Pedogenesis of gypsum soils from gypseous materials

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Abstract
This paper focuses on the pedogenesis of soils which have formed in the Permian Castile formation; a deep water evaporite deposit constituted of varved gypsum and calcite. Soils selected for study were located in Culberson and Hudspeth counties in West Texas and formed from gypsic bedrock (Permian, Castile Formation). Thin sections, SEM analysis, XRD, along with features observable in hand specimen were utilized in order to ascertain the processes of formation. Preliminary analysis of thin sections showed an alteration of the crystal structure and habit from the parent material, which appears to undergo a discernible series of changes as pedogenesis progresses. For soils forming on the Castile Formation, the dissolution of interlocking crystals and the formation of lenticular gypsum crystals, which are commonly associated with pedogenic processes, were observed to occur in soils that had greater degrees of pedogenesis.

Past work by researchers in Spain and the United States has attempted to correctly classify and identify gypsum in soils and geologic materials. Previous research has shown that gypsum can be estimated using specific criterion in the field and by utilizing proper laboratory methodology. However, experience has shown that many researchers continue to handle samples and materials in a manner which leads to erroneous data or costly mistakes. Thus it is vitally important to understand the proper handling procedures in the laboratory and the proper field methods for identification and application. It is also very important to know the pedogenic processes and geologic process which gypsum materials undergo.

Introduction
Gypsum in soils and geologic materials has been studied by many scientists for a wide array of purposes. It is found in both geologic material and soils and is utilized in many different ways. The correct identification and distinction of gypsum from other materials is important for understanding potential uses and limitations. Misidentification can lead to many problems including the misclassification of plants; improper land use; failure of engineered structures; and many other problems. In spite of the necessity of correctly identifying and understanding the properties of gypsum, there remain many hurdles to the proper identification, classification, and utilization of gypsum bearing materials. In soils, the recognition of pedogenic gypsum from geologic gypsum in parent materials, which are predominantly gypsum, can prove extremely difficult or impossible in the field.

This study aims to focus on the pedogenesis of gypsum soils that form in gypsum rich parent materials in order to determine the processes and morphological features that would aid in the correct identification and utilization of gypsum soils. Soils were selected that formed on the Permian-aged Castile formation; a varved, deep water evaporite consisting of greater than 95% gypsum and containing minor components of calcite and miniscule amounts of silicate minerals. The residual formation of soils on the Castile gypsum appears to be occurring as the original material is weathered in situ and to secondary products, chiefly pedogenic gypsum. Distinguishing secondary gypsum from primary gypsum has been difficult for other researchers working with different parent materials, but the morphology of the Castile formation gypsum allows for a more easy determination of secondary gypsum to be made. This distinction is easier due to the very apparent varves, interlocking crystals, and relatively low porosity of the Castile formation (Figure 1).

Methods
Pedons were selected are thought to represent a series of soils in varying stages of pedogenic development. At this point in the project there are no quantifiable constraints on age, but depth to bedrock, horizonation, and silicate accumulation serve as proxies for the determination of length of time of soil development. Soils with a greater depth to bedrock, have a greater number of horizons, have horizons that are more fully developed, or have a greater amount of silicate material overlying the gypsum soil material are considered to be more well developed than those that have a shallow depth to bedrock, few horizons, poorly developed horizonation, or no veneer of silicate material. Sites used in this paper were located in Culberson County in West Texas, USA, southwest of Texas Tech University, which is located in Lubbock, Texas and northwest of Pecos County where further research sites may be located (Figure 2).

Soil mineralogy and morphology was determined using thin sections, SEM, and XRD techniques. The relatively high solubility of the gypsum necessitated special care during the preparation of the thin sections to ensure that dissolution of the original soil fabric did not occur. Oil was used when cutting the soil peds and for the grinding of the final thin section to the appropriate thickness. Thin section slides were then examined using a Nikon Eclipse LV100POL polarizing light microscope equipped with a digital camera and monitor. Soils were prepared for the XRD by first being ground to pass a 60 mesh sieve (>.250 mm) and then were placed onto discs for analysis. Soil samples were analyzed on XRD equipment at Texas A&M University in the Soil Mineralogy Lab. Samples were scanned from 4 to 70˚ 2 θ with a step size of 0.017˚ with a scan time of one second for each step. Care was taken when placing the samples into the disks to ensure that the surface was uniformly prepared so as to ensure a random orientation of the soil particles. Soil bulk density, cation exchange capacity, electrical conductivity, calcium carbonate equivalent, and gypsum content were determined by the USDA-NRCS national characterization laboratory in Lincoln, Nebraska, USA using their standard analytical procedures.

Results

Soil thin section analysis showed a progressive dissolution and reprecipitation of gypsum from the parent material and the soil profile. Gypsum material appeared to have been reworked numerous times and was evident in the thin sections (Figure 3). SEM images showed the dissolution that was occurring along crystal planes in the Castile formation and the subsequent formation of lenticular gypsum crystals (Figure 4). XRD analysis showed a change in the mineral assemblages according to the depth in the soil profile. Soil chemical data determined that most of the nutrient availability for these soils was derived from the silicate material which has accumulated above the highly gypsiferous material. This was easily observable in the field as well where soil productivity is easily correlated to the depth of silicate material at the surface.

Conclusions

Soil formation from highly gypsiferous parent materials such as the Castile formation shows a discernible progression of alteration of the original material to secondary pedogenic products. The rates of formation were not calculated from this study, but a set of dissolution and reprecipitation could be discerned. The original rock fabric first undergoes a dissolution process in which porosity increases and secondary crystals are reprecipitated in voids. Next an innumerable and unknown set of dissolution and reprecipitation cycles advances the weathering of the parent material until a soil texture resembling flour results. This flour-like material then appears to become denser and more tightly packed until a petrogypsic horizon is formed. The petrogypsic horizon does not appear to be a result of cementation of materials together but instead seems to result from a closest packing arrangement of the soil (gypsum) particles.

Figure 1. Varves in the Permian Castile formation are very apparent as the alternating light and dark bands in hand specimen and as the brownish band running horizontally in the inset photo.

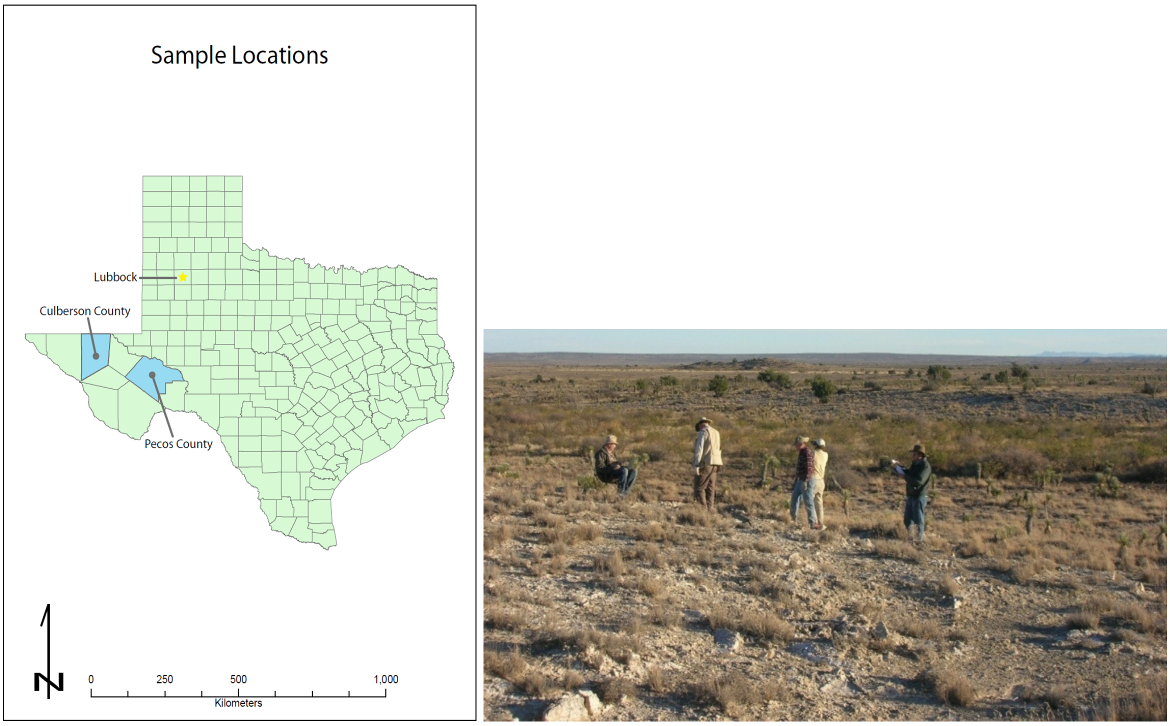

Figure 2. Sites for this study were located in Culberson County on what is locally referred to as the gypsum plain. The photo on the right shows the topography and plant cover typical of the area.

Figure 3. This thin section was taken from a gypsic horizon (10-20 cm depth) and shows a lenticular gypsum crystal, which is disintegrating as a result of pedogenic processes (arrow).

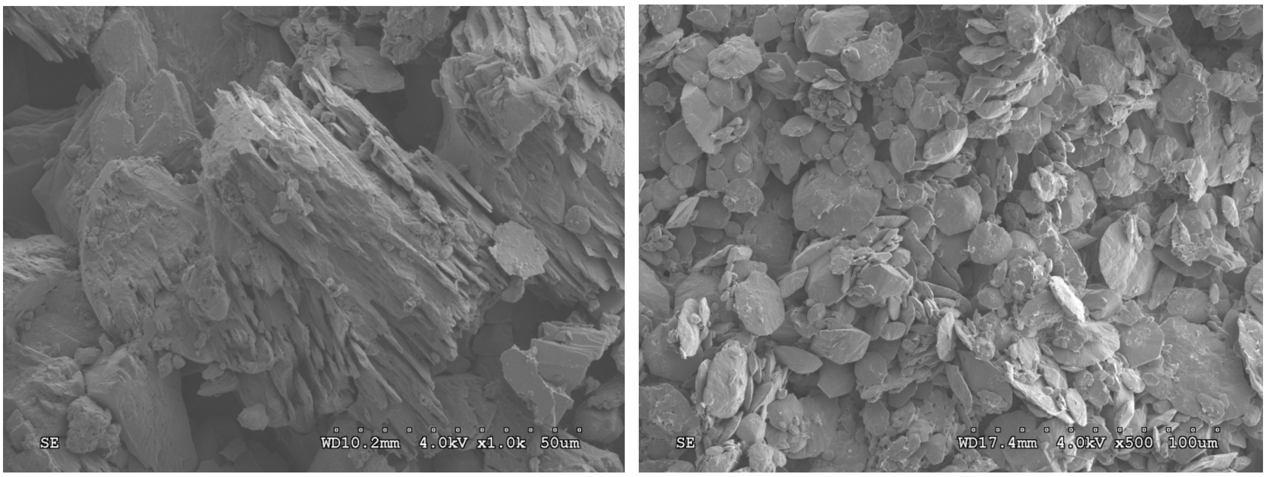

Figure 4. The image on the left clearly shows the dissolution of the original interlocking fabric of the Castile formation gypsum material. The image on the right shows the lenticular gypsum crystals which are commonly associated with pedogenic formation.