The Wasatch Fault

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The Wasatch Fault

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Acknowledgments

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THE UPS AND DOWNS OF THE WASATCH FAULT

The ups...

Many people move to Utah's Wasatch Front, in part, because of the spectacular Wasatch mountain range. Reaching heights of over 11,000 feet, these mountains provide outstanding scenery, a variety of recreational opportunities, a constant water supply, and many other resources. Utahns can thank the Wasatch fault for creating these mountains, which are still rising today. Uplift occurs when a part of the earth's crust shifts suddenly along the Wasatch fault.

The downs...

This sudden motion along the fault causes earthquakes that can be dangerous to people living along the Wasatch Front. Earthquake risk increases as population increases. Approximately 1.6 million people (about 80% of Utah's residents) live along the Wasatch Front. This close juxtaposition of a large active fault and a populous urban area contributes to the Wasatch Front's designation as having the greatest earthquake risk in the interior of the western United States.

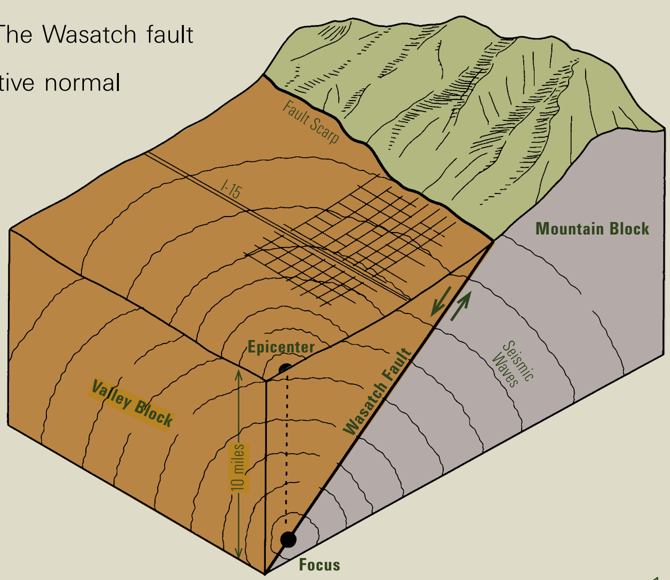
Life near the fault...

The Wasatch fault traces predominantly along the base of the mountains near numerous Wasatch Front communities; many of which encroach on the fault. Land use along this prominent fault is variable and sometimes controversial. While escarpments provide attractive "foothills" locations for parks, trails, and golf courses, they also furnish "view lots" for homes and convenient sites for water tanks, reservoirs, and other facilities.

WHAT IS THE WASATCH FAULT?

A fault is a break in the earth's crust along which blocks of earth slip past each other. This slipping is the earth's way of adjusting to the buildup of strain within its crust. Movement can be horizontal, vertical, or both. The Wasatch fault is called a *normal* fault, because the slip is mostly vertical - the mountain block (Wasatch Range) moves upward relative to the adjacent downward-moving valley block. The 240-mile-long fault is sectioned into 10 segments averaging 25 miles in length. Each segment can rupture independently. The Wasatch fault has the dubious distinction of being one of the longest and most active normal faults in the world.

The Wasatch fault dips to the west under the valley. The initial point of earthquake rupture, the *focus*, typically originates about 10 miles below the earth's surface. That places the earthquake *epicenter* - the point on the ground surface directly above the focus, and usually where the strongest ground shaking occurs - out in the valley. If the earthquake is large enough, rupture can reach the ground surface, displacing the ground along the fault and producing a *fault scarp* (a steep break in slope) up to 20 feet high.



WHERE IS THE WASATCH FAULT?

Globally

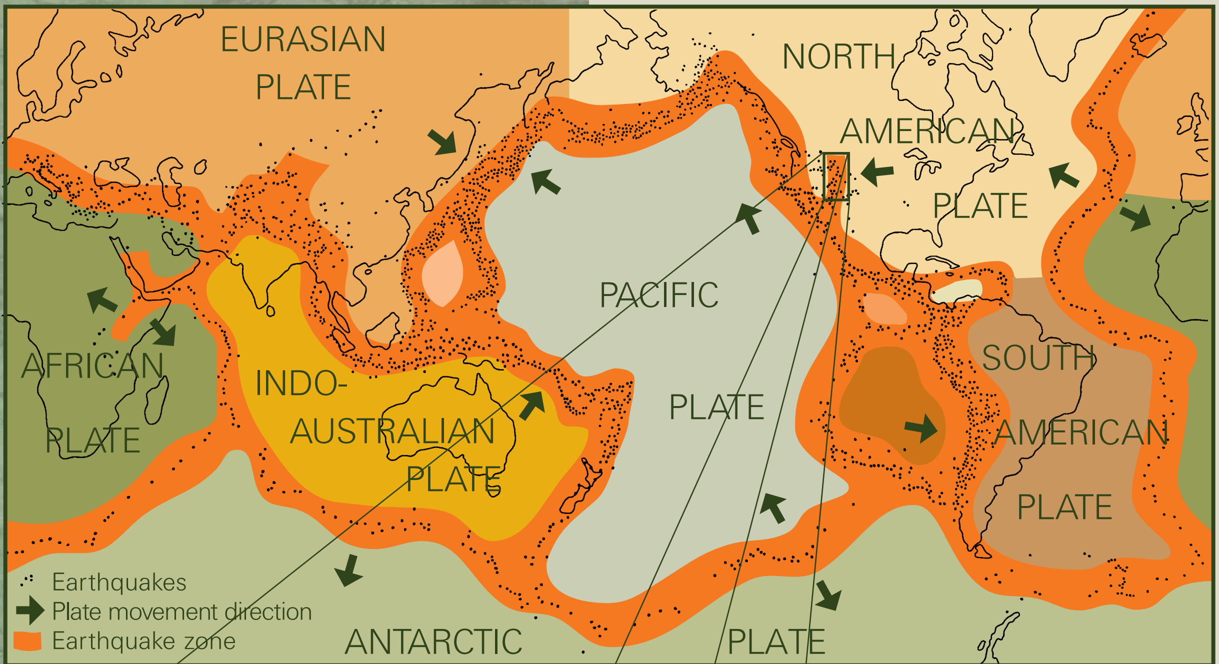
Most of the world's earthquakes and active faults occur in narrow belts that outline a mosaic pattern on the earth's surface, much like the patchwork surface of a soccer ball. These zones define the edges of large crustal plates. The plates move slowly across the earth's surface in different directions. Earthquakes occur as these plates slide by, bump into, plunge beneath, or spread apart from each other. Not all earthquakes and faults occur at plate margins, though. The Intermountain seismic belt (ISB), in which the Wasatch fault is located, is one example. How do we explain this errant thread in the global patchwork pattern?

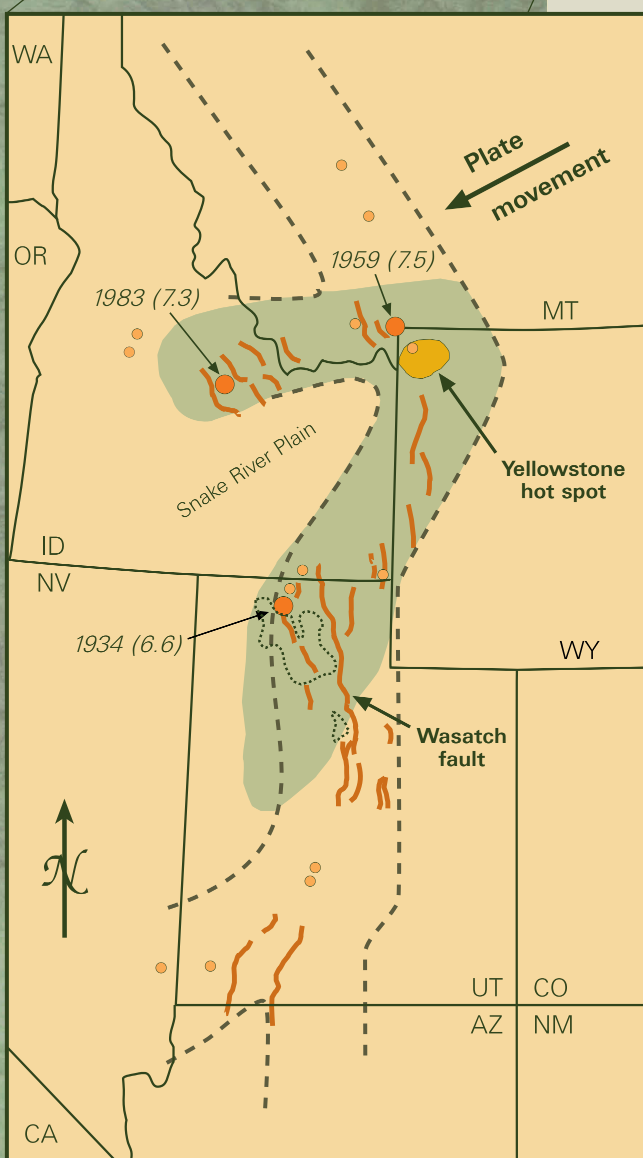
Regionally

The ISB extends 800 miles from Montana to Nevada and Arizona. Located within the western interior of the North American plate, much of the area has been geologically active for millions of years. Earthquake and volcanic activity in the plate interior indicates that the effects of plate movements are far reaching.

Long ago, the area that is now Nevada and western Utah (the Basin and Range Province) was compressed. With changing plate motions, the Basin and Range began stretching and the crust adjusted to this new motion through the process of normal faulting. The Wasatch fault, one such adjustment, marks the eastern edge of the Basin and Range extension.

The extension also set the stage for other regional restlessness in nearby Yellowstone National Park where a concentrated plume of heat from deep within the earth is burning through to the surface (called a *hotspot*). As the North American plate slowly moves southwestward over this stationary hotspot, a trail of volcanic features is left in its wake (the Snake River Plain in southern Idaho). Increased earthquake activity occurs in a U-shaped area where the crust bulges and cracks as it encounters the hotspot (imagine a semi-submerged boulder in a stream; as the water approaches the rock, the current slows and water surges over and around the boulder, and ripples and waves form upstream and to the downstream sides of the boulder in a U-shape wake). Faults within the U-shape area surrounding the hotspot tend to be the most active in the region (see adjacent map). The Wasatch fault is the largest and most active of these faults.





The earth's surface is a mosaic of moving plates; earthquake zones (colored orange) outline the plate boundaries. One anomaly is the Intermountain seismic belt, which lies within the interior of the North American plate. The Yellowstone hotspot is located within this belt.

Active faults

Historical earthquake epicenters ≥ 6.0

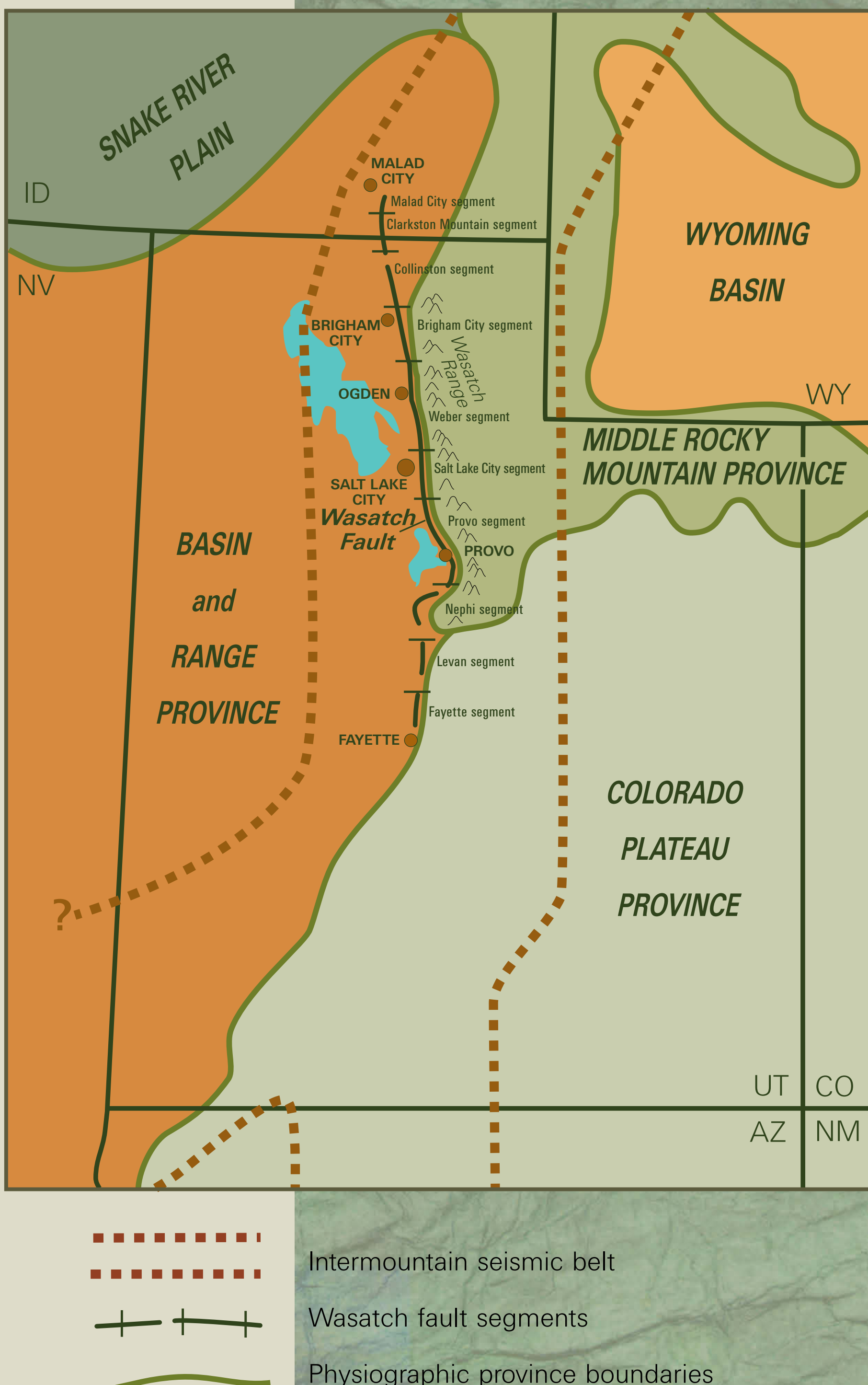
Historical surface-faulting earthquakes – *year(magnitude)*

Intermountain seismic belt

U-shaped area of faults and earthquake epicenters flanks the "path" of the Yellowstone hotspot

Locally

Extending from Malad City, Idaho, to Fayette, Utah, most of the Wasatch fault traces along the western base of the Wasatch Range. The fault is in the transition zone between the relatively thin crust of the Basin and Range Province to the west and the thicker, more stable crust of the Rocky Mountains and Colorado Plateau to the east. The transition zone lies within the Intermountain seismic belt.



The Wasatch fault in 'local' perspective.

SURFACE EXPRESSIONS

(how to recognize the fault)

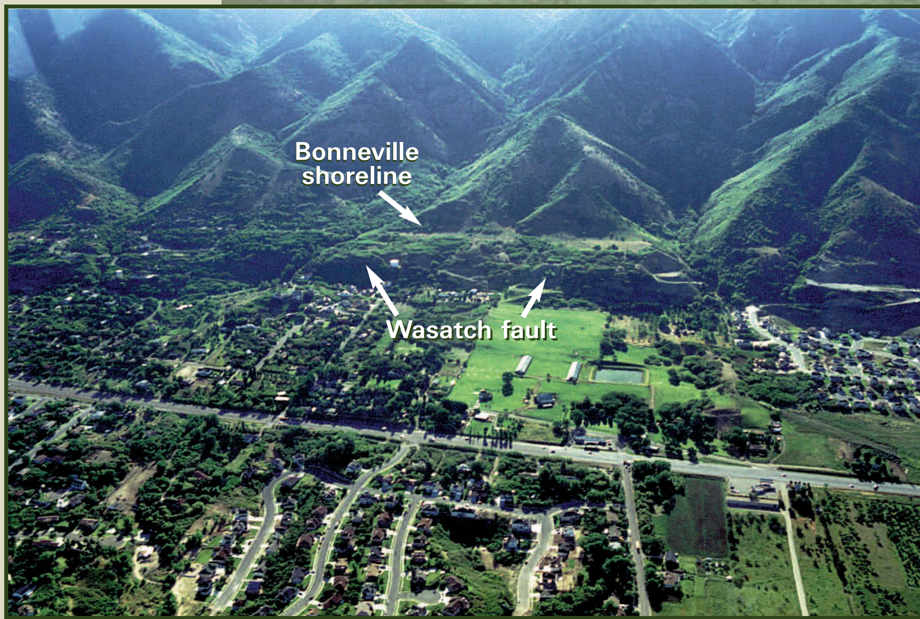
Fault scarps, triangular facets of mountain fronts, and in some places springs, reveal the surface trace of the Wasatch fault. Typically, the fault is easily recognized as a steep, almost continuous escarpment along the base of the Wasatch Range. This escarpment, or fault scarp, forms when large earthquakes rupture and offset the ground surface. A single large earthquake on the Wasatch fault can produce a fault scarp up to 20 feet high. Visible scarps are not continuous along the fault - they disappear at segment boundaries and in areas where natural erosion, deposition, or construction has obscured them.

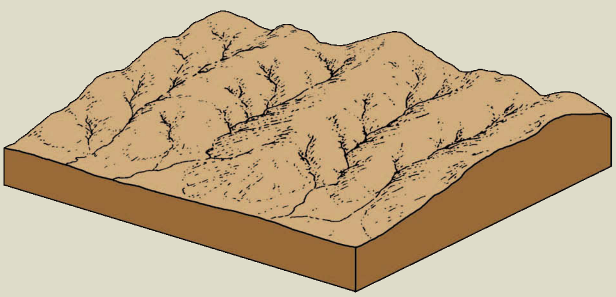
This seam between the mountain range and the valley is often not a single break, but a complex zone of deformation comprised of many parallel faults. Therefore, the term "Wasatch fault zone" is used interchangeably with "Wasatch fault."

Whereas a single earthquake can produce scarps ranging from fractions of inches to 20 feet high, some scarps are over 100 feet high and represent multiple surface-faulting earthquakes. This fault scarp, along Wasatch Boulevard just north of Little Cottonwood Creek in Salt Lake County, is about 130 feet high.

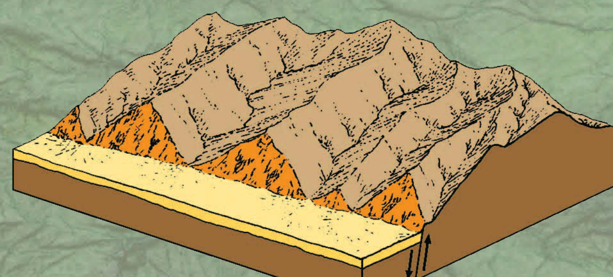
In most places, the Wasatch fault is at the base of the mountains (see next photo). In other areas, the fault extends out from the mountains, such as in the Salt Lake Valley, where Highland Drive parallels part of the fault (shown by arrow)(Rod Millar).

In many areas along the Wasatch Front, the Wasatch fault is visible downslope from the highest shoreline of Lake Bonneville. Both the fault and the shoreline show as breaks in slope, yet they differ. The shoreline maintains the same elevation (usually seen as an obvious terrace at about 5,200 feet) as it traces along the foothills, like a ring around a bathtub. The fault line, however, is more irregular and does not follow topographic contours. East Layton, Davis County.





Original land surface.



Faulting creates a steep fault scarp, which is then cut by accelerated stream erosion. Triangular-shaped facets form between the stream-eroded valleys.

(modified from Hamblin, 1992)

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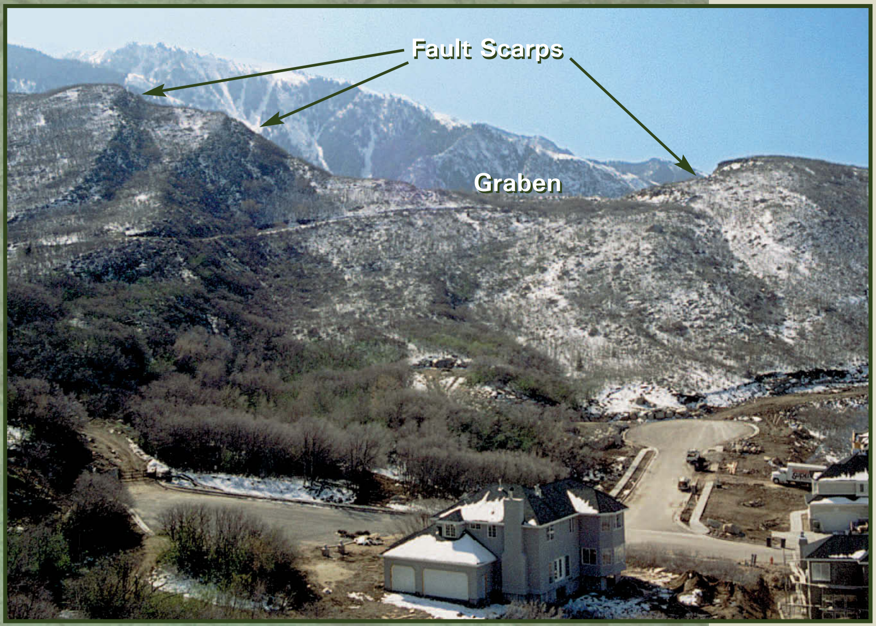
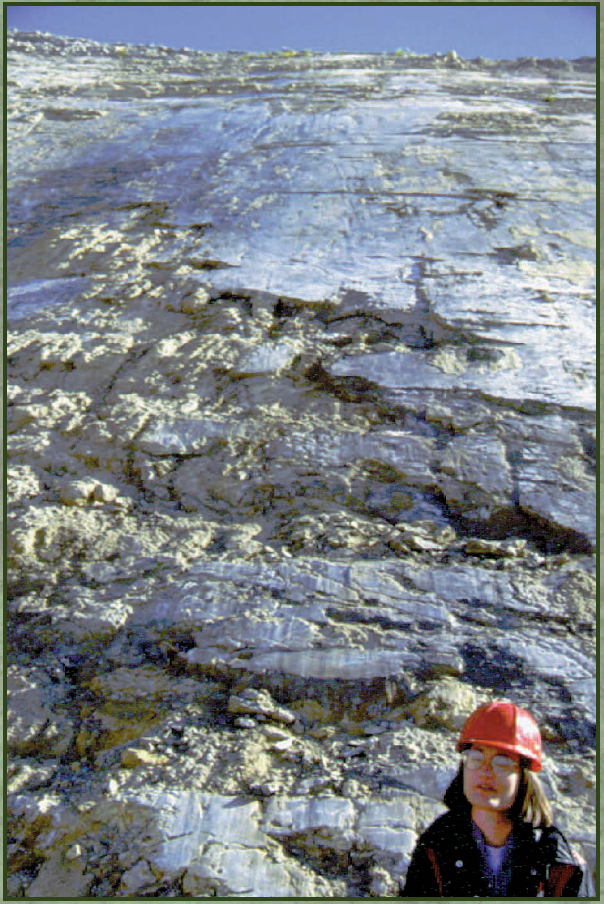
The triangular forms of ridges along the mountain front, *triangular facets*, are the remnants of fault scarps and result from uplift along the fault. These facets are between Hobble Creek Canyon and Maple Canyon, near Mapleton in Utah County (Rod Millar)(reproduced with permission from UUSS).



Large fault scarps trace up and over the "hill" in this photo. In between the two fault scarps on photo left and the fault scarp on photo right is a downdropped block of land called a graben. This photo shows the ground deformation that commonly occurs on the downthrown side (valley side) of the main fault trace. The zone of deformation encompasses parallel faults, and broken, tilted, and downdropped blocks of ground. Mouth of Bells Canyon, Salt Lake County.

Many springs issue along the Wasatch fault, which provides a conduit for ground water to rise to the surface. Fed by spring water, a narrow band of vegetation commonly grows along the fault. This spring (marked by arrow) is in northern Salt Lake City.



Slickensides, grooves and ridges etched into the rock by movement along a fault, illustrate the power of rock grinding past rock deep within the earth. An excavation at the Seven Peaks Resort, in Provo, Utah County, revealed these Wasatch fault slickensides, which have been raised many thousands of feet along the fault.

LAND USE

Your fault?

The east bleachers (left arrow) at the Weber State University stadium straddle the Wasatch fault. Note development above and below the fault (marked by arrows).

Fault scarps provide convenient sites for homes with a view,

and water tanks and reservoirs (marked by arrows) utilizing natural slope gradients (photo near Fruit Heights in Davis County; Rod Millar).

Land uses *more compatible* with an active fault include farms (see the tree farm in previous photo), golf courses, parks, and undeveloped open space.

Farm lands adjacent to the Wasatch fault. The fault traces away from the mountain front and into the valley where Interstate 15 crosses it (marked by arrows) north of Nephi, Juab County (Rod Millar)(reproduced with permission from UUSS).

A golf course is situated above and below the Wasatch fault (marked by arrow) at Seven Peaks Resort, Provo, Utah County (Rod Millar)(reproduced with permission from UUSS).

Faultline Park, 400 South between 1000 and 1300 East in Salt Lake City, is positioned on the fault scarp.

AT A GLANCE

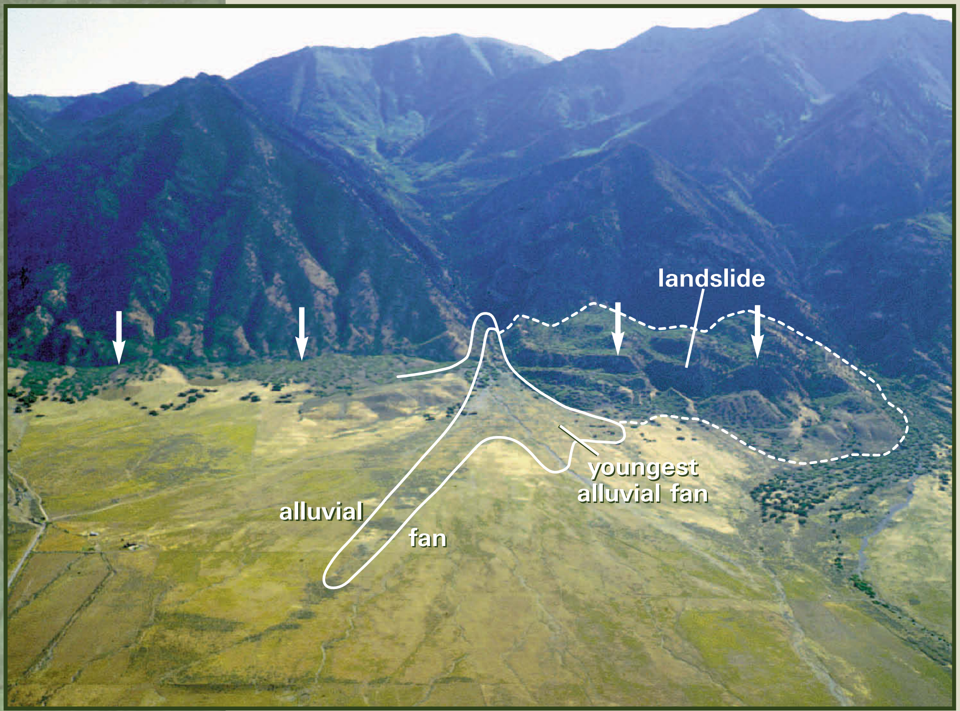
Geological relationships of faults, glaciers, lakes, and streams

Approximately 32,000 to 10,000 years ago, the climate was cooler and wetter in what is now Utah. Glaciers occupied the Wasatch Range and a large lake called Lake Bonneville covered most of Utah's western valleys. As the climate warmed and dried, melting glaciers left rocky debris (called glacial moraines) at the mouths of canyons, including Dry Creek (northeast of Alpine), Bells, and Little Cottonwood Canyons. Meanwhile, Lake Bonneville receded, abandoning shorelines and exposing deltas previously formed by streams dumping sediments into the lake. Streams became the main agents of erosion and deposition, cutting into deltas at the mouths of larger canyons, and spreading material widely in valley areas. Alluvial fans formed near the mouths of steep, smaller canyons. The Wasatch fault crosses glacial moraines, lake shorelines, lake deltas, and alluvial fans. Knowing the ages of deposits or features that bury or are cut by the fault helps geologists determine the approximate timing of Wasatch fault earthquakes.

Multiple fault scarps (marked by arrows) cut across 16,000- to 18,000-year-old glacial moraines at the mouths of Little Cottonwood (left) and Bells (center) Canyons, Salt Lake County. Lower Bells Canyon Reservoir (center), now drained, was "conveniently" situated on land lowered between two fault scarps (called a graben). Some of the scarps are 100 to 130 feet high, indicating they were formed by repeated large earthquakes (possibly as many as seven to ten events) in the past 18,000 years (Rod Millar).

Sand and gravel deposited as a delta into Lake Bonneville about 14,500 to 16,000 years ago by Little Cottonwood Creek are displaced by the Wasatch fault (a water filtration plant sits on this ancient delta. The embankment in the foreground, near the plant, formed as Little Cottonwood Creek incised the delta as the lake receded). High fault scarps (shown by large arrow) indicate several large earthquakes have taken place here over the past 14,500 to 16,000 years. The other arrows show the fault zone branching into three strands in subdivisions adjacent to Wasatch Boulevard in Salt Lake County.

Near Mona in Juab County, the fault zone (marked by arrows) crosses an ancient landslide. The fault also cuts across a younger alluvial fan (approximately 5,000 to 10,000 years old) at the mouth of Pole Canyon. However, the fault does not displace the youngest alluvial fan, which is probably a few hundred years old. The earthquakes at the mouth of Pole Canyon, then, happened between about 200 and 10,000 years ago (Rod Millar)(reproduced with permission from UUSS).



EARTHQUAKES

The Wasatch fault has been active for at least 15 million years as the earth's crust has stretched across the eastern Basin and Range Province (see map on page 4). The fault moves when built-up strain is released suddenly and blocks of the earth's crust break and slip past each other (imagine stretching a rubber band to its breaking point). Numerous other faults exist in this area of extension, usually within the upper part (6 to 12 miles) of the earth's crust.

The global positioning system (GPS) is one technique used by geoscientists to determine rate of strain accumulation along the Wasatch fault.

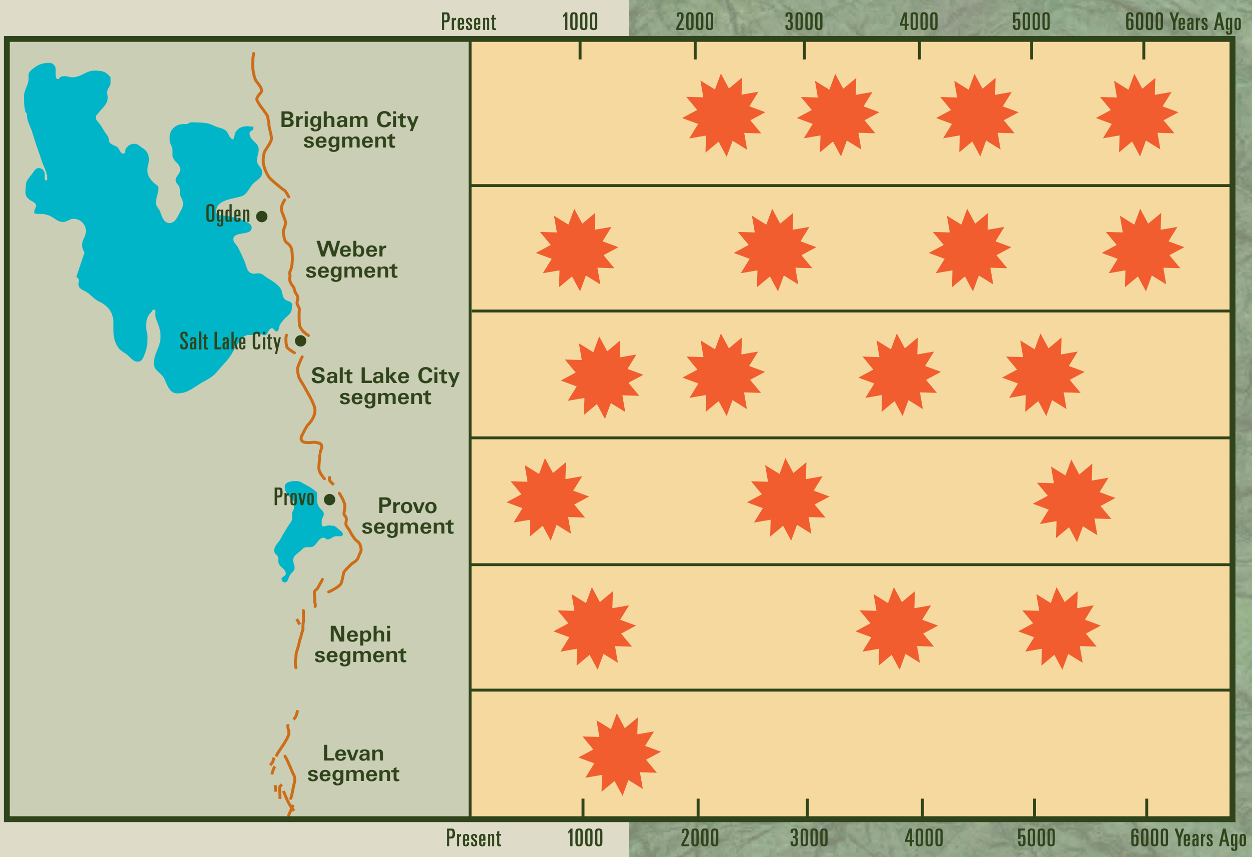
Information about Utah's earthquakes is furnished by historical and prehistorical records. Historical records (since pioneer settlement in Utah) give us an idea of how many felt earthquakes have happened in the Wasatch Front area over the past 150 years. Since the 1960s, instrumental recordings have expanded this information base. However, we are unsure as to how many of the earthquakes took place on the Wasatch fault, partly due to complexities in tying individual earthquake recordings with the underground trace of a specific fault. Other faults exist in the Wasatch Front area that can generate earthquakes.

Although no surface-faulting earthquakes have occurred on the Wasatch fault since settlement in Utah, evidence of numerous prehistoric events exists in the geologic record. This geologic record provides the only information about large Wasatch fault earthquakes. The history and future probabilities of large earthquakes along the Wasatch fault are formulated from a variety of sources - one such source is from trenches excavated across fault scarps.

More than 70 trenches have been excavated across the Wasatch fault to provide information on the timing of large earthquakes (when), recurrence intervals for fault segments (how often), and amount of movement (how big). Radiocarbon dating of organic debris found in this trench across the Provo segment indicates that the most recent large earthquake occurred here about 600 years ago.

When/how often?

Every 350 years?



Geologic studies show that at least 19 surface-faulting earthquakes (shown as starbursts on this generalized diagram) have occurred on the Wasatch fault during the past 6,000 years.

These earthquakes took place on the fault's five central segments (Brigham City, Weber, Salt Lake City, Provo, and Nephi) and one distal segment (Levan). Collectively, the "composite recurrence interval," or how often a large earthquake has occurred on the central portion of the Wasatch fault, is approximately once every 350 years. The last large earthquake happened about 600 years ago on the Provo segment, and possibly earlier on the Nephi segment (although the starburst position indicates a carbon-dated event closer to 1,200 years ago, some researchers estimate an earthquake occurred as recently as 400 years ago on the Nephi segment).

For any individual segment of the central portion of the fault, the "average recurrence interval" is longer - about every 1,200 to 2,600 years. In comparison, each of the distal segments have recurrence intervals of about 10,000 years or more, (recurrence intervals are long-term averages).

HOW BIG?

Magnitude 7.5?

The largest earthquake expected along the Wasatch fault is about magnitude 7.5. Scientists derived this estimate from the amount of displacement created by prehistoric earthquakes, the length of past fault ruptures, and comparisons with historic large earthquakes elsewhere. Prehistoric earthquakes on the Wasatch fault have typically displaced the ground surface about 6 to 10 feet for 20 to 40 miles. Some earthquakes have formed scarps almost 20 feet high. These 'typical' characteristics are estimated to form during earthquakes of about magnitude 7.5 or slightly smaller. This estimate concurs with the two largest historic earthquakes in the ISB. The 1983 Borah Peak, Idaho (magnitude 7.3) and the 1959 Hebgen Lake, Montana (magnitude 7.5) earthquakes displaced the ground surface for 20 miles, from about an average of 5 feet (Borah Peak) and 7 feet (Hebgen Lake) to a maximum of 20 feet (Hebgen Lake). Both earthquakes occurred on normal faults similar to the Wasatch fault.

EARTHQUAKE HAZARDS

Earthquakes can generate several different geologic hazards. In addition to **ground shaking**, other hazards are **soil liquefaction**, **surface fault rupture, flooding**, and **slope failure**. Not only are buildings including homes endangered by these hazards, but water tanks, dams, roads, bridges, railways, airports, and utility corridors carrying electricity, water, sewage, natural gas, petroleum, and telephone service are all at risk. Along the Wasatch Front, many of these structures and utility lines are located on, or cross, the Wasatch fault.

Earthquake hazards can occur miles from an earthquake epicenter; the distance depends on the type of hazard and size of the earthquake. For example, a magnitude 4.5 earthquake can cause rock falls within several miles of the epicenter. Conversely, rock falls and other slope failures, as well as ground shaking and soil liquefaction can occur more than 100 miles away from the epicenter of a magnitude 7.5 earthquake. So, for instance, in a large surface-faulting earthquake along the Brigham City segment, Brigham City could experience all the hazards listed above, whereas Salt Lake City or Provo would likely experience ground shaking, soil liquefaction, and slope failures, but not surface fault rupture.

For further information on earthquake hazards, refer to "A Homebuyers' Guide to Earthquake Hazards in Utah" available from the Utah Geological Survey.

FUTURE PROBABILITY OF THE "BIG ONE"

Certainly, forecasts of future large earthquakes along the Wasatch fault are uncertain. The 6,000-year record contains only a few earthquakes per segment. With this inadequate data base, scientists do not know if Wasatch fault earthquakes occur in regular cycles, if their timing is random, or if they occur in clusters.

When?

Geologic studies show that the last large earthquake on the Wasatch fault happened about 600 years ago, and possibly as recent as 400 years ago. Given that a large Wasatch fault earthquake occurs, on average, every 350 years, the next "big one" may occur at any time. *However*, although the "big one" could strike while you are reading this brochure, the event may not happen in our or even our grandchildrens' lifetime.

What is the probability of the "big one" happening on the Wasatch fault in our lifetime? Roughly 13 percent during the next 50 years. In our grandchildren's lifetime? Approximately 25 percent during the next century.

Where?

Nobody knows where the next large earthquake on the Wasatch fault will take place. A conspicuous absence of movement on the Brigham City fault segment during the past 2,000 years suggests that the probability of a surface-faulting earthquake there may be greater than on other segments. If earthquakes occur regularly on segments, then the Salt Lake City segment may be next in line for a large earthquake.

What can we do?

Utah's Wasatch Front is a desirable place to live, but choosing to live here includes accepting earthquake risk. Earthquakes are part of the earth that we live on; we can't change the fault, but we can learn to live with it. Hazards are present in all regions of the U.S. (hurricanes along the eastern and southern coasts or tornadoes in the midwest, for example); therefore, it is prudent to be aware of what we can do to lessen the risk of damage and injury from natural disasters wherever we live. To find out what can be done to lessen the risk from earthquakes in Utah, see "where to get additional information" on the following page.

Awareness is the first step in risk reduction; hopefully this brochure has illustrated some of the "ups and downs" of the Wasatch fault.

WHERE TO GET ADDITIONAL INFORMATION

Preparedness, response, and recovery; mitigation; home construction:

Utah Division of Comprehensive Emergency Management
1110 State Office Building
Salt Lake City, UT 84114
(801) 538-3400

Preparedness, response, and recovery:

American Red Cross
check local chapters

Earthquake records:

University of Utah Seismograph Stations
705 Browning Building
University of Utah
Salt Lake City, UT 84112
(801) 581-6274

Earthquake hazards, including "A homebuyers' guide to earthquake hazards in Utah":

Utah Geological Survey
1594 W. North Temple
Salt Lake City, UT 84116
(801) 537-3300

Earthquake hazards:

U.S. Geological Survey - ESIC
2222 West 2300 South
Salt Lake City, UT 84119
(801) 975-3742

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