Ecological Setting-Geology, Climate, Soils, Hydrology

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Those of you as agencies or industry that work with academics (and know how we talk) are probably shuddering already because I have three topics and only 20 minutes. So, in order to keep this on track I necessarily will have to be brief. There could easily be a 50-minute discussion on any one of the three topics: geology, soils and climate. So, if you have any questions later I certainly can be contacted at the University of Wyoming.

If we look at geology in the Thunder Basin we find geological deposits that are ranging in age primarily in the Quaternary, Tertiary and Cretaceous Age. Actually they go back as early as the Cretaceous-Jurassic boundary. If I had to describe the Thunder Basin in a single sentence though, I would say that the Thunder Basin Grasslands are in the shadow of the Rocky Mountains. Literally they are in the rain shadow, and certainly the grassland is embedded in the debris that has weathered off the Rocky Mountains when they were formed. Starting with the oldest material we have the Cloverly and Morrison formations at the Cretaceous and Jurassic boundary and there actually was some dry land then in what is now Wyoming. Going into the Cretaceous, for most of the Cretaceous period, what is now Wyoming was under a large inland sea that stretched all the way from the Gulf of Mexico up into Canada.

We have a variety of marine shales laid down in that environment that have some interesting management problems. One of the things that I always try to express to my students is just how frequently simple day to day management problems such as the location of an irrigation ditch, setting a fence post, building a stock pond, are impacted by the events of millions of years ago (geological history that actually interfaces with the modern climate and biological community and so on). In the Cretaceous there are a variety of marine geologic formations laid down. I can go just a few miles west of Laramie and start finding squid fossils in the Sundance formation, which goes all the way up to southern Canada. An example (which is just typical of the marine environments) is the Mowry shale, noted for its millions of fish scales embedded in the sediments from sharks eating fish and then passing the indigestible scales off into the ocean floor.

What we see in general are inter-bedded sedimentary rocks; some with salinity and some with high sulfur contents (that as the sulfur oxidizes become quite acidic). The inter-bedding of the geology provides some variability in the environment. For most of the grasslands the geologic material near the surface is from the Tertiary Age. Indeed, it was during the Tertiary, starting about 60 million years ago with the plate tectonics that uplifted the modern Rocky Mountains, that we had this flood of debris in the form of alluvial fans coming off the uplifted Rockies that actually stripped about twenty thousand feet of sedimentary rock off the granite that you now see exposed as Laramie Peak. The Rocky Mountains have Precambrian core rocks, granites and other metamorphic rocks such as those at the crest in the Snowy Range down by Laramie. The Snowy Range crest was an ocean beach two billion years ago that has been uplifted. There was twenty thousand feet of sedimentary rocks that was eroded off the mountains and partially accumulated in the basins of Wyoming and it also spilled out onto the edges of the Great Plains. This is the material that we recognize as the Fort Union and Wasatch formations. Geologic events are very important to the history of the area in terms of providing the basis of soil formations that support the Grasslands. And also it resulted in Wyoming having the variety of mineral wealth that has contributed significantly to the history of the area. There is coal surface mining across the area and a variety of gas, oil and other mineral opportunities. Most of the surfaces that we deal with are actually surfaces that developed in Quaternary environments. Over the last 2 million years we have had continuous episodes of glaciation in the northern Rockies. There were glacial ice advances in the mountains every 100 thousand years over the last 2 million years. At this latitude, the ice didn't reach out onto the plains. I have worked on the continental till plain at the western edge of the prairie up above the Missouri River in Montana years ago and there the ice came further down into the Dakotas and further down out east on the plains. But we did have significant effect on our landscapes in the basin and Great Plains grassland areas as a result of all the glacial activity in the mountains. We had a lot of wind and we had permafrost. There was permafrost tundra throughout the high basins of Wyoming, certainly further down into Colorado, and on the eastern edge of the Plains. We had mammoths, the large form of bison, and camels running around, also long toothed cats, etc. While most of these are gone, what we are looking at now is a landscape that came into equilibrium in terms of slope gradients and thickness of solum, in an effectively cooler and wetter climate than the modern climate. So, when you see these perched valley floors as I sometimes call them, these areas represent the former level of the landscape in the glacial period. They are now being gullied by erosion and the stream channels are entrenched. A lot of this geologic erosion is the landscape basically trying to come to terms with a much drier climate (with less vegetative cover that protects the surface from erosion). Certainly the landscape is dynamic and while there are features that date back hundreds of thousands of years in the modern soil landscape, we do see evidence of change as the landscape attempts to come into equilibrium with the modern climate.

The climate that we deal with now in the Thunder Basin area is a continental climate noted for hot dry summers. We're in the rain shadow of the Rockies and this very much affects the precipitation distribution. We see that the evapotranspiration demand, the potential water which would evaporate from moist soil and which the plants could transpire, greatly exceed precipitation. It is typically three times the water that we have from precipitation, and we have cold winters. We have large cold air masses that come down out of the Arctic in the winter and usually those air masses are fairly dry.

If we look at precipitation in the region it is about 12 to 14 inches annually and about 80% of this occurs between April and September. The winter is quite dry, and in the months of December through February, there is on average 1/4 of an inch to 1/3 of an inch of precipitation monthly. There is about 30 days of snowfall, but it doesn't accumulate that much because of redistribution by the wind.

The summer average temperature over the last 50 years is 69° F with a high summer temperature around 86° F. The winter average daily temperature is 25° F with the low of 12° F, but as you all know, averages don't really tell you what you are going to have on any given day. The extremes at Dull Center, one of my favorite communities in Wyoming, run from –49° F to 111° F; it seems like any day that you are committed to a field project you are likely to run into extremes more than the average.

It 's interesting to look at the data on the frost-free season also (but this depends on what you choose to define as a frost). If you are talking about native vegetation that ends up being quite frost hardy, particularly in the fall, the hardened plants can endure temperatures below 32° F and still hang on and photosynthesize a while longer. At Dull Center again, the 32° F frost-free season over the last 20 years has averaged about 125 days. If you use 28° F as a frost, the frost-free season was about 146 days. One of the things that I am always amazed at on the Northern Plains are how the plants that do hang on and remain green after a really hard frost.

The soil scientists have divided the world soils into 12 Soil Orders. We have basically three that are extensive in the Thunder Basin grasslands. One of these orders is Mollisols; this order represents the soils of the grasslands of the world. We have a number of scientists at the University of Wyoming that have close collaborations with scientists in Mongolia and the pictures of Mongolian landscapes and those in Wyoming are very similar (unless there are camels in view). The world's grasslands soils share many common characteristics. They typically show a strong accumulation of humus below ground, and so you have a mineral surface layer that will have coatings of humus on the mineral grains giving them a dark brown or black color. I'm not talking about plant litter; I'm talking about the microbial decay product here (coatings of humus on the mineral grains). On the dry end of the plains most of our Mollisols will have significant accumulations of a white material, calcium carbonate, in the subsoil; this is a very low solubility salt.

We see in the world's grasslands a very significant infestation by rodents. One of the big differences between forest soils and soils of the grassland is the amount of below ground activity by burrowing rodents that continually mix the grassland soils. We see a weaker horizonation in the grassland soils as a result of that; that's particularly true on the dry end of the plains (I think at some point the tall grass got too tall for the prairie dogs and the gophers.) You don't see as much evidence of disruption of horizonation on the eastern edge of the Plains, but we certainly see this on the western edge of the plains. Soils that developed under a more humid climate during the glacial period are now taking on the characteristics of the drier climate with an accentuation of the effect due to soil mixing by rodents.

The rodents bring calcium carbonate and gypsum up from the subsoil, put it on the surface and start changing the chemistry of the soils significantly in that way. I worked years ago with an interagency group that looked at the prairie dog as prey bait for the black-footed ferret. In looking at the discussion of the prairie dog effect on soils (because they bring the material up and spread it near the surface), the white-tailed prairie dogs are sloppier. The black-tailed prairie dogs build little volcanoes, and you get a wider effect on simply the volume of material that is mixed by the animal physically in terms of the area that will show all the chemistry, etc.

The Aridisols are the soils of the desert. We have rather unconvincing Aridisols in Wyoming, as I have been told when showing them to people from North Africa, people from the Middle East, to Australians and Indians. On an international cold desert soils tour, we had people ask why we didn't grow wheat over much of Wyoming. I told them that we tried that and they were not seeing the landscape in the winter, that we have a very short growing season. But we do have soils that are characterized in contrast to the Mollisols with much lesser accumulation of organic matter in the surface layer. They also have subsoil carbonates and some will have gypsum and other more soluble salts near the surface. Also, some few soils will have high sodium on the soil chemical exchange complexes (negative charge sites on the clay and organic matter).

The Entisols are relatively weakly developed soils. Our Entisols typically are dry, and they will either be along the alluvial valley floors and flood plains in the region (on surfaces that are actively accumulating sediments from flooding events) or, they will be up on the shoulders of the slopes where they will be associated with the bedrock outcrops on dry south facing slopes. These are extremely weakly developed soils. It tells you something about the splitting and classifying nature of humans though- that we actually recognize 250 different official soils series which are Entisols in Wyoming. Now, Entisols are defined as soils that do not have any diagnostic soil horizons. So, if you ask me to describe an Entisol it only takes two seconds. There is not much to them but we have 250 versions of them.

We have a wide variety of geologies and that really impacts soils even into the Aridisols and the Mollisols orders. It really helps to have some knowledge of geology to understand soils, and this is very true in a dry region like Wyoming. Soils are defined by five soil-forming factors (geologic parent material, climate, biological community, topography and time). Of course in nature nothing is ever simple; these five factors all interact in thousands of combinations in any specific region.

Certainly, I would say that most recently the driving soil-forming variable on the grasslands is precipitation. Of course, this is related to the location of the grasslands in relation to the Rocky Mountains. What you will see if you look at the landscape is that the depth of the soil varies with the landscape position. Steep slopes are unstable against erosion because of the scant vegetation; and the soil rooting volume follows water distribution. If the soil were uniformly distributed like a pancake lying above the rocks across the basin, it would actually not be as efficient for plant products as the system we do have. We get precipitation on the slopes and we get run-off; snow is redistributed by the wind and accumulates in low spots of the topography. As a result, over some thousands of years of geological erosion, the soil will tend to erode off the surfaces that don't get the average amount of water because of runoff and redistribution by wind. That eroded soil material ends up accumulating on the lower third of the slope and the alluvial valley floor. This is where the runoff and snowmelt water is, and this is where the soil rooting volume ends up being thicker in proportion to the extra water. These thicker soils support more grass roots, and hence support taller and thicker stands of grass. The soils are mostly non-saline. We do have calcium carbonate that accumulates in the subsoil, but this has very low solubility. The native vegetation provides a wonderfully compensating mechanism for using precipitation; and every year soils in the prairie are pretty well dried down by the plants.

So, the following year's precipitation goes into a dry soil profile. This is where they got into trouble with saline seeps up in the Dakotas, Montana and into Canada when they starting fallowing for wheat and barley. This fallowing in alternate years allowed, for the first time in the last ten thousand years, an inch of water to move through the soil profile every (fallow) year below the root zone. When this had happened for 50 years, the accumulation resulted in development of a saline water table, which came to the surface in low areas of the grain fields. With the native prairie, when you have a high water precipitation year you get more grass growth, more forbs, more shrubs and you will always dry the profile down. So the following April when precipitation starts picking up again, it is going into a dry soil and there is an empty pore system in the soil that will absorb it and hold it there for plant use. The solids are always dried out by the end of the growing season. One thing that is important for management of these landscapes is to understand that the soils are generally not connected to the water table. We don't have that direct connection in the grasslands that exists in the mountains where excess snowmelt contributes to water table. In the grasslands, water goes into the soil and the plants evaporate it.

In terms of hydrology most of the drainages in the area are ephemeral; that is they respond to individual rainfall or snowmelt events. The relief tends to be on the order of 200 to 300 feet over most of the landscape. If you look closely, you will observe that the uplands are usually underlain by more resistant rock such as sandstone. The first time I went up into the Powder River Basin with a detailed soils map, it seemed to me that there was an awful lot of sandstone that I could see from the truck windshield compared to the clayey soils that were shown on the map. Well it turns out that you see the sandstone because it is holding up the ridges, but when you actually dig soil pits, there is a lot of clay out on the landscape that has weathered out of the shale beds. The estuary sedimentary formations that make up the Wasatch formation seem to be inter-bedded sandstones and shales and are fairly clayey soils throughout a lot of the Thunder Basin.

I don't want to get into the cultural history too much but I do want to make just one point. In the history of the northern plains from Montana to Colorado there was a major failure of an effort to transplant an agricultural system from the Midwest. This crop agriculture failure and the national grasslands system that resulted can be largely attributed to a gentleman named Hardy Campbell. He was very effective as a promoter of dry land agriculture on the west edge of the plains, helping the railroads sell off the land that they got from the U.S. government for building the railroad. He ended up having an agricultural school in Billings, Montana. If you didn't have time to get away and go there, you could take your training by correspondence. I have the 1917 edition of his agricultural manual and this is the period when people were saying that rain followed the plow. According to Hardy W. Campbell the problem that he could see with the Midwest was that they had too much water. In the Midwest, you had to cut down all of those trees before you could farm. You didn't have this problem on the plains. He said if you managed the water effectively you could grow wheat in the dust of the Plains. Well, if you look at the historic climatic data, what you will find is that in the period of homesteading from 1900 to 1915 or so, the northern Plains had greater than average summer precipitation by about 50% and almost 20% to 30% greater annual precipitation. The homesteaders really could grow wheat on a lot of the western Great Plains landscape. In 1906, they built an elevator in Laramie that was designed to load fifty thousand bushels of wheat a day onto railroad cars. Today, you just don't see the farming community that they thought they were going to be able to have back then. The climate went back to "normal".

Going back into the Pleistocene, there was even a more dramatic and significant change in climate. Most of the landscape that is out there today in the Thunder Basin is very predictable in terms of modern climates, snow redistribution rates and so on. You do have continual indications that it is changing and coming into equilibrium with climatic conditions over the past ten thousand years and that is a factor in terms of interpreting the soils and plants in the Basin, interpreting the effects of rodents, grazing, etc.

That’s my 20-minute summary of soils, geology, and climate. I would be happy to fill in details and provide references if you have questions. I don’t know if you have time for questions now or want to wait until later. The best way to contact me is probably email.