

## **Observed changes in geyser eruption intervals in Yellowstone following the 2002 Denali fault earthquake**

We monitored eruption intervals of 22 geysers during the winter 2002-2003 by placing temperature sensors in the runoff channels. All instrumented geysers were located at the main Yellowstone geyser basins (Lower, Upper, and West Thumb Geyser Basins) that had been subject to the increase in earthquake activity (Fig. 1). Data were not available from Norris Geyser Basin due to instrument loss. Of these 22 instrumented geysers, 8 displayed notable changes in their eruption intervals, i.e. the changes were larger than the standard error of the intervals prior to the Denali earthquake. Four geysers were too erratic to show any effects, and 10 geysers showed no significant changes.

There was no common pattern in geyser response to the Denali earthquake. But the most obvious examples were Daisy (Fig. 2), Depression, and Riverside geysers in Upper Geyser Basin, which showed a rapid decrease in their eruption interval within hours following the Denali earthquake, recovering close to pre-Denali eruption intervals over subsequent weeks. Castle Geyser in Upper Geyser Basin responded by having an unusually large number of minor eruptions that do not complete the full expected 20 minute water phase and 30-40 minute steam phase. Starting on 8 November there was one week with no minor eruptions followed by two weeks with a large number of minor eruptions. Pink Geyser in Lower Geyser Basin, and Plate and Plume Geysers in Upper Geyser Basin displayed only short-term (few days) irregularities in their eruption behavior lasting for a few days. Lone Pine Geyser in West Thumb Geyser Basin, on the other hand, showed a gradual increase in eruption intervals that peaked three weeks after the Denali earthquake.

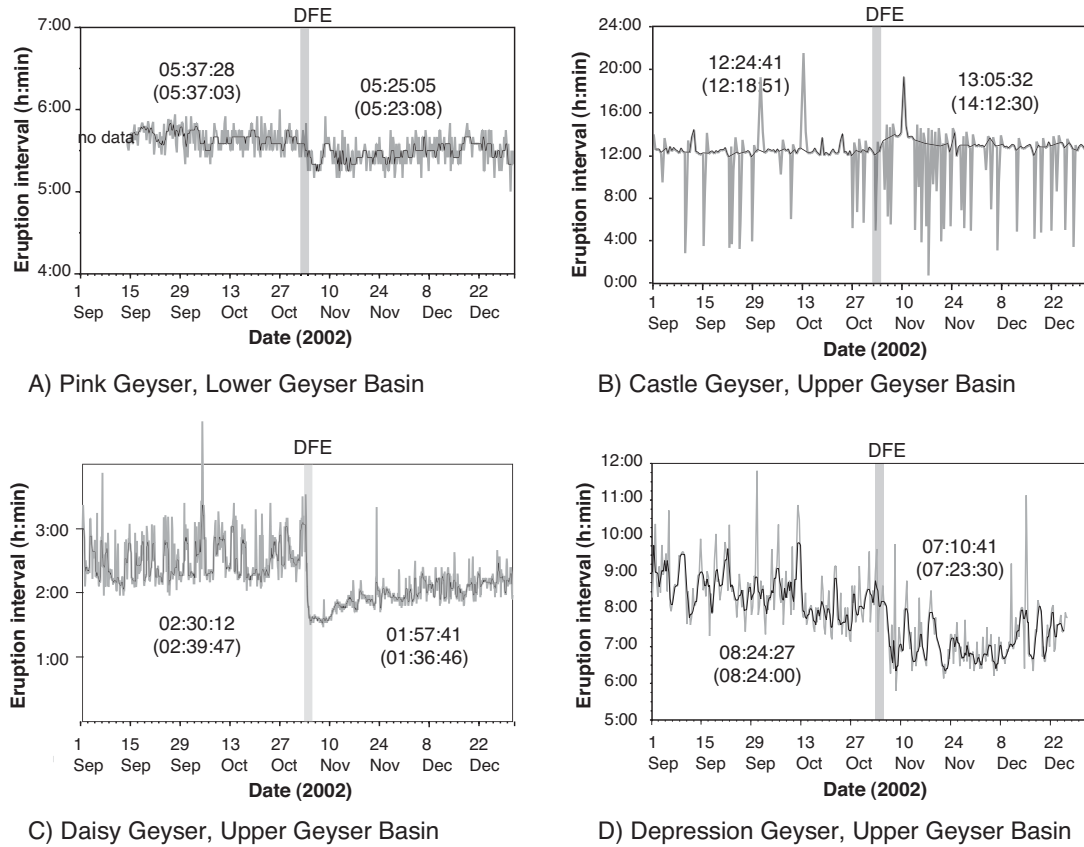
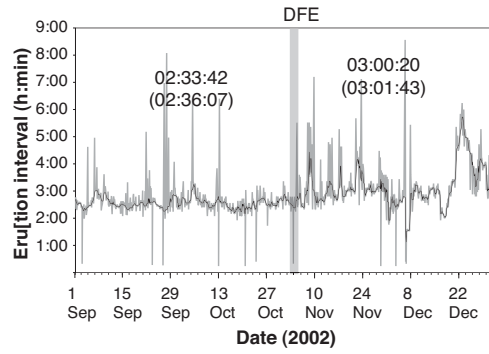
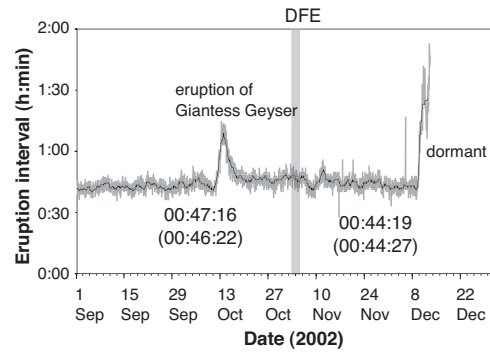


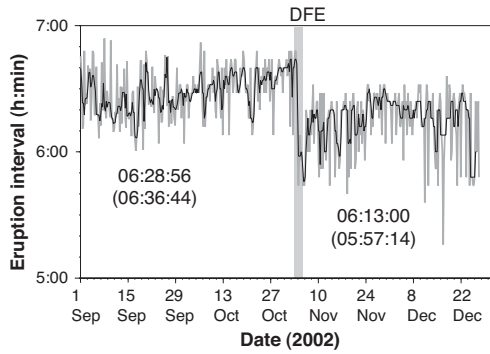
Figure 1. Geyser eruption intervals of Yellowstone between 1 September and 31 December 2003 influenced by Denali fault earthquake (DFE). A, C–H: Gray lines are raw data (individual eruption intervals), and black lines are smoothed data (moving median over several data points). B: Gray line denotes minor eruption intervals, and black line denotes major eruption intervals. Median eruption intervals prior to and after Denali fault earthquake are shown in hour:minute:second (h:min:s) format. Median eruption intervals prior to and after Denali fault earthquake are computed over several weeks and over a few days (in parentheses), respectively. Time of earthquake is marked by bold gray line.



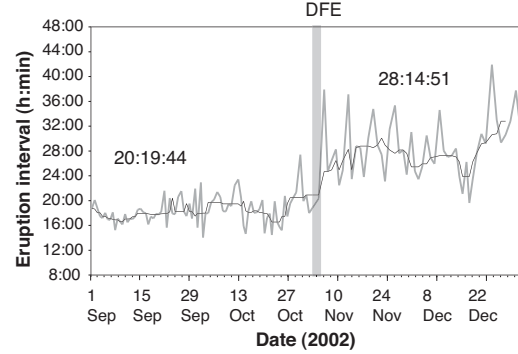
E) Plate Geyser, Upper Geyser Basin



F) Plume Geyser, Upper Geyser Basin



G) Riverside Geyser, Upper Geyser Basin



H) Lone Pine Geyser, West Thumb Geyser Basin

Figure 1. continued.

TABLE 1: SHORT-TERM (FEW DAYS) CHANGES IN ERUPTION INTERVALS OF MONITORED GEYSER PRIOR TO AND AFTER THE DENALI FAULT EARTHQUAKE (DFE). A NEGATIVE CHANGE INDICATES THAT ERUPTION INTERVAL DECREASED FOLLOWING THE DENALI FAULT EARTHQUAKE.

	Time period (days)	Mean interval prior to DFE (h:min)	Standard deviation prior to DFE (h:min)	Mean interval after DFE (h:min)	Standard deviation after DFE (h:min)	Change (h:min)	Change (%)
<u>Norris Geyser Basin</u>							
				No data available			
<u>Lower Geyser Basin</u>							
Fountain Geyser				No changes observed			
Great Fountain Geyser				No changes observed			
Pink Geyser	5	05:37	00:08	05:23	00:09	-00:14	-4.0
<u>Upper Geyser Basin</u>							
Boardwalk Geyser				Inconclusive			
Castle Geyser	10	12:19	00:14	14:12	00:28	+01:53	+15.0
Daisy Geyser	5	02:40	00:20	01:37	00:05	-01:03	-39.0
Depression Geyser	7	08:24	00:36	07:23	00:42	-01:01	-12.0
Grand Geyser				No changes observed			
Grotto Geyser				No changes observed			
Lion Geyser				No changes observed			
North Goggle Geyser				Inconclusive			
Oblong Geyser				No changes observed			
Old Faithful Geyser				No changes observed			
Plate Geyser	7	02:36	00:13	03:02	01:01	+00:26	+16.0
Plume Geyser	7	00:46	00:03	00:44	00:03	-00:02	-4.0
Riverside Geyser	3	06:37	00:14	05:57	00:12	-00:40	-10.0
Rift Geyser				No changes observed			
West Triplet Geyser				No changes observed			
<u>West Thumb Geyser Basin</u>							
Lone Pine Geyser	7	21:04	03:00	26:26	05:41	+05:22	+26.0
Resurgent Geyser				No changes observed			
Generic Geyser				Inconclusive			
Hillside Geyser				Inconclusive			

TABLE 2: LONG-TERM (SEVERAL DAYS) CHANGES IN ERUPTION INTERVALS OF GEYSER FOR WHICH DATA WAS AVAILABLE PRIOR TO AND AFTER THE DENALI FAULT EARTHQUAKE (DFE). A NEGATIVE CHANGE INDICATES THAT ERUPTION INTERVAL DECREASED FOLLOWING THE DENALI FAULT EARTHQUAKE.

	Time period (days)	Mean interval prior to DFE (h:min)	Standard deviation prior to DFE (h:min)	Mean interval after DFE (h:min)	Standard deviation after DFE (h:min)	Change (h:min)	Change (%)
<u>Norris Geyser</u>							
<u>Basin</u>							
No data available							
<u>Lower Geyser</u>							
<u>Basin</u>							
Fountain Geyser							
No changes observed							
Great Fountain Geyser							
No changes observed							
Pink Geyser	14	05:37	00:08	05:25	00:09	-00:12	-4.0
<u>Upper Geyser</u>							
<u>Basin</u>							
Boardwalk Geyser							
Inconclusive							
Castle Geyser	58	12:25	00:25	13:06	00:29	+00:41	+6.0
Daisy Geyser	58	02:30	00:21	01:58	00:14	-00:07	-33.0
Depression Geyser	57	08:38	02:02	07:56	02:16	-00:42	-8.0
Grand Geyser							
No changes observed							
Grotto Geyser							
No changes observed							
Lion Geyser							
No changes observed							
North Goggle Geyser							
Inconclusive							
Oblong Geyser							
No changes observed							
Old Faithful Geyser							
No changes observed							
Plate Geyser	33	02:34	00:28	03:00	00:47	+00:26	+17.0
Plume Geyser	31	00:47	00:06	00:44	00:03	-00:03	-6.0
Riverside Geyser	53	06:29	00:12	06:13	00:15	-00:16	-4.0
Rift Geyser							
No changes observed							
West Triplet Geyser							
No changes observed							
<u>West Thumb</u>							
<u>Geyser Basin</u>							
Lone Pine Geyser	62	20:20	18:48	28:15	27:52	+07:55	+39.0
Resurgent Geyser							
No changes observed							
Generic Geyser							
Inconclusive							
Hillside Geyser							
Inconclusive							

## Observed increases in seismicity at major geyser basin following the 2002 Denali earthquake

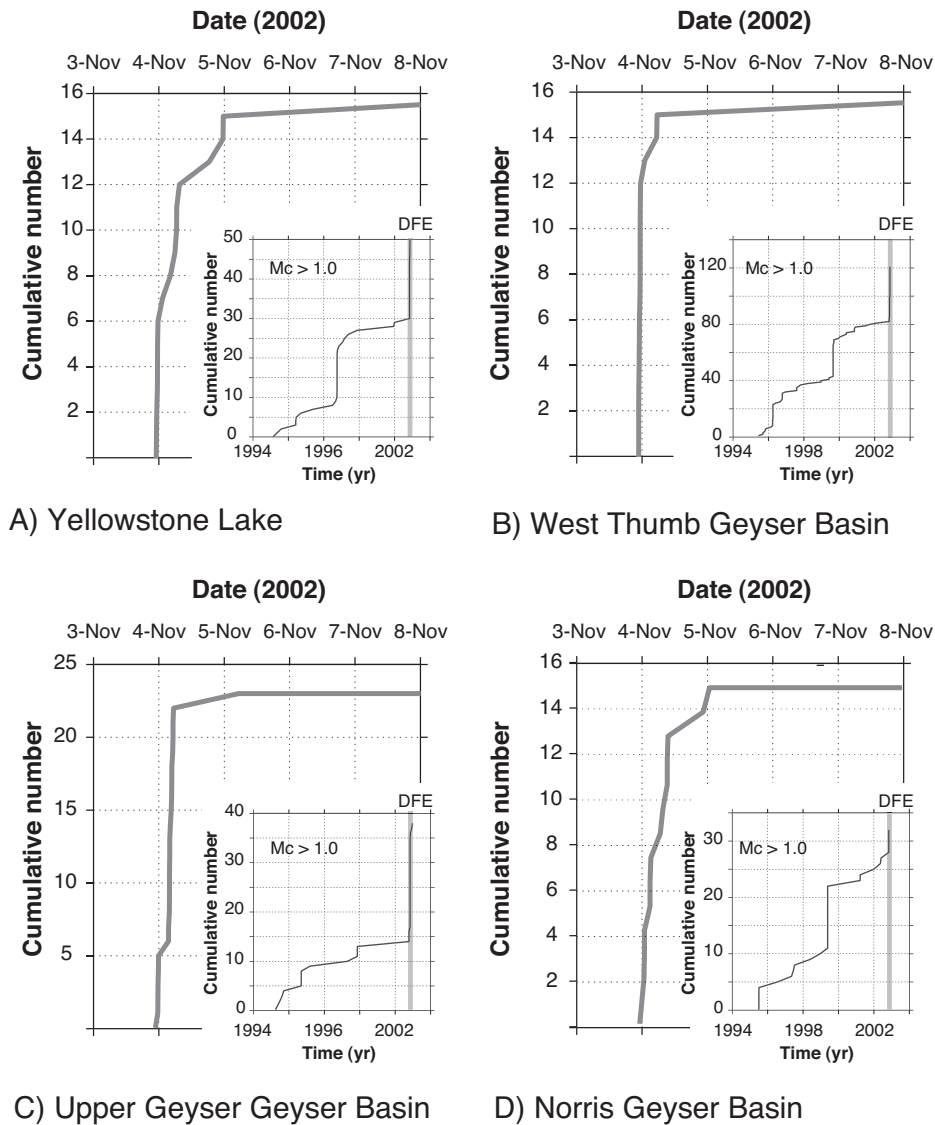


Figure 2. Cumulative number of earthquakes at major geyser basins in Yellowstone following the 2002 Denali earthquake (DFE). A: northern part of Yellowstone Lake, B: West Thumb Geyser Basin, C: Upper Geyser Basin, D: Norris Geyser Basin. Inlay diagrams show cumulative number of earthquakes with magnitude  $> 1.0$  from 1994 to present for each geyser basin. Time of the DFE is indicated by grey line.