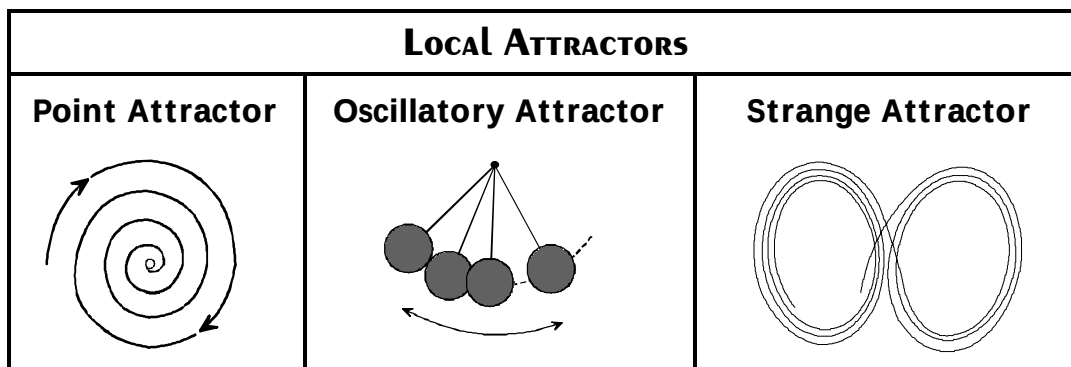


LOCAL ATTRACTORS AND EVOLUTIONARY ATTRACTORS IN THE EARTH'S EVOLUTION

Attractors are any state toward which a system naturally gravitates. Gravity is the most elemental example - a point attractor. Everything on earth is trying to get to - is attracted to - that point at the center of the earth. But, there are attractors, and there are attractors. In the Earth's evolutionary history there are two long term evolutionary attractors, each containing the same three local attractors.

Local Attractors belong in the realm of chemistry and physics. That is, those lowest energy states of chemical/physical equilibrium to which an open system spontaneously goes as it cools or loses energy to a closed system. The first two attractors are the point and oscillatory attractors.

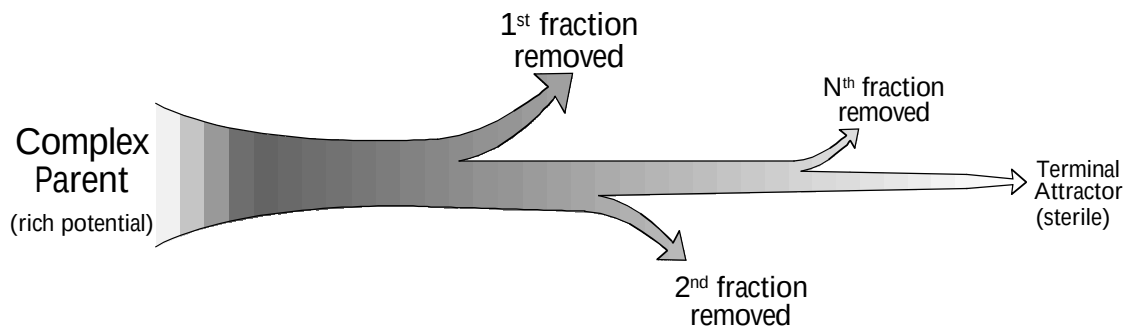
Strange attractors are the third local attractor, but strange attractors open the system to the complexity realm and under the right conditions allow it to transition to the evolutionary attractors.



Evolutionary Attractors include those states or conditions an open system spontaneously evolves toward over evolutionary time through a series of local attractor states. It is an unfolding of latent potential through increasing diversity. These evolutionary transitions take place through the behavior of strange attractor states that open the system and allow it to evolve. Two classes of evolutionary attractors exist.

Fractionating Evolutionary Attractors begin with a complex parent and successively remove - fractionate out - more and more until there is nothing left to remove, and we are left with a sterile end product. These are chemical/physical systems, and igneous and sedimentary rock evolutions are examples. The outcome of this evolution is an increasing

diversity of rocks derived from - fractionated out of - the parent. But each level of derivation is progressively more sterile than the preceding until there is nothing left to remove from the system. Finally, we have an ultimate end product, the **evolutionary attractor state** toward which the system has been drawn, which is incapable of further fractionation, and the evolutionary processes comes to an end. The outcome of these evolutionary systems is deterministic and predictable based on chemical/physical laws. That is, the final end product behaves like a point attractor in that, if the processes are allowed to run to completion, there is a known, predictable, ultimate state the system evolves toward.



Elaborating Evolutionary Attractors are those that begin relatively simple and evolve toward complexity by increasing elaboration. These are represented by biological evolution, but would involve any system that evolves by elaboration. Elaborating Evolutionary Attractors include social systems, technological evolution, political systems, and economies. Their outcomes are axiomatic and deterministic, but unpredictable.

Another example of an elaborating evolutionary attractor is the evolution of elements in stars. The universe began exceedingly simple, with only hydrogen present, but step by step new elements were/are created, and create the foundation for chemistry and the formation of compounds. And, of course, the more elements there are the more complex the chemistry becomes. The universe becomes more complex by elaboration.

Geologic Examples of Fractionating Evolutionary Attractors

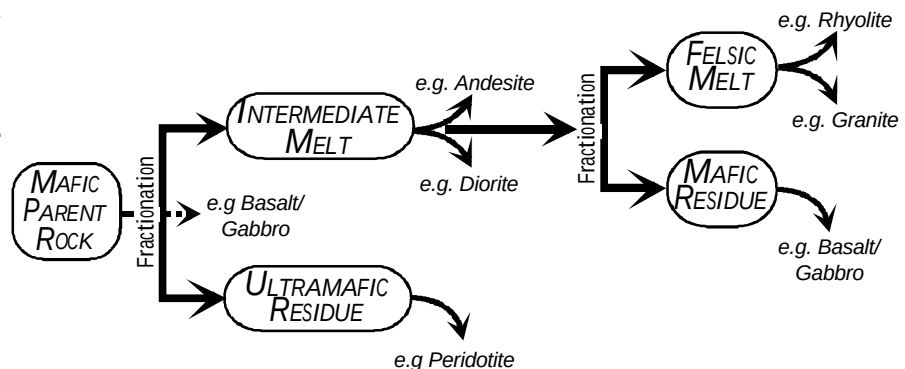
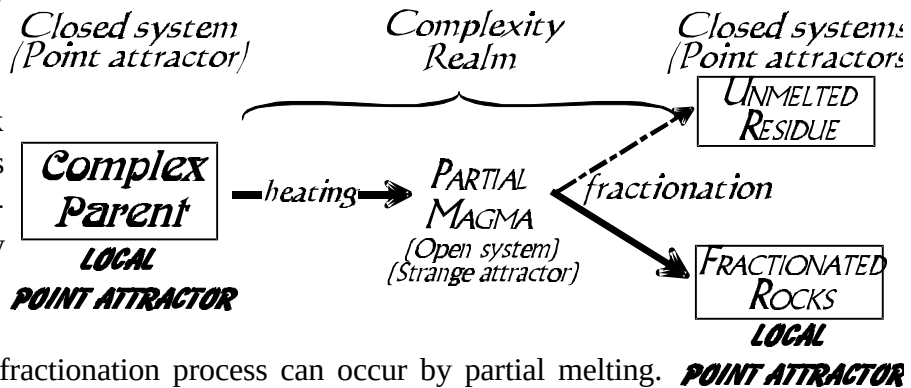
Igneous and sedimentary rock evolutions are good examples of local attractors embedded within fractionating evolutionary attractors. For igneous rocks the original parent rock is of ultramafic/mafic composition, and is the initial state (the point attractor of the initial cooling of the magma). The moon's composition represents a system arrested at this state. However, this parent rock contains all the ingredients necessary to produce all the other igneous rocks, but they must be sweated out through several stages of fractionation. In general these stages

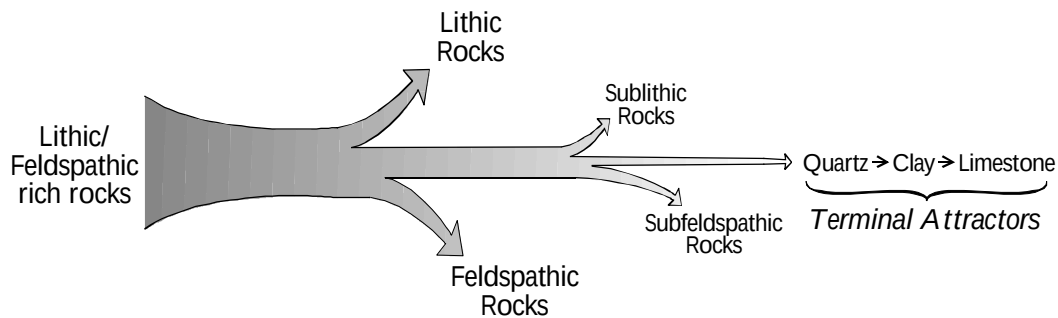
begin at the top of Bowen's Reaction Series and move down in steps through mafic, intermediate, and felsic rocks (each a point attractor) before the system comes to rest with an orthoclase-rich, quartz-poor rock like monzonite (the evolutionary attractor).

The processes by which this occurs is that the closed system of the parent rock (point attractor) is taken into the open-system realm by heating to a partial magma (strange attractor) where the fractionation process can occur by partial melting. When partially melted the system is in the complexity realm. That is, energy and information flow is high enough that lots of new combinations can form, from which a selection processes "chooses" the best for the physical/chemical conditions of the system. If, however, the system moves into the chaotic realm of complete melting then fractionation is not likely to occur. Once the fractionation is done, cooling returns the system to a closed state, but in the interim not only has the diversity of rocks increased, residues more sterile than what we began with are left behind.

Evolutionary fractionation takes place in stages by a succession of heating/cooling events which take each successive fraction into the complexity realm where the potential can unfold. Through geologic time, the system hops through a series of local attractors on its way to the evolutionary attractor. Still, this evolutionary attractor is one dominated by chemistry and physics.

We see a similar system at work in the evolution of **sedimentary rocks** where no matter what rock we begin with, by the time weathering, transportation, and sorting are done everything except quartz has been removed, or transformed into something else. The ultimate end product of these processes consist of only three end members - three attractors - quartz sand, shale, and limestone.





On a larger scale the physical earth as a whole has been a fractionating evolutionary attractor beginning with only a parent igneous rock, and without continents or ocean basins, and has evolved to all the diversity of igneous, sedimentary, and metamorphic rocks, and all the tectonic elements present today. These processes are irreversible and ultimately will continue until either the earth runs out of energy, or everything has been fractionated.

ELABORATING EVOLUTIONARY ATTRACTORS

Life is an elaborating evolutionary attractor in that it began with relatively simple organic molecules, which elaborated into more complex molecules, eventually producing protocells and cells, which speciated into multiple clades, the whole system becoming more diverse and complex through time. The outcome of these evolutionary systems is deterministic, but unpredictable. That is, increasing complexity is inevitable - axiomatic - but each level (stratified stability) of evolution is the result of a strange attractor whose outcome cannot be anticipated ahead of time.

The earth as it is today is the result of the complex interaction of fractionating and elaborating evolutionary attractors interacting in complex ways. The Gaia Theory of James Lovelock explores the nature of this interaction, arguing that without the presence of life the earth would have become evolutionarily closed very early in its history, and little or none of the elaboration that distinguishes the earth from other planets like Mars or Venus would have occurred.

