Montana Bureau of Mines and Geology Open-File Report 753

MBMG Earthquake Catalog, January 1982–August 2015

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The Earthquake Studies Office (ESO) of the Montana Bureau of Mines and Geology (MBMG) began operating seismograph stations in the summer of 1980, and by 1982 had enough data from seismograph stations to begin locating earthquakes and determining magnitudes. These data were published as annual earthquake reports from 1982 through 1990 (see references). In subsequent years, seismicity data were produced but not formally published. Instead these data were provided on request as electronic files. This earthquake catalog includes seismicity data from the previously published 1982–1990 annual earthquake reports together with previously unpublished seismicity data from 1991 through September 2015. It contains hypocenters and magnitudes for 42,417 earthquakes that occurred in Montana and surrounding regions (43°–50°N, 103°–117°W). Note that the reporting area, magnitude threshold, data collection, and analysis techniques have evolved during the period covered by this catalog as data from new seismograph stations and new velocity models became available. Throughout the period covered by this catalog, the MBMG incorporated data from seismograph stations in adjacent states and provinces operated by other seismograph networks, and from seven USGS stations that opened in Montana from 1999 to 2006.

The Montana Regional Seismograph Network has undergone remarkable transformations during the four decades of its operation. In the early years, seismograms were recorded with ink pens on paper records. All phase arrival times were read with magnifying glass and ruler or ocular with reticle and recorded by hand on data sheets, then typed into a data file on the Montana Tech campus mainframe computer. The computer program HYPO71 (Lee and Lahr, 1975) utilized phase arrival times along with seismograph station coordinates and a crustal velocity model to determine earthquake hypocenters. Earthquake magnitudes were determined using coda durations and amplitude measurements from the Butte station (BUT). Additional details about data collection and analysis are provided in the annual earthquake reports referenced below. In early 1984, four stations were installed near Butte to monitor potential seismicity near the Berkeley Pit open-pit copper mine, which ceased operations in 1982 and was allowed to flood. Throughout the late 1980s to the mid-2000s, stations were incrementally added to the network to improve regional monitoring coverage. In 1989, a triggered digital recording system was installed on personal computers in the ESO, and seismic events were analyzed using a combination of digital (Seismic Unified Data System, 1994) and paper records. In 1995, in collaboration with the Confederated Salish and Kootenai Tribes of the Flathead Reservation, six stations were installed in the Flathead Lake region in northwest Montana. The following year, with support from a USGS National Earthquake Hazard Reduction Program grant, nine stations were installed in west-central Montana between Helena and the Montana–Idaho border. In 1999, with assistance from the USGS, computers running Earthworm software (Earthworm Central, 2021) were installed in the ESO, which for the first time allowed the real-time sharing of seismic trace and related data between recording centers within the MRSN and other regional networks and continuous (as opposed to triggered) data recording. Seismic data collected with Earthworm were analyzed using Seismic Analysis Code (SAC, 2020). This upgrade in 1999 significantly increased the number of earthquakes and lowered the magnitude threshold of earthquakes reported in this catalog. This earthquake catalog ends August 31, 2015, when the ANSS Quake Management System software was implemented to analyze, report, and archive seismic events. This new system, with a completely different catalog format, is available going forward from September 1, 2015, as a digital product from the MBMG.

Explanation of Earthquake Hypocenter Parameters

DATE–Year, month, and day of earthquake (referenced to Coordinated Universal Time)

ORIGIN–Origin time of earthquake in hours, minutes, and seconds in Coordinated Universal Time (subtract 7 hours to get Mountain Standard Time or 6 hours to get Mountain Daylight Time).

LAT–Latitude of epicenter in decimal degrees.

LONG–Longitude of epicenter in decimal degrees.

DEPTH–Depth of earthquake hypocenter below ground surface in kilometers.

MAGNITUDE–Earthquake magnitudes determined from: average coda durations (ESO), local (Richter) magnitude from Butte Wood–Anderson seismograph (BUT), and local magnitude from either Missoula WWSSN seismograph or average local magnitude from U.S. National Seismograph Network broadband seismographs 2004–2006. Also see "OTHER MAGS".

NO–Number of P and S wave arrival times used in hypocenter solution [number of stations used for National Earthquake Information Service (NEIS) solutions].

GAP–Maximum azimuthal gap in degrees between seismograph stations as seen from epicenter [not available for most NEIS and Pacific Geoscience Center (PGC) solutions].

DMIN–Distance in kilometers from epicenter to nearest seismograph station used in hypocenter solution (not available for most NEIS and PGC solutions).

RMS–Root mean square of travel time residuals. Lower values typically indicate better hypocenter solutions when sufficient readings (NO >4) are available (not available for most NEIS and PGC solutions). See Lee and Lahr (1975) for details.

ERH–Estimated horizontal uncertainty, in kilometers, of epicenter location. ERH and estimated vertical uncertainty (ERZ) can be computed only when sufficient readings (NO >4) are available (not available for most NEIS and PGC solutions).

ERZ–Estimated vertical uncertainty, in kilometers, of hypocenter depth. In general, the depth is not well constrained unless at least one station is within one focal depth of the epicenter (DMIN<DEPTH) and the epicenter lies within the network of available stations (GAP <180).

Q–Quality of hypocenter solution: "A" is best and "D" is worst. See Lee and Lahr (1975) for a complete description.

SOURCE–Source of earthquake location: MBMG, Montana Bureau of Mines and Geology; NEIS, USGS National Earthquake Information Service; PGC, Canadian Geological Survey Pacific Geoscience Center; UUSS, Origin time, location, and depth from University of Utah Seismograph Stations (but magnitudes and other parameters from MBMG). A "*" indicates that this event is also listed in the USGS Preliminary Determination of Epicenters or Composite Catalog (ComCat; https://earthquake.usgs.gov/data/comcat/). A "T" indicates that this event triggered the MBMG digital system (Aug. 1989 to Sept. 2000).

OTHER MAGS–Additional magnitudes listed in the USGS Preliminary Determination of Epicenters or ComCat for earthquakes of magnitude 2.5 or larger; Mb, body wave magnitude; Ms, surface wave magnitude; MAG, magnitude from various sources and of various types. When multiple magnitude types are listed in ComCat, in order of preferred magnitude type listed here, they are: moment magnitude, local

(Richter) magnitude, and coda duration magnitude. See ComCat for magnitude type for a particular earthquake.

LOCATION/COMMENTS–Descriptive location and comments. "Near" indicates within 10 km of a location. "Felt" indicates that an event was reported felt by people; a roman numeral following "felt" indicates the maximum reported intensity on the Modified Mercalli Intensity scale (https://www.usgs.gov/programs/earthquake-hazards/modified-mercalli-intensity-scale). Geographic locations are in Montana unless otherwise indicated, except Yellowstone National Park, which lies mostly in Wyoming but extends into Montana and Idaho.

References

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