THE ORIGIN OF LOESS

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The evidence of astronomy favours the conclusion that the sun during past ages has been a nova at least on a small scale, as Harlow Shapley of Harvard University has urged. A French scientist, E. Belot, in 1923 also put forth the view that all stars including the sun have been novae. If the sun has been a nova at any time recent, there should be, because of the immense amount of material thrown off, evidence of it in meteoritic deposits on the earth in considerable amount. There is one geological formation that has never been satisfactorily explained, that of loess. The favoured explanations are that it is of eolian origin or else that it is an aqueous deposit. One writer, Philip J. Le Riche, thinks that it is of volcanic origin.

Loess of the type known as sub-aerial has one outstanding characteristic; it possesses what may be called vertical stratification due to the presence in the material of a great many very fine hollow tubes, lined with carbonate of lime, which are approximately perpendicular. The ground-mass of the formation consists largely of rock-forming silicates in which quartz predominates. The particles are sharply angular, showing practically no traces of rounded edges, and in addition the particles are remarkably uniform in size, being finer than sand but on the other hand coarser than fine rock flour such as occurs in glacial till or boulder clay. Pleistocene loess is very widely distributed in the North Temperate Zone in North America, in Europe and in Asia; the Chinese deposits are especially important, being as much as 1,500 feet thick in places. There are also formations belonging to still earlier periods, those in South America known as Pampean or Patagonian loess being important.

Because of its disregard of contour lines Chinese loess is generally accepted as constituting an eolian deposit, but no one has yet shown how this material could be wind-borne from possibly Gobi desert to Shantung province without showing the usual evidence of trituration. Geologists are agreed that wind action does have this effect and, unless some special conditions can be proved to exist under which wind-borne material shows no sign of wear, the sharply angular particles of loess are conclusive evidence that it is not an eolian formation.

In the loess along the Missouri river near Council Bluffs, Iowa, the formation is about 50 feet thick in some places near the river, while 30 miles to the eastward the formation almost vanishes. American geologists urge that the formation there consists of material picked up by the wind from the glacial flood plain of the Missouri. It has been shown by Hobbs that the prevailing winds along glaciated regions are away from the centre of the glaciated area. Then the thick part of the deposit should be, according to experience with wind formations, on the lee side and away from the river, just the opposite of what the conditions actually are.

If loess is a meteoritic deposit, according to the viewpoint here urged, it would still be subject to air currents in its descent to the earth. If an anticyclone existed along the river, the principal deposits would occur near the river. The larger deposit should also occur on the eastern bank rather than the western, this reasoning being based on the assumption that the general drift of the meteoric material at the higher altitudes is from west to east on account of the rotation of the earth. Loess deposits usually are larger on the eastern banks of the large American rivers.

The hollow tubes, lined with calcium carbonate, in loess have never been satisfactorily explained. It is true that many texts suggest that they may have been caused by the roots of plants that formerly grew in the material —this suggestion being made despite the fact that no vegetable remains have ever been found in the tubes. No one has attempted to explain how the hypothetical plants segregated the carbonate of lime from the rest of the material and, of course, the whole proposition is rather fantastic.

The problem of the tubing is really one of chemistry. In the first place if the original material upon deposit contained calcium carbonate, it would act as a cement to bind the material together like the eolianites (eolian rocks) of Bermuda. This would occur because rain water, percolating downward, would not segregate the calcium carbonate which is relatively insoluble except in the presence of carbonic acid in the water, and in the latter case the end product is calcium bicarbonate instead of a carbonate.

If the original material were meteoric, it would probably contain calcium oxide in some amount. Meteorites by their composition show themselves to have been formed in an atmosphere relatively free of oxygen and water. The sun's spectrogram contains strong calcium lines and it is likely that any unusually great amount of material thrown off by the sun would contain more than usual amounts of calcium from the deeper layers of the sun, especially from the parts of the sun known as the chromosphere and reversing layers. Calcium oxide is readily soluble in water, forming calcium hydroxide. In solution this latter product absorbs carbon dioxide which in the form of carbonic acid is normally present in rain water, having been taken directly from the atmosphere, and thereupon precipitates calcium carbonate. The formation of the hollow tubes, approximately vertical but with some ramification and lined with calcium carbonate, in loess by the agency of descending rain water is readily understood if we grant the presence of calcium oxide in the original material.

Chemical compounds are usually limited as to conditions permitting their formation and in this instance it is not clear how it is chemically possible to obtain the segregation of the calcium carbonate in the tubes except under the conditions suggested. If the original material contained calcium oxide, then that material could have been either volcanic or meteoric since calcium oxide (or unslacked lime) does not normally occur in earthy combinations except those that have recently been through a burning process. Lack of characteristic volcanic products further limits the material to a meteoritic origin.

It may also be noted that there is an absence of cross-bedding in loess. In typical eolian and aqueous deposits there is always a certain amount of horizontal lamination and cross-bedding due to uneven rates of deposit and also to shifts in the direction of wind or water currents. Usually there is also evidence of a sifting process, heavier materials being deposited first and nearest the source of the material and the finer materials further away. There are, however, certain parting planes at which occur numerous loess-mannikins (or stone-ginger as the Chinese call them), sometimes a few feet apart but generally more than 50 feet and sometimes several hundred feet apart. These planes are not now usually considered by geologists to represent genuine planes of stratification. Loess undoubtedly lacks the usual characteristics of true eolian or aqueous deposits, and in the absence of further explanation we can scarcely refuse a consideration of other possible origin.

What are the objections to a meteoritic origin for loess? In a personal communication Dr. C. C. Wylie, an authority on meteors at the University of Iowa, suggested that the proportion of quartz in loess did not point towards meteoritic matter and that the uneven distribution of loess was also an objection. Most astronomers favour an even distribution over the earth for meteoritic matter that falls to its surface. The actual data as to meteorites show them to be decidedly uneven in distribution. It is also just as well to remember that the law of gravitation is only an approximation so far as the actual evidence is concerned; probably it represents a mathematical system of limits. Likewise the assumed isotropy of space is based upon Newton's laws rather than on facts. We really have a very poor basis for the deduction that meteors are governed merely by chance as to what part of the earth they strike; it seems much better to stick to Newton's fourth rule of reasoning (which the writer calls the Law of Preferred Induction) and let the actual data decide the matter, according to which meteoritic matter would not be evenly distributed over the earth.

The occurrence of quartz in meteorites is rather rare, but there are examples of it and also of tridymite. Stony meteorites contain a great deal of chondritic material, usually olivine or some other silicate, so formed as to suggest that the original chondrules (very small stony spheres) were suddenly congealed from "drops of fiery rain." This may be the normal result of material thrown off from the sun at the present time. If the amount of the material ejected from the sun were far greater, as for example might be the case in the nova stage, the temperature of the material might be maintained high enough (between 90 degrees and 600 degrees C.) to metamorphose the silica into quartz. At a higher temperature the same material might have become tridymite, and at a still higher temperature it might have given us cristobalite of which latter there is no known sample among meteorites.

The finely splintered material of loess has not yet been accounted for under any explanation of the formation. The groundmass of stony meteorites contains not only many chondrules but also many finely splintered, sharply angular fragments such as might result from fragmentation of chondrules. Large meteors are to be considered as aggregations of material that have been collected together at some point in outer space. Meteors themselves frequently break up after they enter the earth's atmosphere. The break-up of large meteors is supposed to result from pressure of the atmosphere with possibly the shape of the meteor a contributing factor. Chondrules are supposed to break up as the result of collisions. A more reasonable explanation, it would seem, is to ascribe the fracturing of meteors and of chondrules to a change of condition from that under which solidification of the body took place. The investigations of A. Tveten and others show that frangibility of crystals is in some instances at least partly dependent upon magnetic and other conditions existing where the crystal is formed. Regardless of what the correct explanation may be, the empirical evidence is quite conclusive that meteoric material does in many instances undergo a fracturing process.

A careful analysis of loess and of the material of meteorites shows that the proportions of materials are not quite the same. Of silica the average for meteorites is 38.41% and for loess from 58.97% to 72.68%; of alumina, an average of 2.86% for meteorites and from 7.51% to 12.71% for loess; of magnesia, an average of 23.66% for meteorites and from 1.11% to 4.56% for loess; and meteorites contain average amounts of 12.35% of metallic iron, of 13.60% of ferrous oxide and of .92% of ferric oxide, while loess has amounts from .12% to .96% of ferrous oxide and from 2.61% to 5.14% of ferric oxide. Meteorites contain average amounts of 1.88% of calcium oxide, of .16% of carbon and small amounts of carbon monoxide and of carbon dioxide, while loess has as much as 14.90% of calcium carbonate. It does not logically follow that meteoritic deposits are unchanging in character and in amount from one age to another. Petrographical provinces on the earth itself change from one geological epoch to another, and at the basis of this change of provinces may be a change of meteoritic matter from which the earth may have been built. Even among meteorites at the present time there is considerable variation in the case of individual specimens as to contents.

A striking bit of evidence in behalf of a meteoritic origin of loess is that found in studying a report on the Yellow River by Fijnje van Salverda in 1891, where it is stated in a discussion of loess that there are angular stony fragments in the formation evidently not rounded by the action of water, generally found in heaps together and forming stone-agglomerates whose dispersal is always more or less limited. The presence of these stones can not, apparently, be accounted for by the agency either of wind or of water. It will be of interest when further examination is made of them to see whether or not they show evidence of chondritic structure such as is characteristic of meteorites at the present time. These stony fragments are not to be confused with the loess-mannikins which seem to be concretions formed subsequent to the deposit of the original material.

In concluding it may be stated that a careful study of all the evidence bearing on the origin of loess shows nothing really prohibitive to a meteoric origin for the deposit. On the other hand the absence of trituration of particles, the lack of cross-bedding in the material and the presence of calcium carbonate tubes are not only adverse but prohibitive to an eolian or aqueous origin. Conceivably new data might put a new light on the matter but until new evidence is produced we should regard a meteoritic origin of loess as the most probable explanation.