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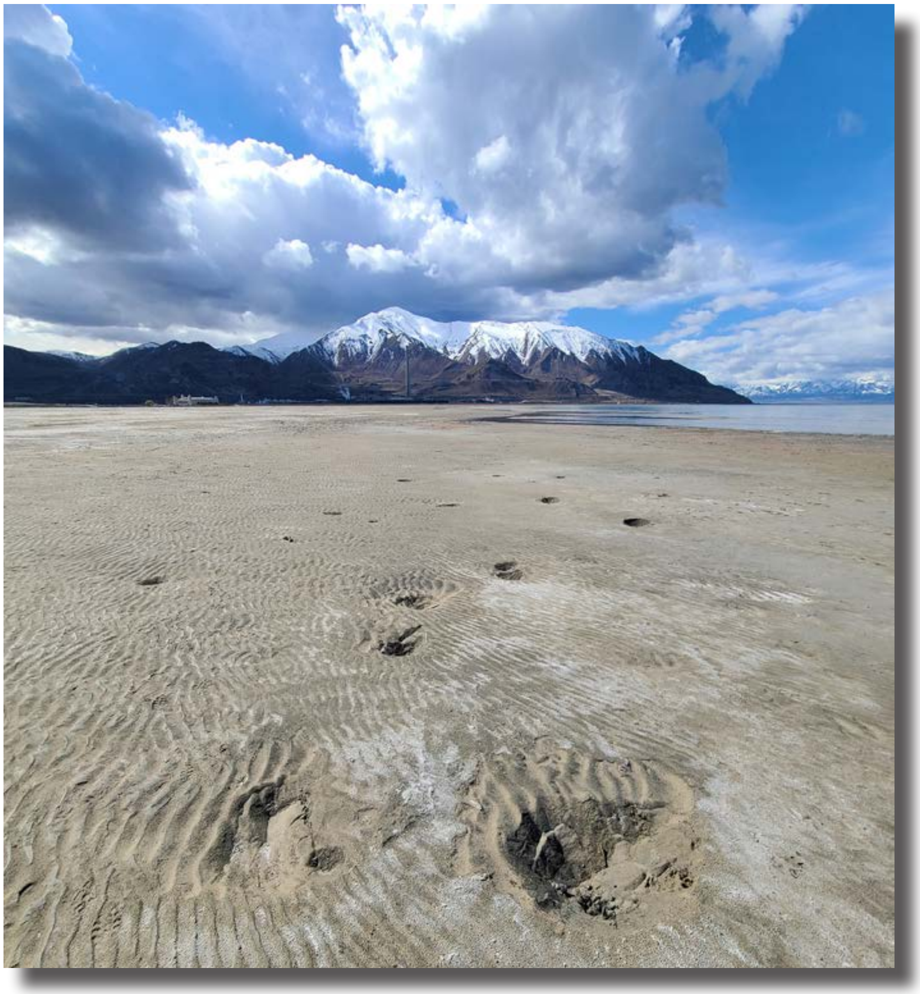
THE MARCH 2020, M_W 5.7 MAGNA, UTAH, EARTHQUAKE—DOCUMENTATION OF GEOLOGIC EFFECTS AND SUMMARY OF NEW RESEARCH

Adam I. Hiscock, Emily J. Kleber, Adam P. McKean, Ben A. Erickson, Greg N. McDonald, Richard E. Giraud, Jessica J. Castleton, and Steve D. Bowman



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Subsidence features on the salt flats near the Great Saltair likely caused by liquefaction from the 2020 M5.7 Magna, Utah earthquake. Photo by Adam Hiscock.

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The March 2020, M_W 5.7 Magna, Utah, Earthquake—Documentation of Geologic Effects and Summary of New Research

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ABSTRACT

The March 18, 2020, M_w 5.7 Magna earthquake was the largest earthquake in Utah since the 1992 M_L 5.8 St. George earthquake. The Magna earthquake occurred in the northwest corner of the Salt Lake Valley, home to 1.2 million people. Immediately following the earthquake, the Utah Geological Survey organized teams to collect perishable field data on the geologic effects of ground shaking near the epicenter, as well as establish a web-based digital clearinghouse to collect, distribute, and archive data related to the earthquake. This earthquake also coincided with the beginning of the COVID-19 global pandemic, which added extra challenges to our earthquake response. Teams used a small, unmanned aircraft system to obtain aerial photos and videos of geologic effects to supplement ground-based reconnaissance. The observed geologic effects of ground motions from the Magna earthquake include liquefaction in the form of sand boils, tension cracks, lateral spreading, and localized subsidence. No primary surface fault rupture was observed. The areas with the highest observed concentration of liquefaction features were close to the shore of Great Salt Lake and near the epicenter, northeast of the town of Magna. Photos and other documentation of the geologic effects associated with this earthquake are critical in helping to understand the hazards associated with moderate magnitude earthquakes in the Wasatch Front region. The earthquake sequence and associated geologic effects were well documented, due to the proximity to a major metropolitan area and the mainshock and aftershocks occurring within the densest part of the Utah Regional Seismic Network. In the two years since the earthquake, numerous studies have been published documenting and interpreting data to characterize the Magna event and discuss how new data add to what is known about seismic hazards along the Wasatch Front.

INTRODUCTION

Over 80% of Utah's population lives along the 350-km-long Wasatch fault zone (WFZ), one of the most active faults in the Intermountain West. The densely populated Salt Lake Valley is bounded to the east by the WFZ, and is also home to the antithetic West Valley fault zone (WVFZ) in the center of the valley (figure 1). Both the WFZ and the WVFZ are Holocene-active normal faults. The March 18, 2020, moment magnitude (M_w) 5.7 Magna earthquake was the largest earthquake in the Salt Lake Valley since the 1962 local magnitude (M_L) 5.2 Magna earthquake, and the largest in Utah since the 1992

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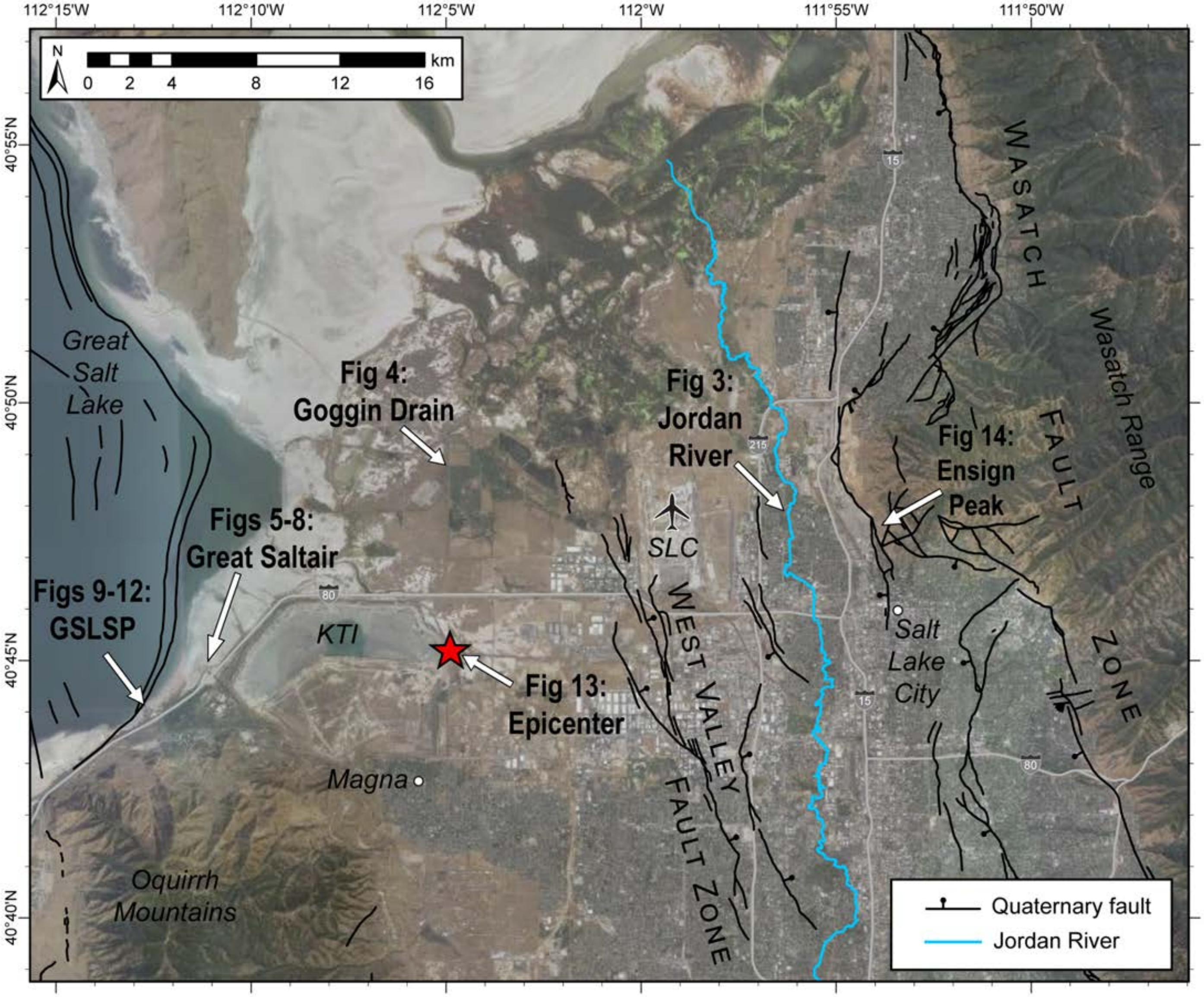


Figure 1. Map of the northern Salt Lake Valley showing figure locations, regional faults, cities, and locations referenced in this report. KTI – Kennecott Tailings Impoundment, SLC – Salt Lake City International Airport. Faults from UGS Hazards Portal (2022), basemap from UGRC (2019).

M_L 5.8 St. George event. The mainshock was located approximately 16 km west of downtown Salt Lake City (40.751°N, 112.078°W) at an approximate depth of 11.9 km (U.S. Geological Survey [USGS], 2022; figure 2). The mainshock occurred within the densest part of the Utah Regional Seismic Network, and additional temporary stations were deployed following the mainshock to monitor the aftershock sequence (Pankow and others, 2021). From March 18, 2020, to February 28, 2021, the University of Utah Seismograph Stations (UUSS) identified 2590 earthquakes associated with the Magna earthquake sequence (figure 2; UUSS, 2021). Based on the interpretation of geologic and geophysical data, the Magna earthquake occurred on a gently dipping part of the WFZ (Pang and others, 2020; Kleber and others, 2021; Messimeri and others, 2021). This earthquake was widely felt along the densely populated Wasatch Front; 26,364 felt reports have been reported to the USGS as of January 18, 2022 (USGS, 2022). The Magna earthquake caused approximately $70 million in public infrastruc-

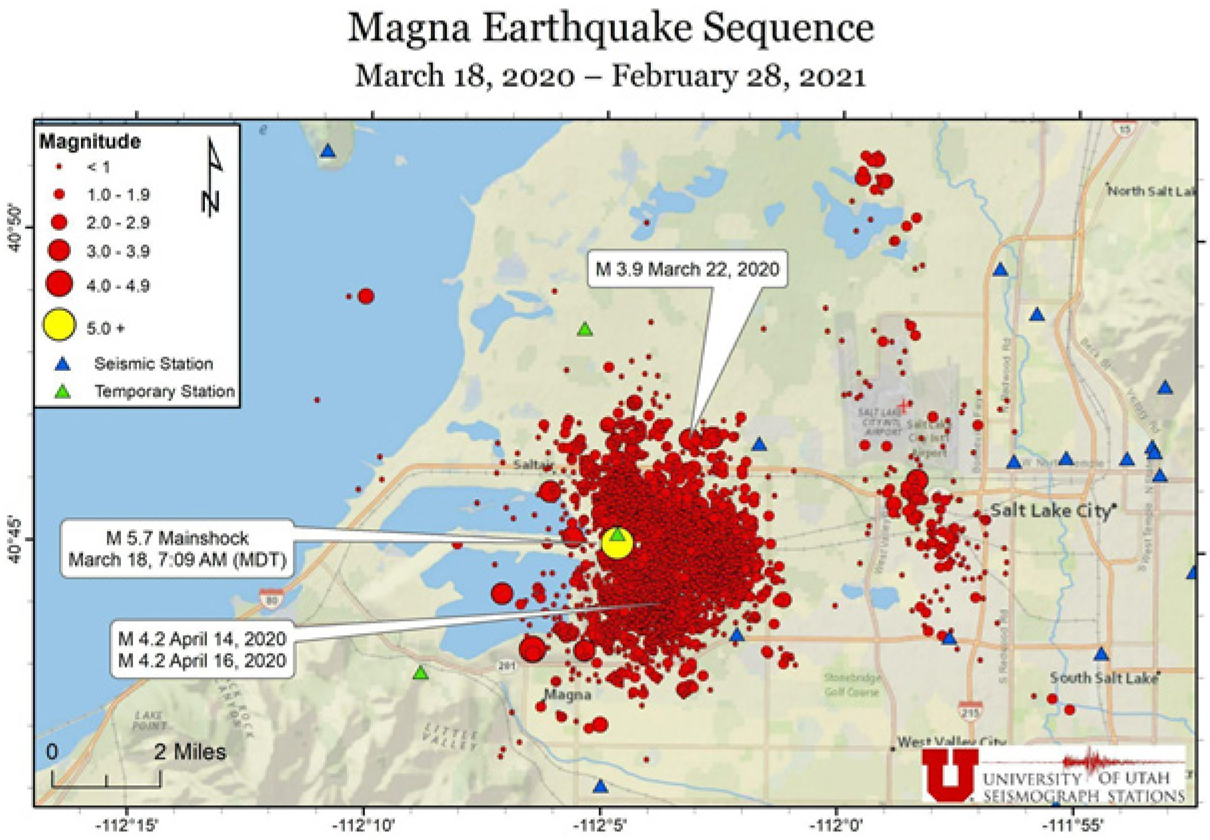


Figure 2. Magna earthquake sequence, from March 18, 2020, to February 28, 2021. Figure from University of Utah Seismograph Stations (2021).

ture damage in Salt Lake and Tooele Counties, with additional damage to residential and commercial property (Kleber and others, 2021).

Abundant paleoseismic data on the timing and size of prehistoric earthquakes on the WFZ and other faults in the Wasatch Front region show a history of large (M > 6.75) surface-rupturing earthquakes in the region. At least 22 surface-rupturing earthquakes have occurred on the WFZ in the past 6000 years, with a 43% probability of a M ≥ 6.75 earthquake occurring in the Wasatch Front region over the next 50 years (Working Group on Utah Earthquake Probabilities [WGUEP], 2016). Despite less data about the timing and recurrence of moderate magnitude earthquakes in the region due to a lack of evidence in the geologic record, the probability of a M ≥ 5.0 occurring in the next 50 years is still 93% (WGUEP, 2016).

Immediately following the Magna earthquake, the Utah Geological Survey (UGS) Geologic Hazards Program organized field teams to collect perishable data on the geologic effects related to the earthquake. The earthquake occurred less than a week after most UGS staff switched to a telecommuting schedule and the State of Utah entered a two-week lockdown due to the COVID-19 pandemic. The timing of the Magna earthquake, near the beginning of a global pandemic, added an extra challenge to the earthquake response for the UGS and other groups (Pankow and others, 2021; McEntire, 2021). Early in the COVID-19 pandemic, there was a lot of uncertainty with public health safety measures and guidelines. UGS field teams did their best to follow available public health measures while performing fieldwork and interacting with the public while responding to the Magna earthquake.

A M_w 5.7 earthquake does not release enough energy to cause surface fault rupture in the Intermountain West region, so field teams focused on identifying ground shaking-related effects. These teams were deployed to areas thought to be susceptible to ground shaking-related geologic effects (e.g., liquefaction, lateral spreading, sand boils, ground cracking, ground deformation) based on geologic conditions such as seasonally high groundwater levels, recent geologic mapping showing underlying fine-grained silt and sand deposits (McKean, 2019; McKean and Hylland, 2019a; McKean and others, 2019; Clark and others, 2020), and proximity to Great Salt Lake. Teams focused their efforts primarily at areas along the Jordan River and the shoreline of Great Salt Lake (figure 1). Liquefaction susceptibility mapping for the Magna 7.5-minute quadrangle indicates the majority of the area around the epicenter of the Magna earthquake has a high susceptibility for liquefaction (Castleton and others, 2011). Additionally, the UGS received reports of ground deformation from local geologists, governmental agencies, and consultants which helped guide reconnaissance efforts.

GEOLOGIC EFFECTS

Jordan River and Goggin Drain

One of the first areas the field teams performed reconnaissance the morning of the earthquake was along the Jordan River. The Jordan River runs south to north through the center of the Salt Lake Valley (figure 1), from Utah Lake in Utah Valley to Great Salt Lake (figure 1). The river is fed by numerous snowmelt-sourced small streams flowing out of the Wasatch Range to the east and the Oquirrh Mountains to the west. In the late Holocene, the course of the river has shifted several times in response to changing lake levels and possibly also in response to surface-fault-rupturing earthquakes and tectonic subsidence associated with the WFZ and WVFZ (Keaton, 1987; McKean and Hylland, 2019b). We inferred that ground deformation effects associated with ground shaking would be concentrated along the Jordan River because the river is a major control on the local groundwater base level in the Salt Lake Valley (Wallace and Lowe, 2009). We observed small, localized features in several places along the river including at several sites near the Salt Lake City International Airport and the Goggin Drain (figure 1). East of Redwood Road along the Jordan River, we observed a small (1 to 2 m wide) lateral spread feature along the riverbank (figure 3). West of the airport at the Goggin Drain, we observed small (5 to 10 cm) wet craters with fresh ground cracking (figure 4), perhaps indicating fluctuating groundwater levels due to earthquake ground shaking (Kleber and others, 2021).

The Great Saltair and I-80/SR-202 Interchange

Multiple liquefaction features were observed on foot and by a small, unmanned aircraft system (sUAS) in the general vicinity of the Great Saltair event center (figure 1). Initially, several sand boils were observed in roadway fill material along the I-80/SR-202 interchange as well as extensional cracking indicating ground failure towards the retaining ponds (figures 5 and 6). Upon investigation with a sUAS, numerous (tens) subaqueous sand boils were observed in several of the ponds around the interchange and were much more numerous than the subaerial sand boils (figure 7A). Water levels in these ponds fluctuate seasonally; oftentimes the ponds are wet in the spring months and dry in the summer months (Kleber and others, 2021). Sand boils ranged from 10 to 50 cm in diameter and were only observed in areas with artificial fill around the interchange and along the margins of the ponds (figure 7B). These observations suggest the presence of the roadway infrastructure on top of the underlying lacustrine deposits may have played a role in the formation of sand boils. A return visit in August 2020, when the ponds around the interchange had dried up, allowed us to examine the previously subaqueous sand boils and dig small trenches across several of them to view them in cross section (figure 7C). Lighter colored oolitic sands were observed in the center of the cross section, cutting and depositing on top of dark, organic-rich clays and silts (figure 7B). Additional sand boils were observed in the parking lots for the Great Saltair event center, but unfortunately had been driven over and destroyed by emergency response crews on the day of the earthquake.

Several days after the mainshock, acting on an informal report of small collapse features from a UGS colleague, we performed reconnaissance of the mud flats along the shore of Great Salt Lake north of the Great Saltair event center. On foot and using a sUAS, we docu-

Figure 3. Small, 1 to 2 m lateral spread along the banks of the Jordan River. Resource ID from the Magna earthquake online clearinghouse labeled in bottom right corner of photo.

mented numerous collapse features in the mud flats near the Great Salt Lake shoreline (figure 8A). These features ranged from 5 to 25 cm in diameter and 5 to 10 cm in depth. They were relatively widespread; in some areas, upwards of 20 features were present in a small area (figure 8B). Other spring-related features are often found seasonally around the Great Salt Lake shoreline, but the sudden onset and relative fresh appearance of these features suggest they were created by rapid groundwater withdrawal due to earthquake ground shaking.

Great Salt Lake State Park

Several days after the Magna earthquake, employees at the Great Salt Lake State Park Marina reported cracking along the main access road and around several parking lots and park buildings. Several tension cracks associated with lateral spreading were observed on foot and with a sUAS along the access road. These cracks indicated approximately 2 to 20 cm of vertical separation within the road surface, on the road shoulder, and along the roadway base (figure 9). Multiple cracks along the roadway base indicated a stepping, en echelon pattern (figure 10A). One of the larger cracks at the roadway base measured approximately 6 m long, up to 30 cm deep, and 10 to 20 cm wide (figure 10B).

Figure 4. Ground cracking in small 5 to 10 cm depressions near the Goggin Drain, indicating fluctuating groundwater levels due to earthquake ground shaking. Resource ID from the Magna earthquake online clearinghouse labeled in bottom right corner of photo.

Additionally, sUAS aerial survey data showed multiple subaqueous sand boils in several ponds near the entrance station to the Great Salt Lake State Park Marina (figure 11). These appeared similar in color and texture to the subaqueous sand boils documented near the Great Saltair event center. Like the other sand boils, these were only observed near the margins of the ponds close to artificial roadway fill from the marina access road. Thick vegetation made follow-up observations later in 2020 to document the sand boils after the water levels in the ponds had dropped, not possible.

Damage was also observed around a maintenance building on the southwestern side of the marina property. Ground shaking causing separation between a concrete sidewalk and the building damaged a vertical natural gas line coming from below ground to the side of the building (figure 12A). Tension cracks up to 10 m long with 5 to 10 cm of vertical separation in fill material around the watercraft dry storage area were also documented (figure 12B; Kleber and others, 2021). These cracks were expanding towards the retention ponds, away from the buildings and developed area, indicating some near-surface lateral spreading in fill material.

Figure 5. Subaerial sand boils near the I-80/SR-202 interchange and Great Saltair event center. Field notebook (10 cm wide) for scale. Resource ID from the Magna earthquake online clearinghouse labeled in bottom right corner of photo.

Epicenter and Other Reconnaissance Areas

The epicenter of the Magna earthquake occurred directly east of the Kennecott tailings impoundment (KTI; figures 1 and 2). A previous Utah Geological Association publication details the seismic hazards associated with the KTI area (Wong and others, 1995). Since the 2020 earthquake, the tailings piles have come back into question for their role in the Magna and future earthquakes (Hu and others, 2021). We did not perform reconnaissance of the KTI area due to a lack of access. We assumed that Rio Tinto performed their own analysis of the performance of their tailing impoundments, but that information is not publicly available at this time.

We performed extensive reconnaissance of the epicentral area outside of the KTI, looking for additional ground deformation. In several seasonally wet areas, we documented small, fresh ground cracks formed in radial patterns (figure 13; Kleber and others, 2021). These features may have formed coseismically and may represent syneresis cracking caused by rapid earthquake-induced dewatering of seasonally wet areas (Pratt, 1988).

More reconnaissance was performed along the western range front of the Wasatch Range and the northern end of the Oquirrh Mountains to look for possible coseismic landslides and rockfalls. We documented one small rockfall deposit north of downtown Salt Lake City near Ensign Peak (figure 14) but were unable to determine if it was caused by ground shaking from the earthquake. Additionally, a nearby landslide in City Creek Canyon showed some signs of reactivation after the Magna earthquake but has previously shown signs of movement in the spring due to run-off, so we were unable to conclusively determine if landslide activity was earthquake-induced.

DIGITAL CLEARINGHOUSE

Within two hours of the earthquake, the UGS established a digital, web-based clearinghouse to collect, distribute, and archive perishable data related to the earthquake (https://geodata.geology.utah.gov/pages/search.php?search=!collection609). The clearinghouse provides timely public-facing information that is used by the media, and provides a permanent archive for data related to the Magna earthquake (figure 15). Various organizations contributed to the

Figure 6. Subaerial sand boil (center of photo) and extensional ground crack with 2–3 cm of vertical separation (indicated by arrows) near the I-80/SR-202 interchange and Great Saltair event venue. Field notebook (10 cm wide) for scale. Resource ID from the Magna earthquake online clearinghouse labeled in bottom right corner of photo.

clearinghouse including the UGS, Salt Lake County, University of Utah Seismograph Stations, U.S. Geological Survey, Utah Department of Transportation, Earthquake Engineering Research Institute, UNAVCO, Utah State Historic Preservation Office, Utah Division of Emergency Management, University of Utah, Utah State University, Utah Valley University, Natural History Museum of Utah, Stanford Research Computing Center, Utah Geological Association, Granite School District, StrongMotions Inc., Geohazards TEP, Poll Sound, Utah Division of State History, and Salt Lake City.

The UGS began a public outreach campaign through social media to encourage citizens to share their media from the earthquake. Using a Google Form available through UGS's various social media pages, 17 people responded, contributing 50 photographs and 15 videos (UGS GHP, 2020), which were added to the Magna earthquake clearinghouse. The majority of the media items submitted to the clearinghouse were photographs of documented damage to structures and ground deformation caused by earthquake ground shaking. Numerous videos submitted documented the varied intensity of ground shaking experienced throughout the Salt Lake Valley. Local, regional, and international researchers also submitted maps and figures to help contextualize the earthquake sequence. As of February 3, 2022, the Magna earthquake clearinghouse contained 949 items (figure 15).

SUMMARY OF PUBLICATIONS ON THE 2020 MAGNA EARTHQUAKE SEQUENCE

In the nearly two years since the Magna earthquake, numerous studies and journal articles have been published documenting multiple scientific aspects of the earthquake (table 1). The March 2020 M_w 5.7 Magna earthquake was one of four moderate magnitude Intermountain West earthquakes that occurred in 2020, including the M_w 6.5 Stanley, Idaho, M_w 6.5 Monte Cristo, Nevada, and M_w 5.8 Lone Pine, California earthquakes. In the first paper to be published after the Magna earthquake, Pang and others (2020) used near-surface geophysical data from the mainshock and ongoing sequence to interpret a listric subsurface geometry for the Salt Lake City segment of the WFZ. A special issue of Seismological Research Letters (SRL) on the Intermountain West (IMW) earthquakes of 2020 was published in March of 2021. An overview of the IMW

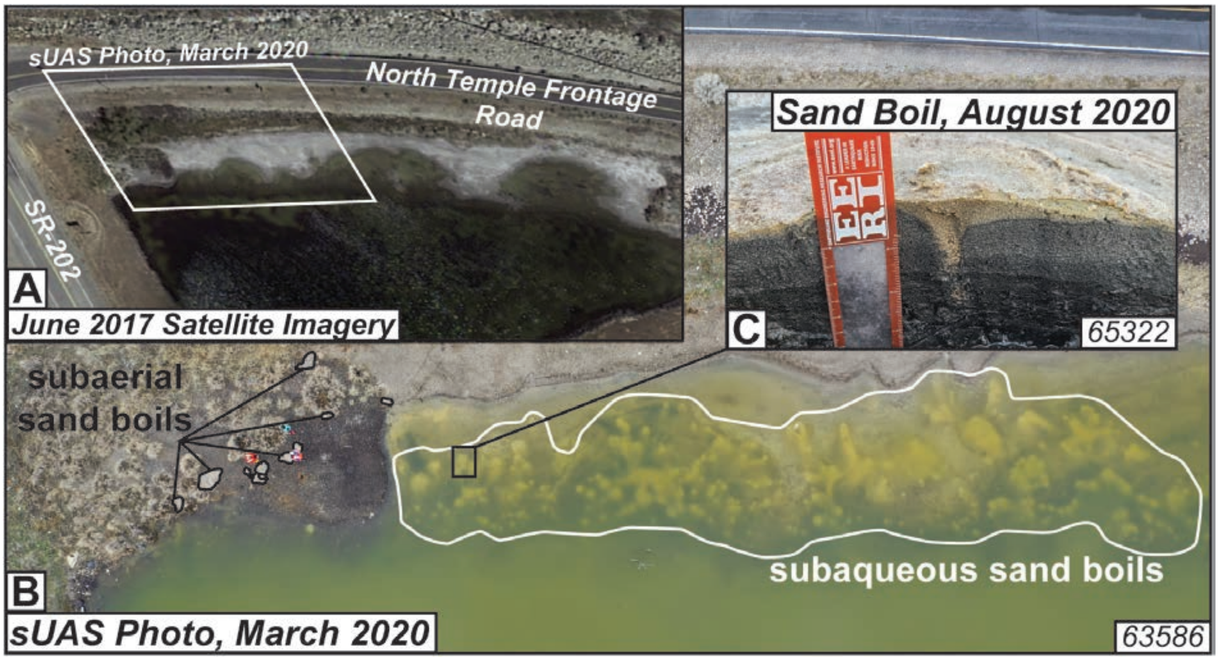


Figure 7. Subaerial and subaqueous sand boils identified along the I-80/SR-202 interchange. (A) June 2017 satellite imagery at a water level somewhat similar to that of March 2020. Note lack of lightly colored features interpreted to be subaqueous sand boils. (B) sUAS image (area of image shown in A) showing subaqueous and subaerial sand boils. (C) Inset photo shows cross section of one previously subaqueous sand boil later in the summer, in August 2020. Figure modified from Kleber and others (2021). Resource ID from the Magna earthquake online clearinghouse labeled in bottom right corner of photos. Satellite imagery in A from UGRC (2017).

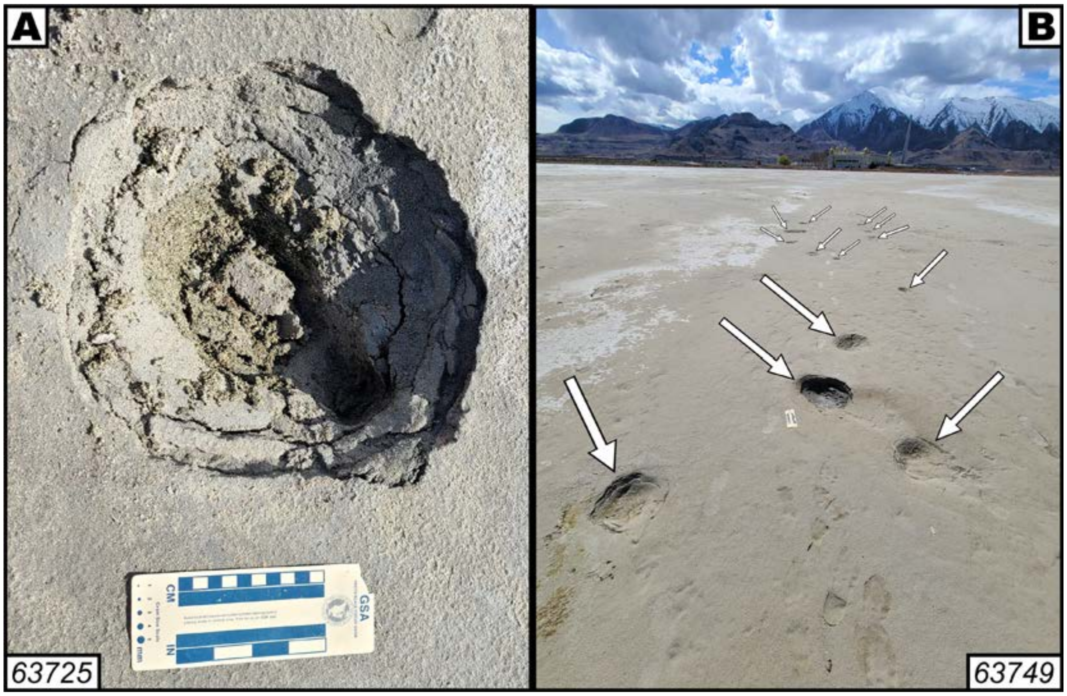


Figure 8. (A) Collapse feature near the shore of Great Salt Lake. Fresh circular cracking suggests these features were caused by earthquake ground shaking and rapid groundwater withdrawal. (B) Arrows pointing to numerous collapse features like the one shown in A. View looking southwest, towards the northern end of the Oquirrh Mountains. Resource ID from the Magna earthquake online clearinghouse labeled in bottom right corner of photos.

Figure 9. sUAS image of the Great Salt Lake State Park Marina Access Road showing an approximately 6-meter-long crack in the roadway base material (shown by arrows). Resource ID from the Magna earthquake online clearinghouse labeled in bottom right corner of photo.

Figure 10. (A) Multiple cracks (shown by arrows) in the roadway base material along the Great Salt Lake State Park Marina Access Road. Primary crack shows approximately 3–4 cm of vertical separation. Field notebook (10 cm wide) for scale. (B) Close-up view showing approximately 30-cm-deep crack. Resource ID from the Magna earthquake online clearinghouse labeled in bottom right corner of photos.

Figure 11. sUAS image of subaqueous sand boils (outlined by white line) near the Great Salt Lake State Park Marina Access Road. Resource ID from the Magna earthquake online clearinghouse labeled in bottom right corner of photo.

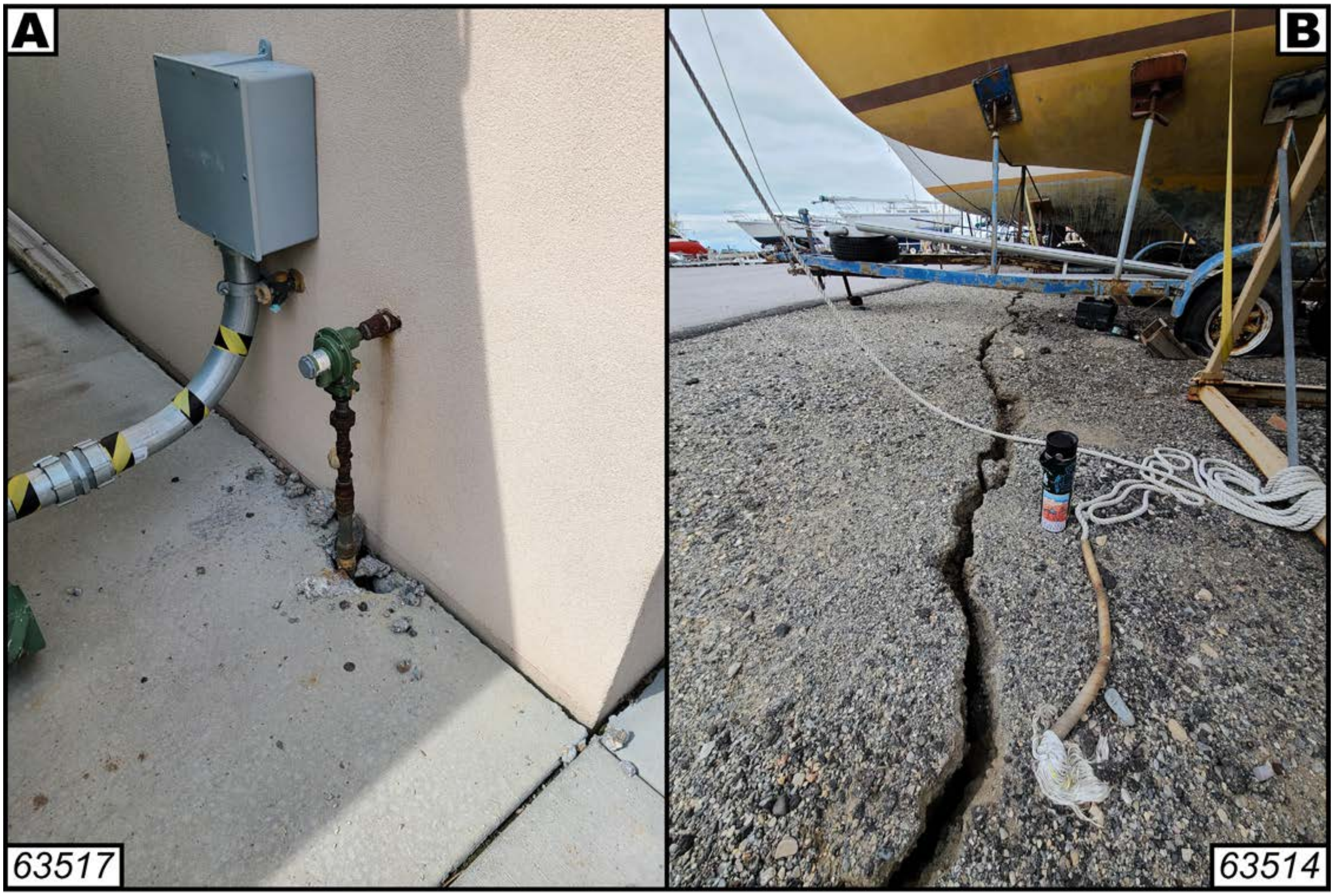


Figure 12. (A) Repaired gas line and sidewalk damage along the Great Salt Lake State Park Marina maintenance building. (B) Cracking in fill material in the dry boat storage area of the Great Salt Lake State Park Marina. Coffee thermos is ~26 cm tall. Resource ID from the Magna earthquake online clearinghouse labeled in bottom right corner of photos.

earthquakes (Gold and others, 2021) set the stage to present important and timely information associated with these sequences including near-field ground motions, geologic observations, kinematic rupture models, aftershock statistics, and seismic hazard implications.

The 2021 IMW SRL special issue begins with a summary article by Wesnousky (2021) contextualizing the seismotectonics of the Magna and other IMW earthquakes as well as statistically analyzing the aftershock sequences. Another summary article discusses a method to use high-rate Global Positioning System (GPS) observations to determine peak ground velocities for the IMW earthquakes of 2020 (Crowell, 2021). Because of the dense regional network of seismometers along the Wasatch Front and the deployment of temporary seismic stations, several papers were written to analyze the data collected by these instruments for the Magna earthquake. Mesimeri and others (2021) determined the hypocenter and rupture characteristics of the Magna mainshock. Holt and others (2021) discussed constraining the magnitudes of smaller aftershocks of the Magna sequence using spectral-based methods for calculating moment magnitude. Baker and others (2021) doubled the total number of hypocenters in the aftershock catalog of the Magna earthquake using machine learning and data from 180 three-component temporary seismometers along with seismic observations from the permanent regional seismic network. Integrating seismic data and geodetic observations from GPS and Interferometric Synthetic Aperture Radar (In-

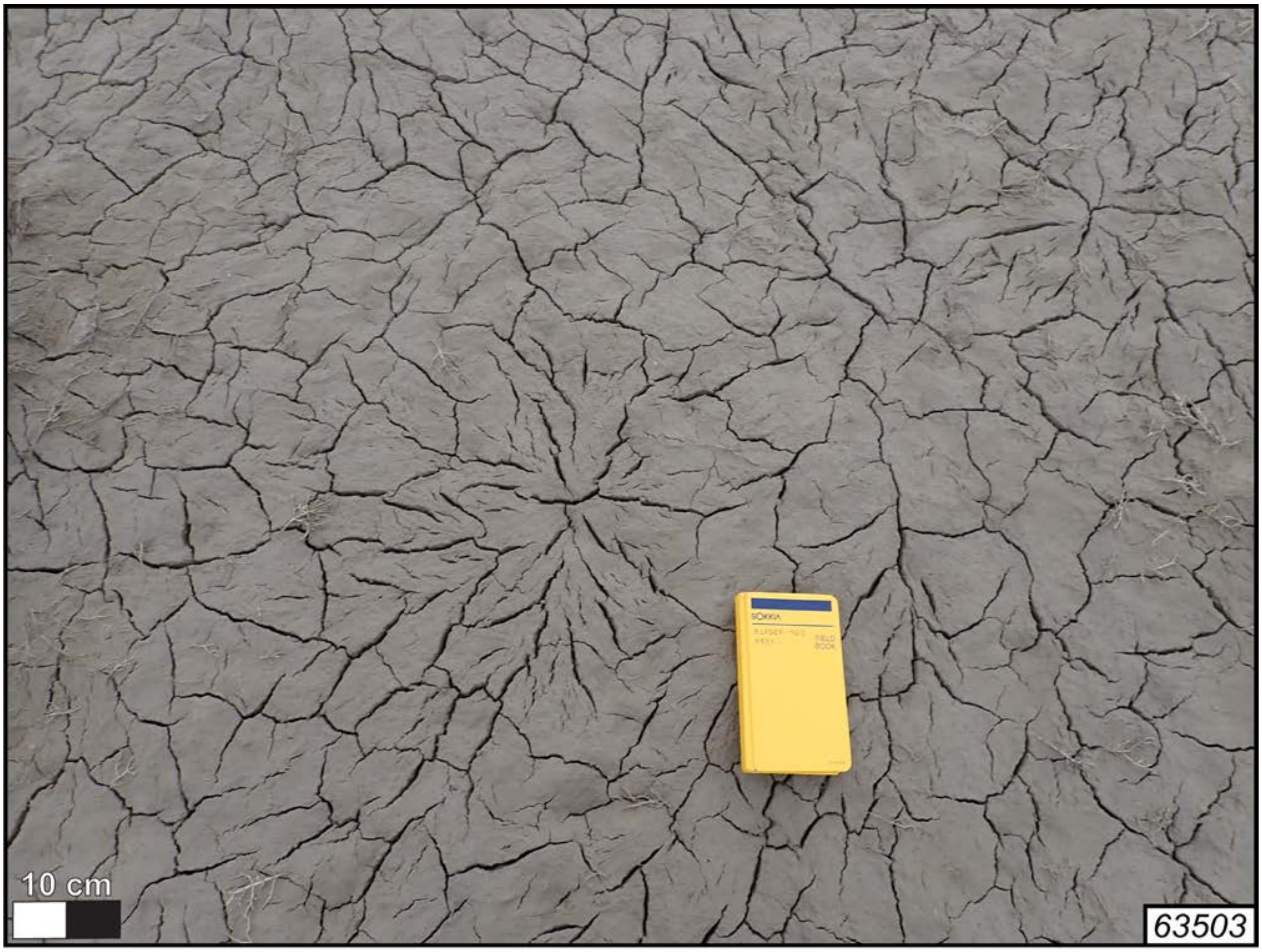


Figure 13. Syneresis cracking near the epicentral area showing a radial pattern characteristic of earthquake ground shaking-induced fluctuations in groundwater. Field notebook (10 cm wide) for scale. Resource ID from the Magna earthquake online clearinghouse labeled in bottom right corner of photo.

SAR), Pollitz and others (2021) determined coseismic slip and afterslip of the M_w 5.7 Magna earthquake mainshock. They concluded that the mainshock and afterslip were due to normal slip on a gently west-dipping fault plane with some afterslip affected by a steeply northeast-dipping nodal plane, presumably a fault. Wong and others (2021) presented a comparison of normal-faulting ground-motion recordings from the 2020 Magna earthquake with ground motions predicted by the Next Generation Attenuation-West2 ground-motion models in the Salt Lake Valley (Bozorgnia and others, 2014). Wong and others (2021) found that the recorded data matched well with the predicted shaking from ground-motion modeling and discussed the seismic hazard implications for a more gently dipping WFZ, as proposed by Pang and others (2020). Finally, Kleber and others (2021) used recent geologic mapping as well as seismic and gravity data to add additional geologic context to seismic observations (Pang and others, 2020), finding nothing contradicting a listric model for the Salt Lake City segment of the WFZ. Additionally, Kleber and others (2021) documented some geologic effects of the Magna earthquake that are discussed more in depth in this paper.

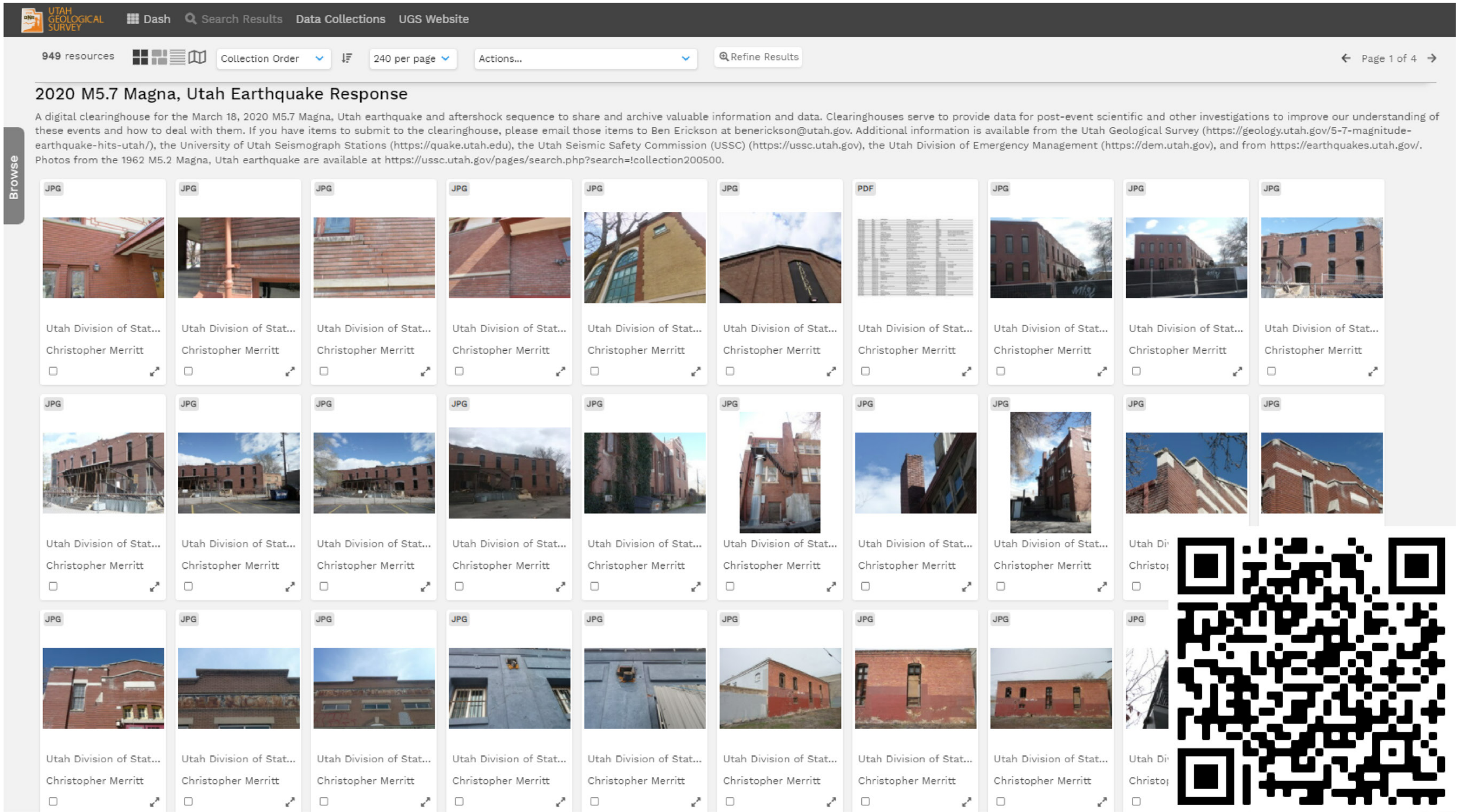
The SRL IMW special issue was very comprehensive in its scientific reporting on the Magna earthquake; however, other publications exist on the Magna earthquake. Pankow and others (2021), in a SRL special issue on scientific response to earthquakes during the COVID-19 pandemic, detailed the coordination to deploy UUSS

Figure 14. Possible seismically induced rockfall near Ensign Peak, north of downtown Salt Lake City. Rockfall deposit outlined in white, blue backpack (~0.5 m long) for scale. Resource ID from the Magna earthquake online clearinghouse labeled in bottom right corner of photo.

and USGS seismic instruments, as well as provide timely scientific information to the public during a pandemic. Also related to disaster response during a global pandemic, McEntire (2021) reported in the *Journal of Emergency Management* the benefits and complications from an emergency management perspective and inferred that lockdowns due to the pandemic could have been why there were no reported injuries or fatalities due to the earthquake. Two papers from lead author Xie Hu discussed the hydrologic and stress changes related to fluctuating groundwater levels and the industrial loads of the KTI in the Salt Lake Valley (Hu and Bürgmann, 2021; Hu and others, 2021). Hu and Bürgmann (2021) used Sentinel-1 SAR (Synthetic Aperture Radar) imagery collected between 2014 and 2019 to observe seasonal, millimeter-scale uplift (springtime) and deflation (winter) in the Salt Lake Valley due to fluctuating groundwater. The hydrologic systems in the Salt Lake Valley are partially modulated by faults and upon investigating poroelastic strain fields, they determined that the M_w 5.7 Magna earthquake was not triggered by stress changes due to fluctuating groundwater. Addressing a similar question on triggering, Hu and others (2021) investigated the potential influence of the KTI material on triggering the Magna earthquake, concluding that the about 60 million tons/year of mill slurry piled on the tailings impoundment since the early 1990s could accelerate or decelerate the occurrence of earthquakes on the order of several hundred years. Because of the 2020 Magna earthquake, there will likely be additional journal articles, publications, presentations, and discussions for decades to come for those living and working in seismic science and hazards along the Wasatch Front.

CONCLUSIONS

Documenting ground effects from the March 18, 2020, M_w 5.7 Magna, Utah earthquake and establishing a digital clearinghouse was critical in the aftermath of the earthquake. Collecting perishable data is important for broadening the understanding of seismic hazards along the Wasatch Front in the wake of a moderate-magnitude earthquake. Liquefaction was the most widely observed geologic effect from this earthquake. A combination of seasonally high groundwater levels,



2020 M5.7 Magna, Utah Earthquake Response

A digital clearinghouse for the March 18, 2020 M5.7 Magna, Utah earthquake and aftershock sequence to share and archive valuable information and data. Clearinghouses serve to provide data for post-event scientific and other investigations to improve our understanding of these events and how to deal with them. If you have items to submit to the clearinghouse, please email those items to Ben Erickson at benerickson@utah.gov. Additional information is available from the Utah Geological Survey (https://geology.utah.gov/5-7-magnitude-earthquake-hits-utah/), the University of Utah Seismograph Stations (https://quake.utah.edu), the Utah Seismic Safety Commission (USSC) (https://ussc.utah.gov), the Utah Division of Emergency Management (https://dem.utah.gov), and from https://earthquakes.utah.gov/. Photos from the 1962 M5.2 Magna, Utah earthquake are available at https://ussc.utah.gov/pages/search.php?search=!collection200500.

Figure 15. Screenshot of the UGS's 2020 M5.7 Magna, Utah Earthquake Clearinghouse (https://geodata.geology.utah.gov/pages/search.php?-search=!collection609, or scan QR code above).

Table 1. List of publications on the 2020 Magna, Utah, earthquake. Table 1 continues on next page.

Publication Title	Authors	Journal	Link/DOI	Keywords
Monitoring the 2020 Magna, Utah, earthquake sequence with nodal seismometers and machine learning	Baker, B., Holt, M. M., Pankow, K. L., Koper, K. D., and Farrell, J.	Seismological Research Letters, vol. 92, no. 2A	https://doi.org/10.1785/0220200316	Seismology
Near-field strong ground motions from GPS-derived velocities for 2020 intermountain western United States earthquakes	Crowell, B.W.	Seismological Research Letters, vol. 92, no. 2A	https://doi.org/10.1785/0220200325	Seismology, Geodetic Data
Preface to the focus section on the 2020 intermountain west earthquakes	Gold, R. D., Bormann, J. M. Bormann, and Koper, K. D.	Seismological Research Letters, vol. 92, no. 2A	https://doi.org/10.1785/0220210001	Earthquake Geology, Seismology, Geodetic Data, seismotectonic setting
Toward robust and routine determination of Mw for small earthquakes: application to the 2020 Mw 5.7 Magna, Utah, seismic sequence	Holt, J., Whidden, K. M., Koper, K. D., Pankow, K. L., Mayeda, K., Pechmann, J. C., Edwards, B., Gök R., and Walter, W. R.	Seismological Research Letters, vol. 92, no. 2A	https://doi.org/10.1785/0220200320	Seismology, Machine Learning
Aquifer deformation and active faulting in Salt Lake Valley, Utah, USA	Hu, X. and Bürgmann, R.	Earth and Planetary Science Letters, vol. 547	https://doi.org/10.1016/j.epsl.2020.116471	Hydrology, Active Faulting, Stress Modeling
Stress perturbations from hydrological and industrial loads and seismicity in the Salt Lake City region	Hu, X., Xue, L., Bürgmann, R., and Fu, Y.	Journal of Geophysical Research: Solid Earth, vol.126	https://doi.org/10.1029/2021JB022362	Hydrology, Active Faulting, Stress Modeling
Geologic setting, ground effects, and proposed structural model for the 18 March 2020 Mw 5.7 Magna, Utah, earthquake	Kleber, E. J., McKean, A. P., Hiscock, A. I., Hylland, M. D., Hardwick, C. L., McDonald, G. N., Anderson, Z. W., Bowman, S. D., Willis, G. C., and Erickson, B. A.	Seismological Research Letters, vol. 92, no. 2A	https://doi.org/10.1785/0220200331	Earthquake Geology, Seismology, Geophysics
When emergencies and disasters collide: Lessons from the response to the Magna, Utah earthquake during the COVID-19 pandemic	McEntire, D. A.	Journal of Emergency Management, vol. 19, no. 7	https://doi.org/10.5055/jem.0615	Emergency Management, Pandemic

the presence of fine-grained Great Salt Lake and Lake Bonneville sedimentary deposits, and the potential for significant ground shaking from regional earthquakes creates a high liquefaction hazard along much of the Wasatch Front (Castleton and others, 2011). Even the moderate magnitude of the 2020 Magna earthquake was sufficient to create damaging liquefaction features. Recent geologic hazard mapping by the UGS aims to identify areas of high liquefaction susceptibility based on geologic conditions in the subsurface (Castleton and others, 2011; Castleton and McKean, 2012). Based on our observations following the Magna earthquake, these maps correctly identified liquefaction hazard areas in the Salt Lake Valley. Future hazard mapping should incorporate observations from the Magna earthquake to help refine and improve identification and mapping of liquefaction susceptibility along the Wasatch Front.

This earthquake was a timely reminder that the Wasatch Front is seismically active, despite the lack of large-magnitude earthquakes in historical times. The probabilities of one or more earthquakes occurring in the Wasatch Front region for various earthquake magnitudes are: 43% for a large (M ≥ 6.75) earthquake, 57% for a M ≥ 6.0 earthquake, and 93% for a M ≥ 5.0 earthquake, such as the Magna earthquake (WGUEP, 2016). Despite the 2020 Magna earthquake, paleoseismic data indicate that the Salt Lake City segment of the WFZ remains overdue for a major surface-rupturing earthquake, as enough strain was not relieved in this quake to drastically alter the probabilities reported in 2016 (WGUEP, 2016; Pang and others, 2020). Despite the lack of fatalities and injuries, the presence of damaging ground-shaking-related geologic effects serves as a reminder for the region's population of what the effects of a large-magnitude earthquake (M ≥ 6.75) would have on the Wasatch Front.

Table 1 (continued). List of publications on the 2020 Magna, Utah, earthquake.

Publication Title	Authors	Journal	Link/DOI	Keywords
Backprojection imaging of the 2020 Mw 5.5 Magna, Utah, earthquake using a local dense strong-motion network	Mesimeri, M., Zhang, H., and Pankow, K. L.	Seismological Research Letters, vol. 92, no. 6	https://doi.org/10.1785/0220200326	Seismology
Seismic wave propagation and basin amplification in the Wasatch Front, Utah	Moschetti, M. P., Churchwell, D, Thompson, E. M., Rekoske, J. M., Wolin, E., and Boyd, O. S.	Seismological Research Letters, vol. 92, no. 2A	https://doi.org/10.1785/0220200449	Seismology
Evidence for a listric Wasatch fault from the 2020 Magna, Utah, earthquake sequence	Pang, G., Koper, K.D., Mesimeri, M., Pankow, K.L., Baker, B., Farrell, J., Holt, J., Hale, J.M., Roberson, P., Burlacu, R., Pechmann, J.C., Whidden, K., Holt., M.M., Allam, A., and DuRoss, C.	Geophysical Research Letters	https://doi.org/10.1002/essoar.10503691.1	Seismology, Earthquake Geology
Responding to the 2020 Magna, Utah, earthquake sequence during the COVID-19 pandemic shutdown	Pankow, K. L., Rusho, J., Pechamnn, J. C., Hale, J. M., Whidden, K., Sumsion, R., Holt, J., Mesimeri, M., Wells, D., and Koper, K. D.	Seismological Research Letters, vol. 92, no. 1	https://doi.org/10.1785/0220200265	Emergency Management, Seismology
Coseismic fault slip and afterslip associated with the 18 March 2020 M 5.7 Magna, Utah, earthquake	Pollitz, F. F., Wicks, C. W., and Svarc, J. L.	Seismological Research Letters, vol. 92, no. 2A	https://doi.org/10.1785/0220200312	Seismology
Seismotectonic snapshots—The 18 March 2020 Mw 5.7 Magna, 31 March 2020 Mw 6.5 Stanley, and 15 May 2020 Mw 6.5 Monte Cristo Intermountain West earthquakes	Wesnousky, S. G.	Seismological Research Letters, vol. 92, no. 2A	https://doi.org/10.1785/0220200314	Seismology
The 18 March 2020 M 5.7 Magna, Utah, earthquake: strong-motion data and implications for seismic hazard in the Salt Lake Valley	Wong, I., Wu, Q., and Pechmann, J. C.	Seismological Research Letters, vol. 92, no. 2A	https://doi.org/10.1785/0220200323	Seismology

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