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Carbonate Concretions in the Karlicher Loess Profile, Rheinland[1]

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Abstract. A loess profile near the town of Kärlich in the Rheinland of Western Germany contains various forms of carbonate which are described in detail. A systematic relationship concerning a transition from finely divided grains of carbonate to large complex concretions is given. The stratigraphic presence of three distinct zones of carbonate concretions and the results of analysis for carbonate content in the entire profile are presented as additional evidence for a ternary (and possibly a quaternary) climatic differentiation of the most recent glacial stage in the Middle Rhein region.

". . . Through infiltration of CO_2-rich rain water a process of decarbonation and thereby also a formation of loam occurs in the upper soil zone: Lössloam (from the brown color). Lower in the profile the carbonate is precipitated in the form of bizarre concretions, *Lösskindeln* (*Lösspuppen, Lössmännchen*). Such climatically induced Lössloam horizons can often be recognized as interglacial soil formation horizons. . . ." (Beringer and Murawski, 1957, p. 105)

Two suggestions have been advanced as to the origin of carbonates in loess, one that the carbonate was deposited along with other loess grains and the other that the carbonates are the product of weathering of feldspars, etc. Although the latter suggestion may seem plausible, it could not account for all of the carbonates often found. In addition, German loesses located near the Alps or Dolomites have a higher carbonate content than those in Middle Europe. Loesses in the Kaiserstuhl area are reported to contain around 40 percent carbonate whereas loesses in Middle Europe have about 15 percent to 25 percent carbonate. This would point to the fact that calcareous material from the Alps and Dolomites has influenced the carbonate content of the loess deposited in southern Germany. A. Scheidig (1934) gives an average value of between 10 percent and 25 percent.

Carbonate-free loesses reported in Greenland are very friable and lack any definite structure (Scheidig, p. 74). The structure of loess,

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and especially the characteristic to maintain vertical walls, may be in some way influenced by the presence of carbonates.

Carbonates in loess range from a fine-grained whitish powder to extremely thick agglomerated beds extending over a large area. The latter have been reported in the Pampas of South America and are known as "Toska-Beds" (Scheidig, p. 79). Normally, however, carbonates are most prominent as small nodules or concretions often called "loess kindeln" or "loess puppen," because of the frequent doll-like shape. These are usually spherical, also lumpy or knobby, and may be scattered irregularly throughout the loess profile or form definite zones.

Two main factors are involved in a change of carbonate content in a profile. These are leaching, with attendant solution of carbonates, and the forming of carbonate concretions.

Geographic Location of the Karlicher Profile

An interesting carbonate-rich profile is in a quarry on the upland rim of the Neuwieder Basin near the town of Kärlich in Western Germany, about two miles northwest of the city of Koblenz (latitude 50°24′; longitude 7°28′). The quarry surface is at an elevation of 201.1 meters. The river Rhein which flows nearby has an elevation of about 67 meters. The average annual precipitation for the neighboring town of Andernach over a thirty year period is 603 mm., and the mean annual temperature is 9.3° C (Quiring, 1936).

The quarry wall exposes 41 meters of sediment. The stratigraphic sequence supplemented by borings is as follows:

0 – 10.6 meters	Würm (Wisconsin) loess, interlayered with volcanic tuffs and carbonate concretion zones
10.6 – 25.5 meters	Riss (Illinoian) loess, stratified, probably redeposited
25.5 – 36.5 meters	Hauptterrasse (main terrace gravels) from the Rhein river
36.5 – 70.5 meters	Interlayered Tertiary clays and volcanic tuffs
+70.5 meters	Bedrock of the Reinische Schiefergebirge (Devonian Graywacke and Schist)

The Würm loess here is separated into three layers. To avoid confusion, the loesses are designated as Würm I, II and III, with I being the deepest loess layer and III the uppermost (Figure 1).

The Presence and Forms of Carbonate

The various forms of carbonate which occur in the Kärlicher loess profile may be classified as follows:

powder

cylinders
 open
 closed
concretions
 single-spherical
 complex-spherical
Toska-similar beds[4]

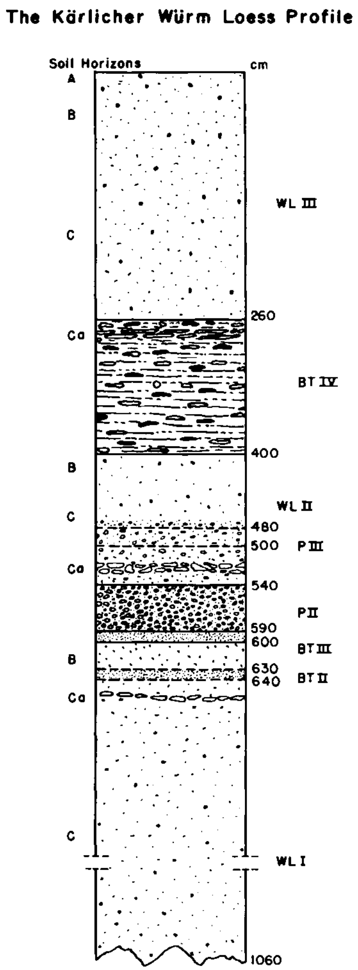

Figure 1. The Kärlicher Würm loess profile. WL = Würm loess; BT = Basalt tuff; P = pumice. The Roman numerals refer to the original stratigraphic sequence in the entire Kärlicher profile.

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[4]The scale on all photographs illustrating the carbonate concretions is divided into 0.5 mm units.

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A wall of loess which has been left undisturbed for some time has a whitish coating. Through the processes of solution, capillarity, and desiccation, carbonate effloresces on the surface.

A clod of unweathered loess shows small irregular seams of whitish powdery carbonate on a freshly broken surface. These seams frequently line old root channels and shrinkage or frost cracks (Figure 2). This form of carbonate is found in all unweathered loess of the Kärlicher profile. The reaction with hydrochloric acid is a strong effervescence.

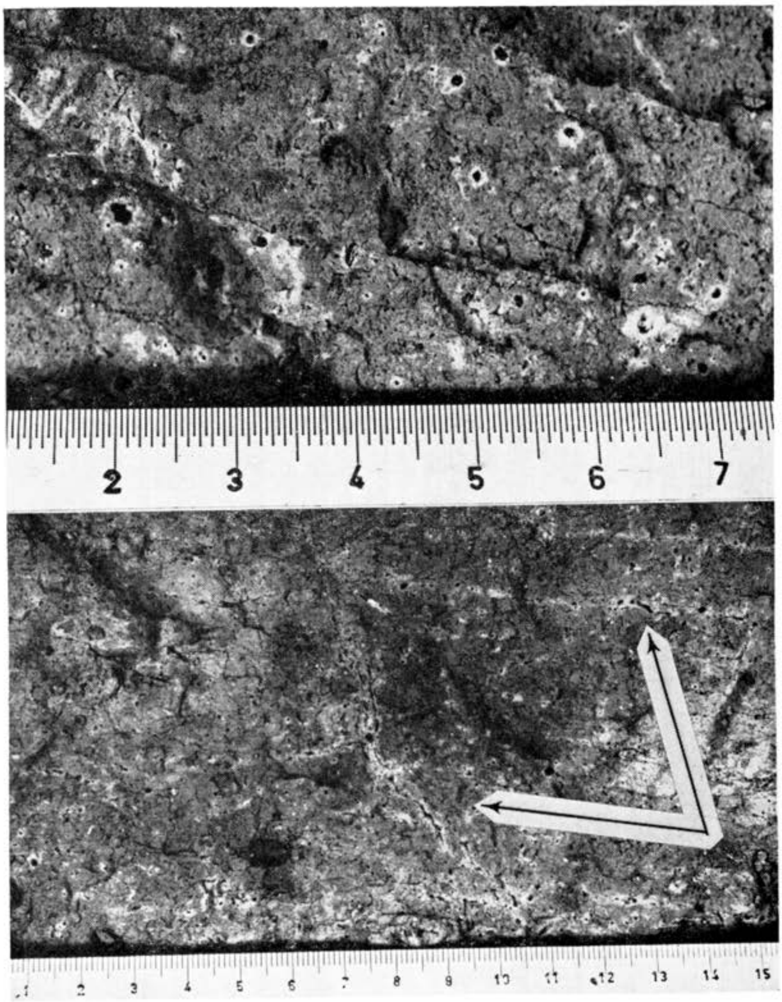

Figure 2. (Above) A top view of a loess fragment taken at 500 cm. depth. (Below) A side view of the same fragment. Note the whitish carbonate lining in the slanting root channel; also the horizontal carbonate lining.

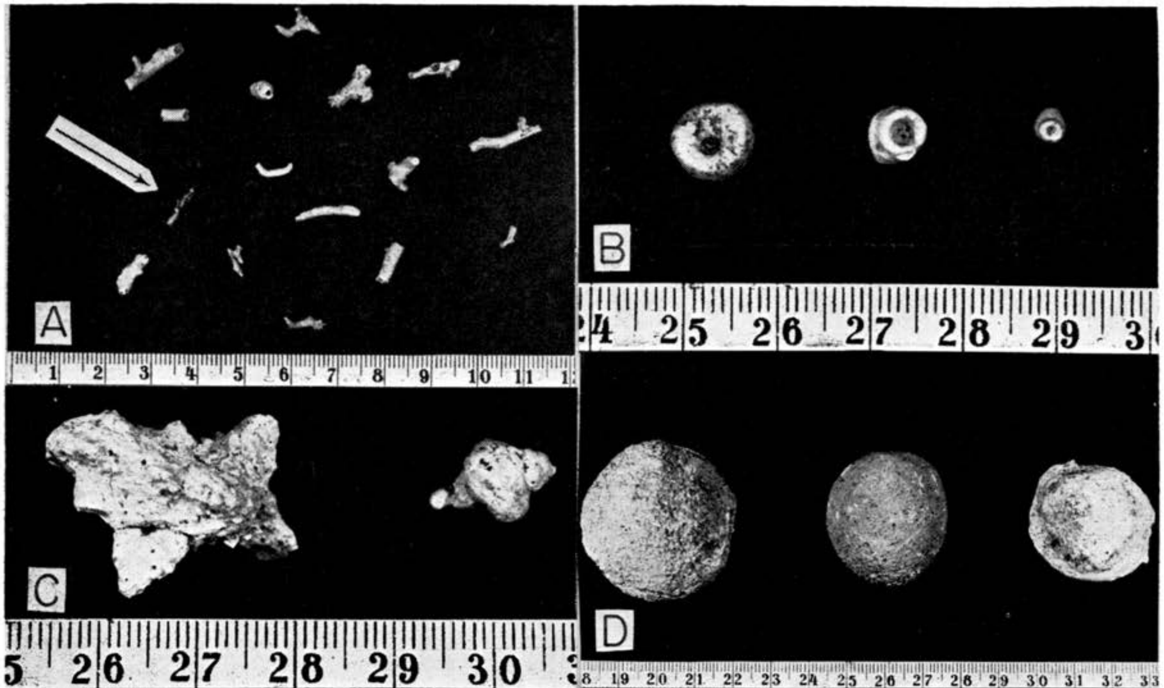

Figure 3. A. Open carbonate cylinders found in the Würm loess. Note the protuberances and the minute holes on the tip of each protuberance. At left center is a decayed root partially lined with carbonate. B. A vertical view of closed carbonate cylinders. C. Potbellied carbonate concretions. D. Single spherical carbonate concretions.

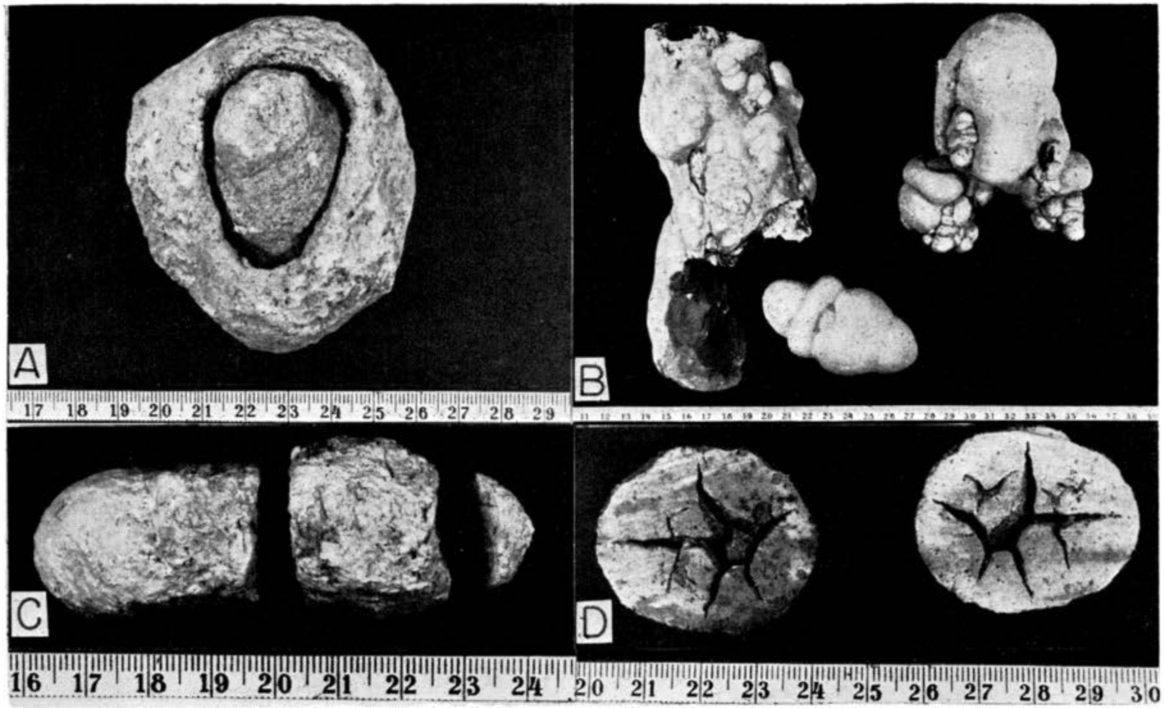

Figure 4. A. A single spherical carbonate concretion displaying a type of annual growth or weathering. B. Complex spherical carbonate concretions. These are by far much smaller than those normally found in the Kärlicher Würm loess profile. C. An example of the joined variant in carbonate concretions. The specimen was found with its longest axis vertical in the profile—blunt end upward. D. Shrinkage cracks in carbonate concretions.

Carbonate is also found as small cylinders (Figure 3A). Since these cylinders are extremely fragile, wet sieving was the best method for obtaining specimens. Old root channels probably served as the waterways for percolating, carbonate-rich water, since the branching of these cylinders seems much like that of a root. Very small protuberances are located on the outer side of these cylinders, and the tip of each protuberance has a very minute hole. As a rule, the inner walls are white in color and the outer surface a straw-yellow.

Very small cylinders are hollow; larger ones are closed or plugged (Figure 3B). Often such clogged cylinders resemble a miniature thimble.

Another variant of this group also is cylindrical but appears to have a potbelly (Figure 3C). As the old root channel becomes plugged with carbonate and clay, the carbonate-rich waters are directed laterally and the carbonate tends to form a ring around the cylinder to give it a potbellied appearance.

The single spherical type of concretion may range in size from a few millimeters up to 80 mm. or more in diameter (Figure 3D). Occasionally such concretions show a type of annular growth or weathering (Figure 4A).

The complex spherical concretions are closely related in appearance to the single spherical. These concretions appear to be aggregates or conglomerations of single spherical concretions with a gradual and smooth transition from one concretion to the other (Figure 4B). These are by far the most frequently occurring type of concretion in the Kärlicher profile. The number of nodules comprising one of these complex concretions appears to be limitless.

A related variety may be termed the jointed type (Figure 4C). The individual concretions are loosely cemented together, and may easily be separated. The joint is usually convex/concave with the bottom side of each unit concave. Particularly interesting is the fact that the joint-plane is always parallel to the ground surface; a joint vertical to the ground surface has not been observed. On the underside of large flattened concretions, cone-like protuberances, much like stalactites, are often found.

The last main type of carbonate concretion was found in the Riss (Illinoian) loess. The section in which it was found had been subjected to severe local tectonic disturbances, and this may account for its presence. The zone observed was not made up of individual concretions, but was continuous horizontally. A maximum thickness of 50 cm. and horizontal distribution of 10 to 15 meters was observed. This bed of carbonate accumulation was so dense that quarrying operations required the use of dynamite. At the time of observation these carbonate Toska-similar beds were found in the lower part of the Riss loess. The upper portion of this bed consisted of cemented lenses of gravel and sand; the lower part was of cemented loess grains.

The occurrence of various forms of carbonate accumulations suggests a systematic relationship, i.e., a transition from finely-divided grains of carbonate to the complex concretions. The sequence may be as follows: dissolved carbonate percolates through old root channels, and slowly forms small open cylinders. As precipitation continues, the cylinders close and assume a potbellied appearance. This process of growth continues, forming at first a single spherical concretion and later on an integration of several concretions. The result is the complex spherical type. The Toska-similar bed is an extreme form of carbonate accumulation.

Almost all larger concretions display shrinkage cracks on the inside, possibly because percolating waters contain not only dissolved carbonate, but also colloidal clay which, upon drying, shrinks together (Figure 4D).

Horizontal Distribution. The stratigraphic occurrence of carbonate concretions in the younger Würm loess is very constant with relation to the top of each specific loess horizon. However, in the Riss loess one particular carbonate zone splits into two definite zones, each separated vertically by about two meters. The carbonate zones in the older loess also are not continuous horizontally, as is true in the Würm loess. It was found by tracing the horizontal course of these concretions that they gradually disappeared, i.e., their size and occurrence diminished.

Vertical Distribution. In the Kärlicher Würm loess profile there are three definite zones of carbonate accumulation:

at 280-290 cm. depth in Basalt Tuff IV
at 510-530 cm. depth in WL II
at 650-660 cm. depth in WL I

The concretions found in these zones were primarily of the single and complex spherical types.

Samples of the Würm loess were taken, and soil passing a 2 mm. sieve was analyzed for carbonate content using 19 percent C.P. HCl and a double-chamber glass reaction vessel connected to a mercury manometer. The results obtained gave the percent by weight within a statistical error of $\pm$ 0.2 percent. Since the material analyzed obviously excluded carbonate concretions as such, percentage of carbonate has no definite connection with any zone of carbonate accumulation (Figure 5). The average percentage of carbonates present in all three loesses is 11.9 percent.

Carbonate analysis of the extreme lower part of WL I indicates

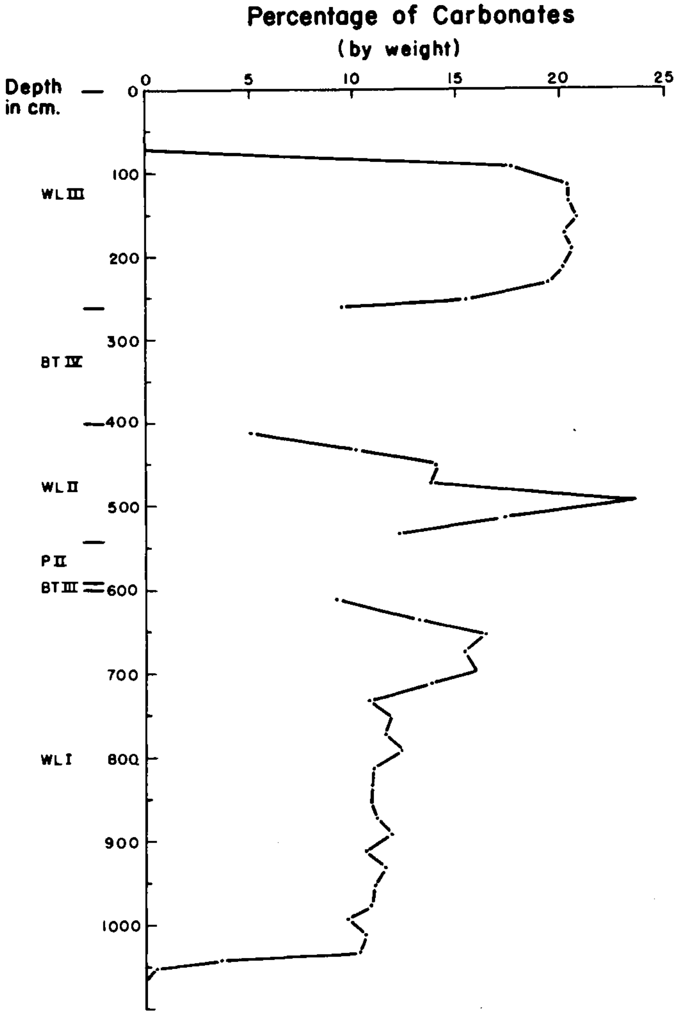

Figure 5. Percentage by weight of carbonate in the Kärlicher Würm loess profile.

either that the loess deposited here was almost free of carbonate, or mixing with the weathered surface of the Riss loess occurred. Between 730 cm. and 1030 cm. the percentage of carbonate oscillates around 11.0 percent. The upper part of WL I shows a leaching of carbonate with subsequent accumulation farther downward in the profile. Grain size analysis and field observations indicate that WL I is truncated.

The carbonate content at the base of WL II being higher than in the upper part of WL I indicates that fresh, unweathered loess was deposited at the beginning of WL II. Soil formation with accompanying leaching of carbonate is clearly seen at the top of WL II. Again grain size analysis and field observations substantiate this. The unusually high percentage of carbonate at 490 cm. depth is due to the presence here of a very coarse-grained pumice layer with few grains less than 2 mm. in size.

The base of WL III exhibits the same phenomena as the base of WL II, since the carbonate content is higher than in the loess below it. The interpretation given to the base of WL II is applicable here also. The absence of carbonates in WL III to a depth of 70 cm. is obviously due to the long period of weathering which also resulted in a "Braunerde" or a Brown Forest-similar type soil with a well-developed ABC profile. It is believed that the reason for the carbonate accumulation zone attributable to weathering of WL III being found so deeply in the profile (at 280-290 cm. depth in Basalt Tuff IV) is that the interstadial (the European Alleröd, or the North-American Two Creek substage plus the long interglacial since then) has moved the carbonate deeper into the profile.

Microscopic Analysis. Several thin sections of some of the more typical carbonate concretions were prepared and studied under the petrographic microscope.

In a typical cross-section of a carbonate cylinder numerous small channels were observed along with the main and somewhat larger channel. All channels are lined with grains of carbonate which have no good crystal form.

Grains of carbonate also line the cracks present in the other concretions. Not infrequently an opaque substance, perhaps iron and/or manganese oxides, also lines these cracks.

Striking is the fact that the grains of carbonate are always rounded. This is interpreted as indicating that crystallization and re-solution alternate continually, but that conditions necessary for complete crystallization are not reached.

Discussion

Within the past few years European pedologists, mineralogists, and geologists have presented tenable evidence that the last glacial period can be differentiated into climatic variations. Therefore each glacial stage may be broken up into "interstadial" and "stadial" substages. The interstadial is defined as ". . . a relatively short warm period between two colder periods within one glacial stage. . . ." (Beringer and Murawski, 1957, p. 85). The colder periods are referred to as stadials.

In 1919 W. Soergel advanced the theory that it was possible to differentiate the Würm glaciation. Recently E. Mückenhausen (1954) has found pedologic evidence in support, and P. Woldstedt (1955, 1956) has presented more evidence in support of a climatic differentiation of the youngest glaciation. This last evidence was based on a study of European fauna, flora, and paleolithic cultures.

Recently petrologic studies have been conducted which indicate that the Middle Rhein region has been subjected at least four times to climatic conditions favorable to loess deposition (Rosauer, 1957). This conclusion was based on the stratigraphic occurrence of various frost forms and paleosols and the specific mineralogic composition of the Kärlicher Würm loess profile.

That each of the Würm loess horizons can account for a definite zone of carbonate accumulation adds additional evidence supporting a climatic differentiation of the Würm loess in Europe. The stratigraphic distribution of carbonates in the Kärlicher Würm loess profile indicates three (and possibly four) periods of loess deposition and subsequent weathering.

Conclusion

The Kärlicher Würm loess profile presents evidence for substantiating a climatic differentiation of the most recent glacial stage in the Middle Rhein region. The definite zone of carbonate accumulation below a leached zone in each of the three loesses is interpreted as indicating interstadial weathering.

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