

# LOESS TYPES AND THEIR ORIGIN.

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**ABSTRACT.** Loess is widespread in the southern part of European USSR and extends through the Kirghiz steppe to Lake Balkhash and farther northwest to Yakutia. Different types of loess are distinguished: primary loess of aeolian origin and secondary loesses, redeposited and originated by other processes. Degraded loess and compact stone-loess are also recognized. Dust from which primary loess originated is believed blown by anticyclonic winds from fluvio-glacial alluvium of glaciated areas and foreglacial deserts, and deposited over adjacent prairies. In distinction from this "cold" loess, the other, "warm" primary loess has been blown from the exposed mountain ridges and foothill thallus of Central Asiatic Mountains and adjacent deserts, and deposited in the surrounding prairies, but part of the dust in these areas was also blown in from the distant areas of glaciation.

An alternative, soil-hypothesis of loess ascribes its origin to soil-forming processes from any fine-grained formation deposited by water in foreglacial and foothill alluvial plains. Comparative petrographic, chemical, and mechanical analyses of different types of loess give little support to this hypothesis, and the true water-laid loesses have greater compaction and offer more resistance to pressure than does the typical, porous, wind-blown loess.

The secondary loesses are more widespread than the primary loess, but are much thinner than the latter.

Richthofen's aeolian theory is emended by elucidation of the part which deserts played in origin of loess dust. Obruchev's critics point out that the Sahara desert is not surrounded by belt of typical loess; however, dust from Sahara is constantly carried away to the Atlantic and the Mediterranean, and is the original material of loess in Algeria, Tunisia and Tripoli. The Nile Valley and Arabia to the east are unsuitable for dust accumulation. The whole of equatorial Africa presents climatic conditions very different from those of east-central Asia, where yellow loess is widespread, and in places is underlain by a more ancient reddish loess, which, beside the color, differs also by having greater clay content and lesser porosity.

**L**OESS and loess-like rocks are widespread in the south of the European part of the USSR. They cover the Ukraine almost to the shores of Black or Azov seas, and stretch along the northern foothills of the Caucasian Mountains. Toward the north they make tongue-like penetrations toward the towns Vitebsk and Moscow, and also along the right bank of the Volga River to Kazan.

In the Asiatic part of the USSR they cover the southern half of the Kirghiz steppes (prairies) and the foothills of the Altai, and spread out between the Caspian and Aral seas to Kopet-Dagh Range and from there stretch to the plain of Syr-

Daria River and to Lake Balkhash. They cover also the slopes of the Tien-Shan and Pamir-Alai ranges, and spread over Fergana and Ili valleys. They are encountered also in the eastern half of Minusinsk Basin, near Irkutsk, in the southern zone of Trans-Baikalia, and in the north between Nizhni Vilui and Lena Rivers, and westward and eastward from the town Yakutsk on Nizhni Aldan River.

Russian investigators now recognize two kinds of loess, which differ in origin and in characteristic features: (1) typical loess, which could be called *primary loess*, and (2) clay-like loams, sandy loams and sands, which may be grouped as *secondary loess*. The primary loess is an aeolian formation, while the secondary loess is either the result of redeposition of primary loess by water, or is an alluvial and deluvial fine-grained earthy formation, which acquired its loess-like characters by weathering and soil forming processes. The primary loess can, on the other hand, lose its typical properties *in situ*, in which case it is called *altered* or *degraded loess*.

In central Asia an ancient loess has been found; a compact marly rock, frequently schistose, and with insignificant porosity. This rock is called stone-loess.

Most Russian students believe that loess in European Russia and Siberia is a direct consequence of Pleistocene Glaciation. They postulate that widespread ice sheets were centers of anticyclonic winds which blew down the ice-free adjacent plains. Numerous streams and flooding glacial waters ran to these plains, and these carried gravel, sand and mud, and deposited them to form what we call fluvioglacial alluvium. Intense thaw during warm seasons caused their overflow; during cold seasons they were in retreat, and left behind them wide areas covered by loose friable deposits. As the anticyclonic winds blew they were raising from these deposits quantities of fine sand and dust. Similar materials were blown also from exposed grounds and from frontal moraines, eskers, kames and outwash plains. From these wide areas of peri-glacial deserts the winds carried the dust far into the adjacent steppe, where it was deposited over the wide watersheds, well covered by herbaceous vegetation; under protection of this vegetation the settled dust became converted into loess formation. Along the glacial

streams, which traversed this steppe, banks were exposed at their retreat during cold seasons and these became sources of local dust, to be added to that brought from greater distances. Because of this the loess near such banks is coarser grained than farther away from them. The loess which was thus formed from sources created by glaciation may be called *cold loess*. Another loess type, *warm loess*, was formed in the past, and is still being created by the deserts and semiarid parts of the continent, particularly along vast territories of Central Asia. The ample areas from which wind raises quantities of dust are the bare surfaces of mountain ridges and hills, loose talus along their foothills, salty flats and flat shores of lakes exposed during their drying in summer, fall and winter seasons, and the banks of rivers, which become exposed and dry when waters retract after flowing far into deserts at times of maximum overflow. An important part in raising dust is played by the small blowouts formed in great number in the hot time of day upon the plain. As hot air moves up above them, it sucks the dust from the surface and raises dusty whirlwinds high into the air. The winds which, in the fall, winter and spring blow away from the deserts of Central Asia, are generally directed toward the south, east and west and so they carry the dust to the margins of these deserts. The heavier sand particles are deposited first and form loose sands, while the lighter particles are deposited in the surrounding steppes, where they accumulate under cover of the herbaceous vegetation and form loess. The sandy areas in the marginal parts of the deserts are being continuously stricken by winds and present an additional source of dust, which is raised and carried to the steppes. In this manner were formed the thick beds of primary loess in China and western Manchuria, and on the northern slopes and foothills of Nan-Shan and Kuen-Lung, northern and southern foothills and slopes of Tien-Shan. In all the slopes and foothills of these Ranges and others in Central Asia, materials of "cold" loess play an insignificant rôle at the present, but during glacial epochs much of it was added to the material representing "warm" loess. Thus in the primary loess of these areas certain quantities of local material—from mountain ridges, scattered sands, and fluvial and lacustrine deposits—were added to exogenic material carried in from far away.

In 1915 another hypothesis, the so-called soil-hypothesis, was offered in Russia, which has had and still has many sup-

porters.<sup>1</sup> According to this hypothesis any fine-grained deposit may be converted into typical loess as a result of weathering and soil forming processes. The formation thus produced and simulating loess, consists of an accumulation of lime acquiring a granular structure in consequence of the coagulation of minute colloidal particles to larger ones and to rather stable dusty and fine grained aggregates. Original stratification disappears and porosity characteristic of loess is produced. The advocates of this hypothesis hold that the chief factor involved in transportation and deposition of the loess-forming material is running water both in peri-glacial and foothill alluvial plains, where this water carries in and deposits eluviated material of which typical loess is formed.

Detailed petrographic study in connection with chemical and mechanical analyses of various loesses showed, however, that loess-forming processes can neither produce the calcium saturation characteristic of loess, nor explain the inertness of colloidal (alumosilicate) and carbonate parts to each other in the same loess. Besides, as erection of large buildings upon loess in the Ukraine shows, the loess, when saturated with water, becomes condensed under load and subsides, causing deformation in the heavy buildings. The fact that this tendency toward subsidence is observed only in primary loess proves that they were not deposited by water and never were thoroughly and intensely soaked in it—that is they were accumulated gradually in dry steppes from dust brought in by winds and not by water.

In regard to origin it would be necessary therefore to distinguish (1) primary (or typical) loess, cold and warm, an aeolian product, the material for which was brought in from periglacial and inner deserts, and deposited upon dry steppes; and

(2) Secondary loess, consisting of different loess-like clays, loams, sandy loams, which represent alluvium, talus, proluvium, as well as primary loess redeposited by water; all of these were to greater or less extent a subject of loess forming processes and acquired certain, but not all, characteristics of loess.

Secondary loesses are much more widespread than the primary ones. They are frequently encountered in the zonal devel-

<sup>1</sup> This explanation has recently been advocated by R. T. Russell for the loess of the lower Mississippi Valley. See *Geol. Soc. Amer., Bull.* vol. 55, 144, pp. 1-40. Ed.

opment of primary loess alongside with the latter, but their thicknesses are limited to several meters, while that of primary loess is usually up to ten, twenty, and not infrequently to forty or fifty, and in China even to one or two hundred meters. According to Richthofen, the originator of the aeolian hypothesis, Central Asia was almost completely covered with loess, which filled the valleys and hollows between the mountains, and was produced as a result of the weathering in the mountains, the loess-forming material from these being moved downward by water and wind. Obruchev has observed that in central Asia there is no loess: it appears only in the marginal zones. His observation of the distribution of loose sands and loess along these marginal zones made it possible to emend the theory proposed by Richthofen and so to elucidate the part played by the desert as a source of dust and sand. Antagonists of this theory point out that the vast Sahara desert is not surrounded by a belt of typical loess. They forget, however, that the red dust from the Sahara is carried away by winds blowing westward to the Atlantic (as it has been observed to settle on sailing ships since long ago), and northward to western Europe, as well as forming loesses in Algeria, Tunisia and Tripoli. In the East the desert is bordered by the Nile Valley where dust blown in becomes mixed with alluvium and cultural soils. Still farther eastward lie the Red Sea and the Arabian desert, which are unfavorable for dust accumulation. Southward from the Sahara stretches the equatorial zone which is rich in atmospheric precipitation. In general, the climatic conditions in northern Africa are quite different from those observed in Asia. Regions convenient for accumulation of a thick dust formation, so common there, are almost absent here. Nevertheless, here too loose sands occupy great areas in the western, northern, and eastern margins of the desert.

In China the beds of primary yellow loess are underlain in places by beds of reddish loess, which is distinguished from the yellow variety by greater clay content and lesser porosity. These beds are frequently covered by a layer of gravel. This older loess was probably deposited in early Quaternary time when in Central Asia took place an extensive outwash and blow-out of the higher territory beds, where the red beds of the upper Cretaceous and Tertiary continental deposits occupied considerable areas in hollows between the higher ground. From these areas the reddish dust was brought to China and accumu-

lated to produce the older loess, which since has become a subject of intense degradation *in situ*. Locally it is underlain by darker red clays with Pleistocene faunas.

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DISCUSSION.

THORP: Regarding the loess in China, some of the reddish color in the older loess is probably due to the soil-forming processes that were active after older beds of loess were formed and before younger deposits were made.

BRYAN: Obruchev made argument for formation of loess in northwest China, southeast of the Ordos Desert, but I believe it is essentially glacial in character. The loess blown from the Ordos Desert was probably due to periglacial climatic effects (i.e., strong anticyclonic winds). There are known to have been more extensive glaciers in the mountains of Tibet than exist there at the present time.

TO THE ANSWER BY THORP TO BRYAN'S REMARK: The loess-like rocks of southern China seem more likely to represent not the recent, but rather the older "cold" loess, which is connected with the ancient glaciation of Tibet, and subsequently degraded under the very moist recent climate of southern China. At such climatic conditions the eolian loess cannot be formed, but instead various kinds of red soils (krasnoziem) are usually developed.

ELIAS: Some processes, generally called "soil processes," are supposed to be responsible for both building up and deterioration of loess. To say "soil processes" is not enough; we must be more specific.

OBRUCHEV'S ANSWERS TO REMARKS.<sup>2</sup>

TO JAMES THORP: If we assume that the reddish color of the more ancient Chinese loess resulted from some soil processes then we should postulate for the time of its origin much warmer climate accompanied by greater humidity. However, a simpler explanation of the reddish color of the ancient loess is fur-

<sup>2</sup> Submitted in written form after the meeting.

nished by the wide development of the red Tertiary and upper Cretaceous deposits in central Asia, which are now largely covered by the yellow Quaternary deposits, and which were the source of the ancient loess. Besides, moist climate is generally unfavorable for the origin of loess.

**TO KIRK BRYAN:** The greater thickness (to 400 meters?) of the loess, which is to the south of Ordos, is directly at its border, that is to the south of the sands, and diminishes farther to the South. If this loess were a "cold" one and had originated in connection with the glaciation of Tibet, which, by the way, is fairly distant from this country, then its thickness would have been on a decrease in the opposite direction: from the south northward. Besides, this hypothesis leaves without explanation the occurrence of the large area of Ordos sands to the north of the thick loess. In European Russia the sands are located between the southern border of glaciation and the area of the development of the loess, which is a natural consequence of the proximal deposition of the coarser material by the anticyclonic winds, while the dust has been carried farther away. Thus in China the sands should have been deposited to the south of the loess, closer to the border of Tibet, if it were a "cold" loess.

**TO M. K. ELIAS:** In order to explain what is meant by "soil processes" a special report would be necessary, which the author could not furnish because of not being a specialist on soils. Much attention has been devoted to this question in the recent Russian literature.