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E105

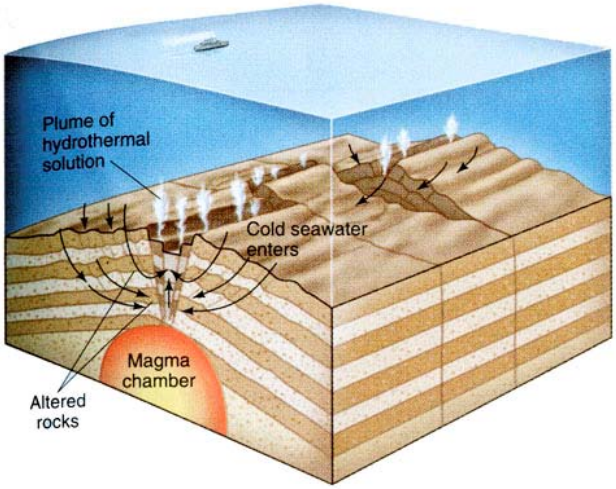
Hydrothermal Alteration and Mineral Deposits

If you thought geology was boring then you have not entered the world of hydrothermal alteration! This is where all of the fun begins. It is exciting to be able to study a process that combines so many different aspects of science. Hydrothermal alteration involves the geosphere, hydrosphere, and biosphere. It also contains geology, biology, chemistry, and even physics. Where else can you get such a wide variety of studies compress into a single specific phenomena.

Hydrothermal Alteration

Minerals can be concentrated in many ways. They can be precipitated by salts, separated by fractionation of magmas as the magma cools, they can be put in the formation of placers, and many other ways. But this report is going to talk about hydrothermal processes and its alterations.

So what exactly is a hydrothermal process? A hydrothermal process is when minerals are concentrated "by hot, aqueous solutions flowing through fractures and pore spaces in crustal rock"(Skinner, Porter, Botkin, 1995). In short, water that enters the earth's crust and flows close enough to a heat source will of course heat up, leach the nearby rocks, turn into a hydrothermal solution and rise. The hydrothermal solution rises through cracks and fractures and picks up dissolved minerals and elements on its way, therefore altering the original rock. As the solution cools on its way to the surface its re-deposits the minerals along its trail, therefore creating a vein of minerals. That is a brief introduction to hydrothermal alteration.



An example of a hydrothermal system and its circulation. From "The Blue Planet" by Brian J. Skinner (1995).

Water

It is important to realize that hydrothermal alteration does not occur just at the oceans with ocean water or just from ground water because it is already underground. The process of hydrothermal alteration can happen with any type of water. The water can come from the sea or ocean, groundwater, rivers and streams, overall surface water, metamorphic water, and even magmatic water. Now you are probably wondering how in the world does surface water get all the way down by the internal heat source to be heated. One example is when an ocean plate subducts down under a continental plate. When it does this it is saturated with seawater and takes it down underground until it gets close enough to the magma chambers and hot enough to become an aqueous solution. This is all part of the hydrothermal system.

Hydrothermal System

A hydrothermal system consists of hot liquids that travel below the earth's surface. These fluids do not travel just straight up and down, but also laterally and

diagonally. They move at different temperatures and pressures and are considered "hydrothermal activity" whether discharged or not (Pirajno, 1939). There are two parts to a hydrothermal system, 1) a heat source and 2) a fluid phase. When these are put together and begin to circulate is when the solution collects its minerals, transports them, and eventually deposits them. How close to the heat source do these fluids have to get? Hydrothermal alteration can happen anywhere between the temperatures of 50 degrees Celsius to above 500 degrees Celsius. How close would you have to be to get that hot?

Alteration in Depth

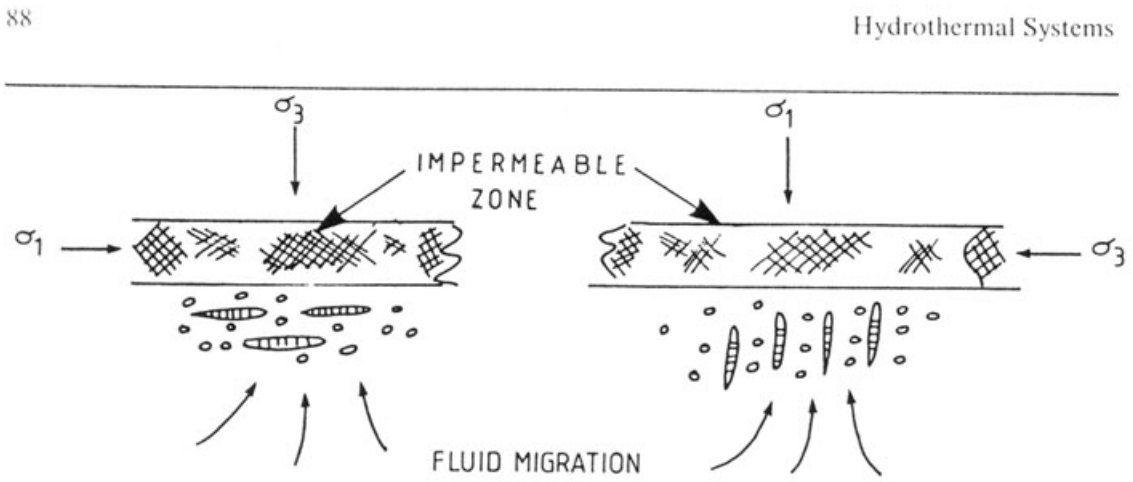
Hydrothermal alteration involves "mineralogical, chemical, and textural changes, resulting from interaction of hot aqueous fluids with rocks through which they pass"(Pirajno, 1939). Hydrothermal alteration occurs in low temperature and low-pressure settings. When one gets a mixture of gas and aqueous solution, it then invades the nearby rocks. This throws off the equilibrium of the original rock. To fix this some of the minerals in the rock take on different forms or change into totally different minerals. There, we have our alteration. This change in the minerals creates a new equilibrium that allows the rock to adjust to its new settings.

Factors of Alteration

There are many factors involved with hydrothermal alteration. A few are, the type of rock being invaded by the aqueous solution, the composition of the aqueous solution, and the concentration of chemical potential of the fluid. Other important factors are temperature, pressure, and permeability.

Some rocks are more easily invaded then others. For example, depending on the permeability of a rock, will figure into how much of the aqueous solution can actually get

into the pores and fractures. Permeability is the measure of how easily a solid allows a fluid to pass through. If a fluid can pass through easily then more of the rock will be altered and the other way around. Also remember, as the fluid moves through the rock it is collecting and re-depositing minerals. As it deposits these minerals they clog up the back trail allowing little or no other solution to pass through. This in turn will shorten the mineral vein.



An Impenetratable zone created by deposition of minerals from a hydrothermal system. Adapted from "Hydrothermal Mineral Deposits" by Franco Pirajno (1939).

Size of the Mineral Deposit

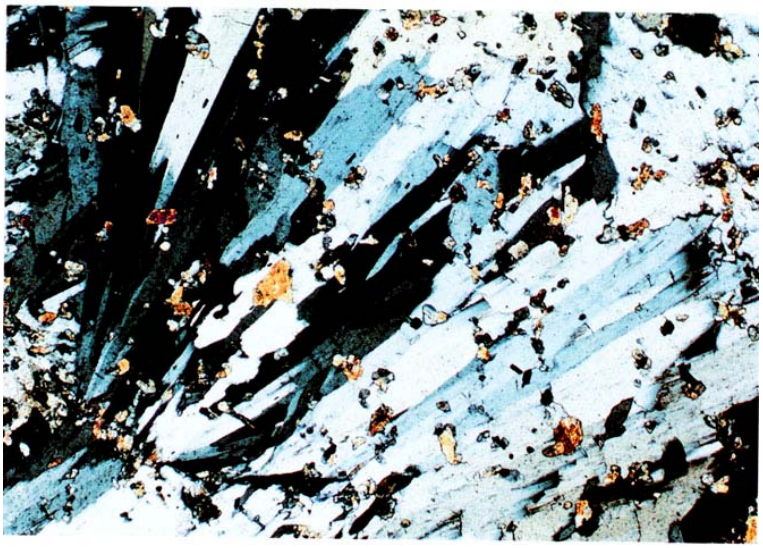
Permeability affects the size of a mineral deposit and so does the rate at which the solution cools. The slower the hydrothermal solution cools the longer the vein will be. Rapidly cooled solution will reform and crystallize the minerals quicker, therefore depositing them in a shorter area. Although this vein may be smaller, it will have a higher concentration of minerals in it than the slowly cooled vein. Other effects, such as pressure and compositional change can decide how big and/or concentrated a mineral vein is.

Economics

So what if this process is changing rocks and redistributing minerals. What's the big deal? Well, to our economy not all of it is a big deal and a lot of it they do not care about. But some of the veins created by hydrothermal alteration are comprised of valuable minerals and ore. Many of these veins are mined for gold, copper, lead, and many other valuables we use in our economy today. Mining is a huge industry and it pays to dig up valuable minerals and ore. The trouble is finding them.

Veins and Halos

The ore bodies are in fact rather difficult to find. That is why when exploring for ore it is easier to find the alteration halos that surround the ores. The difference between the ore and the surrounding rock may just be simple recrystillization or it may undergo major physical and chemical changes. It may look the same and just have change permeability. It could have change to a color that you could recognize, but what if it then got weathered and turned a totally different color?



An example of a hydrothermally altered rock. Figure from "Atlas of Alterations" edited by A.J.B. Thompson and J.F.H. Thompson (1996).

For example, clay minerals are usually white or greenish gray, when altered it may be bleached. So how do you tell the difference between the altered vein and the original rock? Instead if you look for the halo you will be able to find a more distinct difference or pattern.

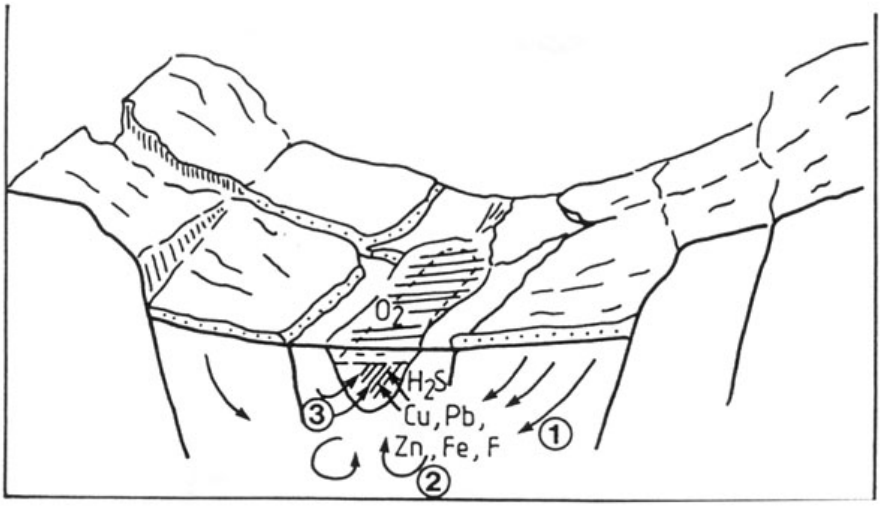
Types of Alteration

There are also different types of alteration. Alterations are generally classified by the result after alteration, not the actual alteration process. The three main types of alteration are pervasive, selectively pervasive, and non-pervasive. Pervasive alteration means that most of the original rock-forming minerals are replaced. We then work down the latter to selectively pervasive which is where alteration occurs to only a specific few minerals. And finally non-pervasive, where only certain portions of the overall rock have been altered. All three types of alteration affect the "intensity" (Pirajno, 1939) of an alteration. The intensity refers to the state of the replacement rocks and also the textural destruction of the original rock (Pirajno, 1939). All of this makes for a wonderful world of hydrothermal alteration.

Conclusion

Now we all know a little about hydrothermal alterations. They have many factors governing them including the energy source, source rock, the water, movement of the solution, and the discharge site.

We know that the ultimate source of heating is from the internal part of the earth, but that hydrothermal processes are confined to the upper lithosphere. That the water, whether from surface or ground, circulate near the heat, leaches the surrounding rocks transport the minerals and finally discharges them.

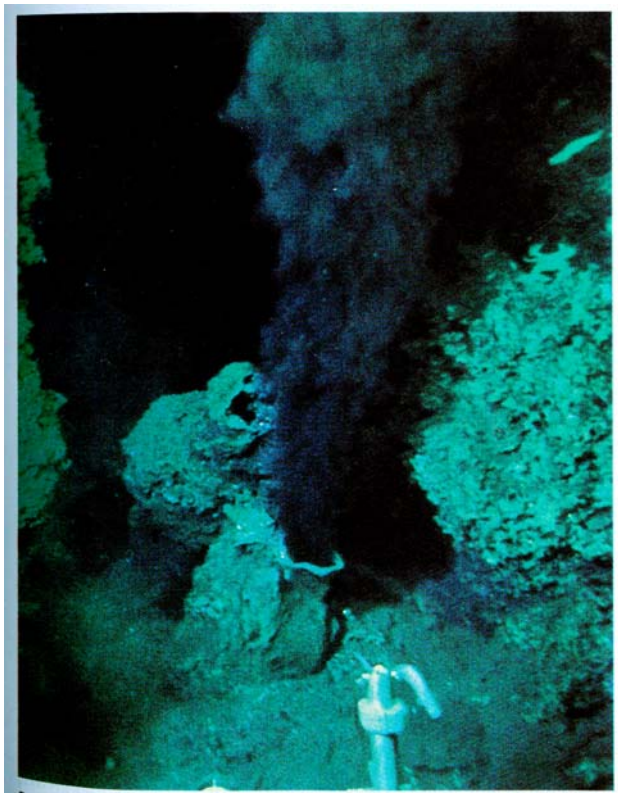


An example of mineral flow due to hydrothermal circulation. Taken from "Hydrothermal Mineral Deposits" by Franco Pirajno (1939).

The size of the depository area depends on cooling rate and permeability. It also depends on which minerals are being deposited and at what temperatures they return to their solid state. These factors also decide how concentrated an area will be or whether it will be spread out.

This all leads to the factor that deposits are sometimes hard to find and that many explorers look for "halos" that are more easily discovered. This ties in with the fact that there are different types of alteration. Alterations can be simple recrystallization, a change in permeability or a significant physical and/or chemical change.

Do not forget that ore deposits are economically important! We mine for many different valuable ores today including gold, copper, lead, etc. One can find mines all over the world. That is because hydrothermal alterations are not restricted to one part of the earth. The process can work in mountains, valleys, plains, lakes, and oceans. The can even happen down in the earth and never discharge and we will never know about them. There could be one in your backyard.



A hydrothermal discharge area located under the ocean. Taken from "The Blue Planet" by Brian J. Skinner.

As stated earlier, it does not get any better than a good old-fashioned hydrothermal alteration!