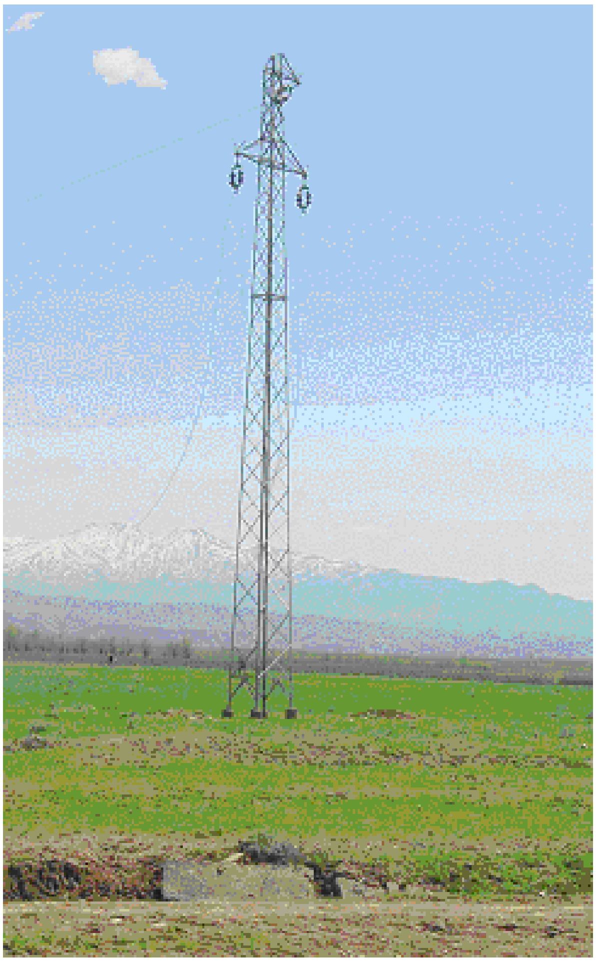


Figure 18. Power Pylon about 100 m Away from Çeltiksuyu School (Note loose alluvial soil and ground water seeping from ditch in foreground. This pylon had snapped the power cables on the west side. Soil here and at the school appeared to be S_E/S_F in the UBC characterization.)

Figure 19. Pylon Immediately on West of That in Figure 18. (Could this have been an indication of an extremely powerful fling that caused the cables to rupture? The truss members appeared to be unaffected.)

Figure 20. View Looking West from Çeltiksuyu. (Deep alluvial plain in foreground.)

Figure 21. Four-Story Residential Apartment in the North-West (Source: Dr. Erhan Karaesmen)

Figure 22. Just-Completed High School Building in City (The two shear walls flanking the hallway are the only ones in the longitudinal direction. Wall facing this one damaged worse. The only wall in the transverse direction appeared to be in a state similar to this. Source: Dr. E. Karaesmen.)

Figure 23. Another Recently Completed Building That Experienced Ground Story Failure (Source: Dr.E. Karaesmen)

Figure 24. Collapsed Building at East Exit from City

Figure 25. Regional Office Building of Public Works and Settlement from Inner Court (An identical replica in Bolu had suffered heavier damage in 1999 with column in middle shearing due to short column action. The situation here was one of impending failure in same way.)

Summary and a Few Generalities

With the unacceptable exception of the tragic collapse of the dormitory block at the Çeltiksuyu boarding school where 85 people lost their lives the earthquake on May 1, 2003 was somewhat localized and did not cause widespread damages. This judgment is expressed if the state of the city 32 years ago is taken as the yardstick. When damage assessment surveys are completed there will emerge a more detailed image of the situation than what has been drawn in this preliminary reportage. The ground motion record of the main shock was properly recorded, and we anticipate that its closer examination will perhaps permit us to speak in more quantitative terms about its effects on the built environment. The peak ground acceleration of 0.54 g in one component does not seem to match expected building damages for the stock in Turkey.

The relief and search and rescue operations went well. Civil Defense teams from several neighboring provinces intervened immediately, and were able to retrieve many children alive from the dormitory building. Military units and volunteers helped effectively. The Turkish Red Crescent established their mobile kitchens for food. Fairness of tent distribution caused some citizens to protest the governor, but more was rushed to the area. With some 12 000 tents handed out (far more, it would seem, than was strictly necessary because this many tents would accommodate the entire city) this complaint was not heard any more.

The national media in Turkey broke into its well-established ritual of blaming unscrupulous contractors and their colluding control engineers appointed through local political pressure for the damage and collapse of institutional buildings. We refrain from commenting on the accuracy of this rushed judgment to public executions. The routine practice for erecting many of the buildings intended for governmental services (such as hospitals and health clinics, administrative centers, public libraries, tax collection offices, etc., besides schools) are usually done from template designs that have been developed by the General Directorate of Construction Affairs. The rationale for this is to save from architectural services fees, and ensure closer quality assurance. So there exist standard buildings constructed all over the country for 10-classroom schools, or 120-bed hospitals. As the example of two identical class-room buildings belonging to two different schools in Bingöl has demonstrated forcefully, possible design errors are also automatically transmitted from location to location. In principle, buildings to be built in areas of different seismic hazard have slight design modifications, usually in the form of adjustments in reinforcement. It seemed that in both instruction blocks the typical situation of strong girder and weaker columns existed. We do not know why in a city that experienced a major earthquake only in 1971 two expensive school buildings were approved for construction without the simple expedient of guarding against this type of failure. Assuming that contracting services or workmanship or material quality can not be ensured as have been made known by newspaper experts, then perhaps a number of targeted minimum design requirements may be imposed by the Ministry so that even in the existence of all disadvantageous factors these buildings will still be immediately usable after an earthquake. Surely, the minor expense in construction costs would more than make up for the constantly recurring replacement costs and the social trauma that accompanies it.

A set of general policy changes that must be adopted nationwide have been summarized in the white paper report prepared in 2002 by the National Earthquake Council, a body of experts that was created in the aftermath of the 1999 earthquakes to serve primarily as an evaluation panel for earthquake predictions that paraded in the media. (They were back this time also, with “experts” voicing during prime time TV slots stupefying and contradictory theories that few mortals among the viewers could fathom.) We cite a few of the principal policy recommendations from the National Earthquake Council report here.

- Natural disaster policies should be oriented toward mitigation, and not post-event intervention.

- The pace of adopting legislation for mitigation during the period when memories of the 1999 earthquakes were still fresh should not be allowed to lapse.

- National bodies empowered for enforcing mitigation policies should be protected from political upheavals.
- The existing agencies in disaster policy enforcement should be strengthened rather than new ones created.

- Steps should be taken toward linking Urban Development legislation with Disaster Mitigation legislation so that they work in complementary fashion. The White Paper lists the detailed road map for this action.

- Building construction supervision legislation should be strengthened, and supported by other quality assuring steps. Again, the Council report tells how this might be achieved.

- The Compulsory earthquake Insurance Decree that is still awaiting parliamentary action should be converted into a law. (In Bingöl only 280 homeowners had bought their insurance policies.)

- Quality of engineering and architectural services should be ensured through legislation enabling professional engineers and architects.

- Local government role in building construction control should be redefined and privatized with appropriate description of liabilities.

.

- Standardized designs for governmental service buildings should be re-examined.

- Template designs for schools should be endowed with far more stringent design requirements.

Acknowledgments

We thank the President of METU, Professor Ural Akbulut for arranging our speedy travel to Bingöl via Malatya (where we were accommodated) and the President of Inönü University in Malatya, Professor Fatih Hilmioğlu and the Dean of Engineering Professor Musa Sarıkaya for their hospitality.