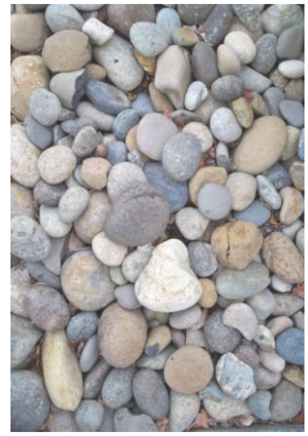
Your Geologic Services



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What engineering geologists do is a lot like what doctors do. We explore, diagnose, and fix, sometimes using esoteric science. Doctors have the advantage over us geologists, though. Lots of medical dramas appear on TV. People go to a doctor several times in a lifetime.

Using the services of a geologist isn't something people do every day. It's something you do about once in a lifetime. For example, you're about to retire, and you own some land on which you want to build a couple of homes. And you may need to engage the services of an engineering geologist. But you haven't done this before, and you may not even know someone who's gone through the process. What guidance do you have?

Let's give you some guidance and bring you up to speed. Down below you'll learn things like

- Who's your geologist?
- What's this geotechnical engineering stuff?
- What your geologist looks for
- What's geology?
- How government gets involved
- Our limitations

Who's your geologist?

Your geologist is someone who at a minimum has a bachelor's degree in geology or closely related subject.

Also, he or she has a state license to practice geology.[1] Before being given a license, the geologist has to have worked for a few years, gotten signatures from other geologists, and passed exams that take the better part of a couple days. Most times, the minority of test takers pass the exam. Many take the test over and over before finally passing or giving up.

That's the minimum. More likely than not, your geologist has way more than the minimum qualifications. He or she may have a master's degree or Ph.D. He or she may have scored high on the exam on the first try. Your geologist may have many years of experience.

If he or she doesn't have at least several years of State-licensed experience, they're probably working for a firm, in which case the geologist is working under the supervision of a senior geologist. The senior geologist will issue instructions along the way and review the junior's work product before it leaves the shop. If your geologist is a free lance, then he or she most likely has many previous years, perhaps decades, of experience, much of it while practicing in a tightly controlled corporate environment. As in medicine, dentistry, and law, so it is in geologic practice.

What's geology?

Geology is the study of the Earth. Specifically its geosphere (rock and soil) and, to a lesser extent, its hydrosphere (water), as opposed to its biosphere (life) or atmosphere (weather). Geologists analyze how rocks and soil came to be and where you can find the different types.

Geologists use a few basic principles to decipher the situation they look at. Here are a few (ten) of those basic principles. These principles generally date back only a couple centuries.

1. Superposition. Sedimentary and volcanic layers are deposited in a time sequence, with the oldest on the bottom and the youngest on the top.

2. Original horizontality. Sedimentary and volcanic rock layers are usually laid down in a horizontal position. Where layers are seen tilted, it was caused by disturbance after being deposited.

3. Walther's law. Sedimentary deposits found one on top of another are a record of two environments that were once next to each other in the past.

Shale: The ocean floor occupied this spot.

Sandstone. The sandy beach moved out toward the sea.

Shale: The nearby ocean floor moved closer to the land.

Sandstone: The nearby sandy beach moved out to the sea.

Shale. The nearby ocean floor shifted closer to the land.

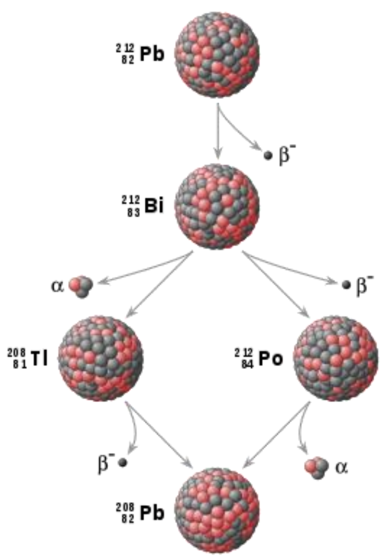
And so on and so forth. All because the land and sea went up and down relative to one another. And all these shifts took place in this one spot.

Later, this whole mass of ancient rocks was uplifted hundreds of feet, giving us this present view, but that's another topic unrelated to Walther's law (see *7 Plate Tectonics*, below).

4. Uniformitarianism. The geologic processes we see happening today, like volcanoes, ocean waves, stream flows, and erosion, are the same processes responsible for the geologic events of the past. The present is the key to the past. We see the results in the rock record.

5. Faunal succession. Sedimentary rock layers contain fossils of plants and animals. These fossils show up in the rock record in a specific, reliable vertical order that can be identified over wide horizontal distances. By wide distances we mean on continents separated by oceans, like North America and Europe. If you find trilobite fossils in Canada and in Scotland, you know the rocks the bugs are found in were deposited in the same time period.

However, this method only gives relative rock ages. As in: this layer is older than that, and that layer is younger than this, or that yonder layer is the same age as this here layer.

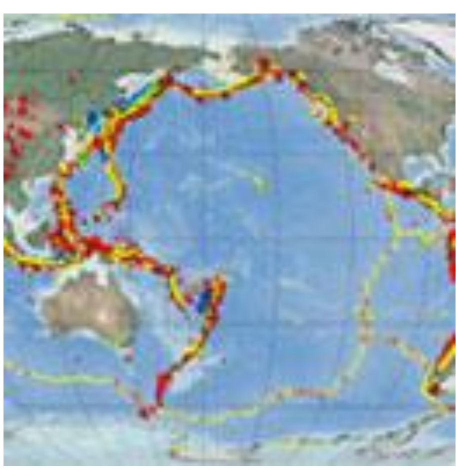


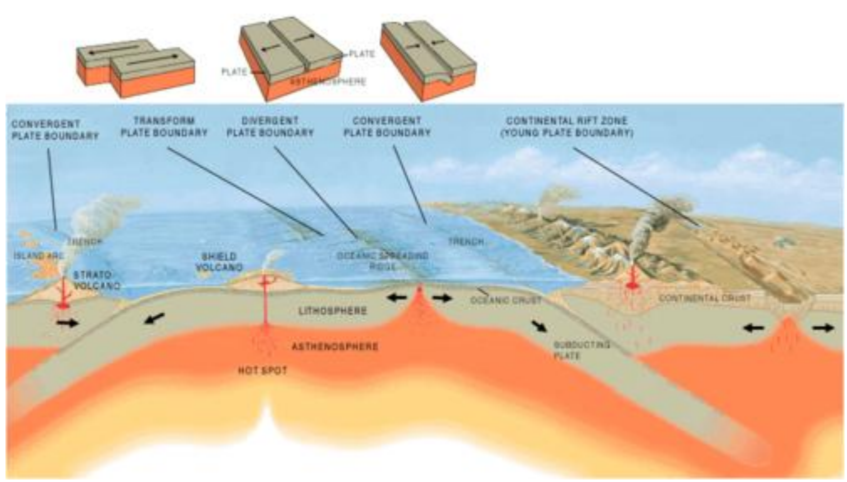
6. Absolute age dating. Rocks can be assigned absolute ages. These are true ages, as in "this rock crystallized 3.5 milliion years ago." Geologists collect samples in the field and send them to a laboratory for radiometric age dating. This technique uses known rates of decay of radioactive elements, such as carbon 14 and uranium.

Age dating may come into play when geologists want to decide if an earthquake fault is active (less than 10,000 years old) or not (more than 10,000 years old).

Paleomagnetism plus a few other esoteric techniques provide additional ways to obtain absolute rock age dates. Absolute age dating was developed about 5 decades ago.

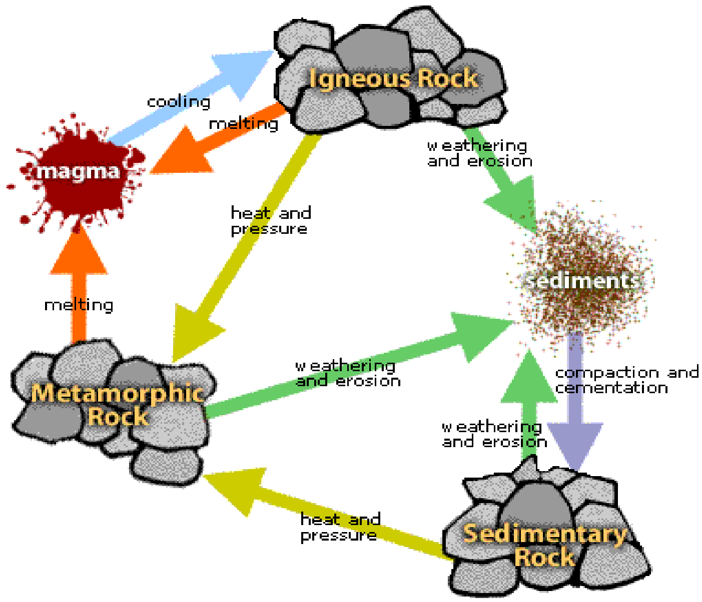
7. Plate tectonics. The Earth's crust is made of plates. Where two plates join, the relationship may move sideways relative to each other, or apart, or together. Lots of things happen along plate boundaries, like faulting and earthquakes, volcanoes, and mountain building. Geologists were finally able to piece together the principles of plate tectonics about 4 decades ago.





8. Three rock types. Rocks come in three types: igneous, metamorphic, and sedimentary.

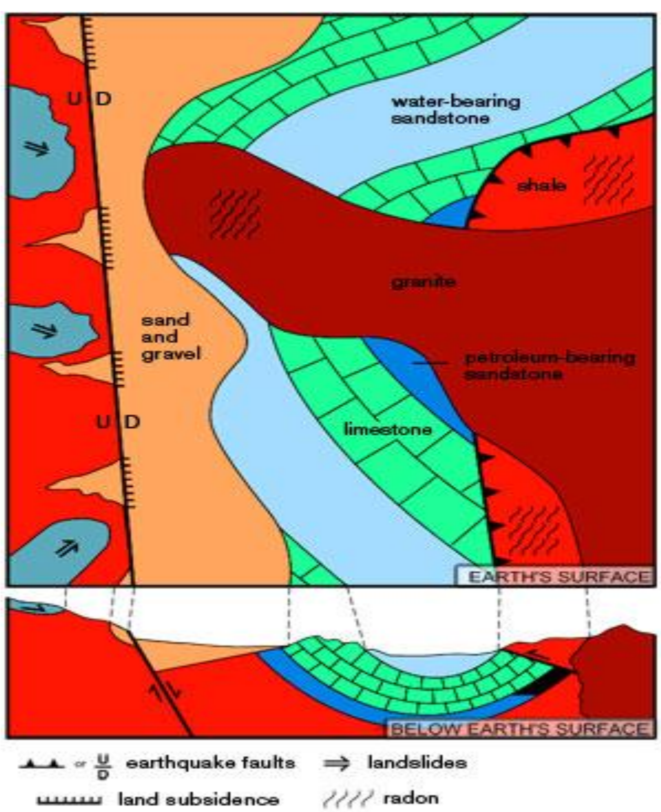
- Igneous: rocks made when magma or lava cools and crystallizes. Granite is one example.
- Metamorphic: rock that is heated and compressed, resulting in new minerals and textures. Marble and slate are examples.
- Sedimentary: rock made when particles settle out of a lake, stream, or ocean and get cemented together. Sandstone is an example.



9. Rock cycle. The Earth recycles rocks of the three three types. It can all be very complex, due to plate tectonics, #7 above.

Magma and sediment aren't rocks but they are still important parts of the rock cycle that geologists study.

Thankfully, geologists working on a site usually only have to deal with two or three of the arrows shown in the diagram at left.



10. Cross-cutting relationships. Rocks or cracks that cut across other rocks or cracks are younger than those other/older features.

For example, in this diagram, first, shale was deposited. Then petroleum-bearing sandstone, lime-stone, and water-bearing sandstone were deposited. Then all these four of these rock deposits were folded and faulted. Outcrops were eroded. Then granite, from some subterranean magma, intruded into these rocks. Then sand and gravel were eroded from the shale on the left side of the map. Faulting offset some of the sand and gravel (plus the older shale). Finally, landslides formed in the shale on the left.

Intrusions, inclusions, and unconformities are additional features that geologists use to under-stand age relationships.

The subdisciplines within geology each have a few principles of their own. In hydrogeology: the groundwater table tends to be a subdued replica of the ground surface. In stratigraphy: certain features can be used to indicate "younging," which is the direction in which younger and younger rock layers are arranged. In petrology: certain minerals will crystalize earlier or later in a body of magma. In sedimentology: streams tend to be good at rounding rocks but lousy at sorting the material, while seas tend to do the opposite.

There's lots more to geology than this. But you get the idea: using a few basic principles, geologists can decipher most of the geology of most sites.

What's this other geotechnical engineering stuff?

Geologists often team up with geotechnical engineers on a project. Geologists and geotechnical engineers have similar, or different, or overlapping roles on a project.

Geologists. We geologists focus on deciphering the past and see how this affects present and future conditions. We understand how and where the forces of nature have crystallized, deposited, contorted, and shifted various types of rock and soil to end up where they are. We point out where certain good or troublesome rock, soil, and water conditions show up now. We point out where natural shifts, such as earthquake faults and landslides, show up now and could show up in the future. Sometimes some mathematics is involved.

Geotechnical engineers. Our sister profession, geotechnical engineering, looks at how rock, soil, and water behave under force, right now. That force is usually gravity, pulling down. At times, forces push sideways, or even up, like when an earthquake wants to pull part of building up out of the ground. Geotechnical engineers understand how forces work on rock, soil, and the concrete foundations and other parts of a building. The forces of a manmade structure act on the ground, and the forces of the ground act on our foundations and buildings. Often much mathematics is involved.

Here's a desert scene in the American west.

The dam may look more impressive than the underlying geology. But is the dam concrete really more important than the rock it's built on?

Imagine this site before construction, while the dam was being planned. Geologists and geotechnical engineers worked together on the project. But they focused on different aspects.

Imagine you could listen in on their thinking and planning.

What they'll be thinking

Geotechnical engineers: Lots of forces going on here. Water pressure through the rock. Water pressure on the dam. Dam pressure on the rock. Lateral pressure on the rock and wanting to move it into the canyon. All of it driven by gravity.	Geologists: Deposition and uplift have created a special geologic rock-outcrop pattern. Notice the rock layers tilting upstream. Some layers may be strong, some weak. There also may have been some rock shifting. Let's find out where and why.

Where to focus exploration, testing, and analysis

Geotechnical engineers: We'll take rock samples where forces are critical, like where dam bearing pressures and water pressures are most severe. We'll send samples to the laboratory to test how strong they are and recommend how to design the dam. But we're not in the best position to tell where nature has placed strong or weak rock, or predict where nature has hidden them below ground.	Geologists: We'll find where various rocks and soil are located and why, and where they will show up even where they're hidden. We can tell you where nasty earth shifts have occurred, so the earth won't slip out from under the dam. We can spot where to get strong rock nearby to make the concrete for the dam. However, we're not in the best position to test foundation rock strength or use the data to design the dam.

This comparison is very simplified. But the analogies to general construction involving foundations and retaining walls should be straightforward.

How government gets involved

If you're planning to construct a building on your land, then government will get involved. This likely will be your local county or city planning department.

Local government originally got involved in this by taking responsibility for whether or where someone could locate a building. Once government took on this task, they then felt responsible for how safely the building is constructed, in other words, quality control. They inspect the structural elements, plumbing, and electrical wiring. This system has its roots in the Code of Hammurabi, from 1700 BC.[2]

Around the middle of the 20th century, everyone began understanding how geologic hazards could affect properties and lives. Local governments began inspecting for geologic safety. They don't inspect directly themselves, but they do require that an approved geologist create a responsible geologic report for a site.

You may feel a tinge of frustration at all this inspection. "It's my land and my house and I'm going to be living in it." You may choose whether or not to go to a doctor, and you may choose to accept ignore his advice. A house isn't quite like this, however. Even if you intend to live in your new, custom-built house for the rest of your life, it will eventually, someday, become the home of some new family. These new residents could be practically anyone. These members of the public expect some quality control by someone. (Even you yourself have undoubtedly lived in a house at least once in your lifetime not built under your care.) Your local building department has taken on this task of quality control. This is the way events have evolved, for better or worse.[3]

What your geologist looks for

Your geologist may create a geologic map of your site. Your geologist isn't doing this as part of some esoteric, scientific study of your site.[4] We do this so we can understand and explain what issues, if any, are present on your site.

An active fault. A fault is a special type of crack in the earth. It's not just an ordinary crack like in your garden soil or sidewalk. A fault is where a chunk of earth crust the size of a continent or mountain range on one side slips sideways relative to earth on the other side.[5] Relative movement could total a hundred miles over a few million years. The San Andreas fault is like this. Other faults have an up-down style of movement. Faults of this type help form mountains, like the fault that runs along the east side of the Sierra Nevada.

Fault movement may happen gradually, like on some parts of the Hayward fault or San Andreas fault. The photo below shows gradual creep on the Hayward fault. Or, fault movement may occur in an earthquake, which breaks the buildings on the crack and causes building damage and human casualties nearby. The Hayward fault, by the way, both creeps and lurches in tremendous earth-quakes, and it could be responsible for "the big one" someday.

The way we often address this issue is to explore and find a large enough area where no faults are found in which it is safe to build. Another way is to find where existing faults may lurk and recommend zones a safe distance away from them. There's no known way to safely build on (or very near) one of these earthquake faults. The State of California regulates how building may proceed in earthquake fault zones.[6]

Ground shaking. Geologists develop estimates of possible future ground shaking in an earthuake. Ground shaking is usually strongest near the responsible fault and dissipates with distance, but strong ground shaking, as most California residents should know, can occur many miles from a fault rupture.

Landslides. Landslides come in several different styles and sizes. The photo at right shows a good example: the La Conchita landslide.

Most landsliding hazards involve landslide deposits that are already there. Geologists use a variety of techniques to find landslides. When landslides are young, just a few years to a few hundred years old, they can be easy to find. When they are older, and some can be 50,000 years old, they can be difficult to identify. It may be possible to build on a large landslide. However, much analysis may be needed to show that such contruction is reasonable.

Stabilizing a large landslide can cost well into the $millions.

On the other hand, a landslide hazard at a site may only involve potential small earthflows. In this case, we may conclude the issue is only a nuisance, and the property owner only needs to prepare to shovel minor debris off a driveway once every few years after a storm.

The State of California publishes maps of zones of potential earthquake-induced slope instability.[7]

Slope stability is a catch-all term. It includes spotting existing landslide deposits, potential wedge pop-outs in rock slopes, and possible degradation of cut slopes. Your geologist should be able to advise on gradients of proposed cut slopes.[8]

Shallow groundwater. Shallow groundwater can

- be a nuisance under houses, in the form of buckled wood flooring and musty closets,
- promote mold, wood rot, and termites,
- lead to foundation settlement or uplift,
- wreak havoc on walkways and driveways,
- destabilize hillsides.

Geologists can look for signs of shallow groundwater and analyze these versus proposed development elevations. We can then recommend subdrainage systems to carry off groundwater.

Hard rock, soft soil, expansive soil, existing fill. Hard rock can be a nuisance during construction. Soft soil may require beefy foundations. Expansive soil/rock may require special treatment or deeper foundations. Existing fill may be compressible, particularly if no records of proper placement exist. The fill may require removal and replacement. Geologists are usually adept at spotting these zones and helping engineers develop solutions.

Rockfall hazard. Rocks may tumble off a slope and impact houses, pedestrians, or cars. Geologists can recommend setbacks or barrier fencing where needed.

Naturally occuring asbestos. Serpentine is the California State rock. It also contains asbestos. Geologists can notify developers where these conditions exist and provide rough guidelines.

The neighbors. Neighboring properties may be imposing slope instability, erosion, or rockfall issues onto your property. Or vice versa. Your project may impose extra stormwater runoff and erosion risks onto your downslope neighbor's property.

Other. Other unusual geologic conditions include tsunami hazards, flooding potential downstream of reservoirs or next to streams and lakes, streamside or beach-cliff erosion, mine tunnels, and naturally occuring mercury.

Wrapping up this little tutorial

We hope you appreciate what we geologists can do and how we do it.

Our abilities aren't unlimited, however. We can't just do "a test." Geologic investigation takes a lot more than that. Yes, we may need to drill. Or excavate test pits with an excavator. Or both. In fact, we might need to dig a long, wide trench, depending on what issues are present on your property. Our eyes come in handy when scanning the landscape, but we usually need to see what's going on below ground and prove to ourselves and to others that ground conditions are trustworthy.

If you're sensitive to costs, consider this: Perhaps you have a property and house in mind that together will one day be worth $850,000. Isn't it wise to spend maybe 2% of the project value to check that the earth below it won't melt away in the next storm or earthquake? Most people would consider that money well spent.

Or look at it this way: Would you rather see a few thousand dollars go to backhoe operators, drillers, and scientists (geologists), or see $100,000 go up in smoke in legal fees? Those could be the two options you face. Effort can be spent up front to minimize problems, or money can flow to attorneys at a rate of $500 per hour to settle and fix problems that show up down the road. Whom would you rather like to see roaming your property: builders in their coveralls, working to carry out your vision, or lawyers in their suits haggling over a sunken corner of your house?

Or, look at it this way: You, in your job, provide a useful service for others, right? You bet. View us geologists and engineers in the same light. We're at your service. Think of your geologist as a team partner in the successful development of your project, like your architect.

While geology sometimes seems like science in search of problems, remember that a good geologist will be on the lookout for all the good areas on your property to build on. If your site is a good one (and most are), then your geologist will write an effective report that shows the site is indeed a good one. If there's an issue to address, then a good geologist will be a team player among your project engineers and designers in weighing cost-effective solutions. Your geologist wants your project to succeed.

"The best geologist is the one who's seen the most geology."

— an old S.F. Bay Area engineering geologist

Footnotes

[1] http://www.pels.ca.gov/

[2] Hammurabi was a ruler in ancient Mesopotamia, now Iraq. One law, translated into English, reads "If a builder builds a house for someone, and does not construct it properly, and the house which he built falls in and kills its owner, then the builder shall be put to death."

[3] This situation needn't be the case, and my sympathies are with you. Urbanized housing may have been around for some 3,700 years or more, during which time government has had time to dig its fingers into the pie. Automobiles, 747s, and digital devices are a bit more recent, and all are manufactured and sold with little or no government inspection. The government inspection bureaucracy, usually slow on its feet, couldn't sink its tentacles deeply into these recent, rapidly evolving technologies. Homes *could* be sold with private-sector certificates of quality control, with buyers favoring and paying a premium for houses with the desired certificates. You can build an addition to your house without inspection and see how long you can get away with that without the local building department finding out and wanting to up your property tax valuation. But you may want to disclose your uninspected addition to the eventual future buyer of your home, and accept a lower purchase price.

[4] We geologists do science, but we apply our science knowledge and techniques to be of service to your project. Rest assured, we aren't doing our Ph.D. dissertations on your site.

[5] Faulting is due to geologic stress, as in plate tectonics. See earlier discussion of *Plate Tectonics*. Earth shifting due to local slope conditions and gravity falls under the heading of landsliding.

[6] http://www.conservation.ca.gov/cgs/rghm/ap/Pages/Index.aspx

[7] http://www.conservation.ca.gov/cgs/shzp/Pages/Index.aspx

[8] Unless your geotechnical engineer has taken on the task of designing cut slopes.