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Analysis of sediment yields during the historic period in the loess region of the Yellow River basin

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Abstract The major factors affecting sediment yields in the Loess region are the land surface, climate and human activity. The first two factors have been important throughout the geologic history of the loess region which extends back over several million years. The influence of the last factor only appeared in the historical period when human activity could affect sediment yield. The period of human history is considered to extend back over 4000–5000 years. In the different historical periods, the sediment yields in the loess region experienced great variations in response to different rates of accelerated erosion. This paper discusses these changes and rates.

Analyse des transports de sédiments dans la région du loess du fleuve Jaune pendant la période historique

Résumé Les facteurs principaux affectant la production de sédiments dans la région du loess sont la surface du sol, le climat et les activités de l'homme. Les deux premiers facteurs ont joué un grand rôle pendant l'histoire géologique de cette région du loess, qui couvre plusieurs millions d'années. L'influence du dernier facteur est apparue au cours de la période historique au moment où les activités de l'homme étaient susceptibles d'affecter la production de sédiments. On considère que cette période historique remonte jusqu'à 4000 à 5000 ans BP. Au cours des différentes périodes historiques, la production de sédiments dans la région du loess a présenté de grandes variations en réponse à différents taux d'accélération de l'érosion. Cette communication discute ces taux d'érosion et leurs variations.

INTRODUCTION

The lower Yellow River carries the largest sediment load of all world rivers. According to data collected from gauging stations in the basin, 85% of the sediment transported within the lower Yellow River is derived from the loess region of the middle Yellow River.

Factors affecting the sediment yields from the loess region are the land surface, climate and human activity. The land surface is taken to include its geology, geomorphology, and vegetation cover; climate implies primarily

precipitation. The effects of the first two factors can be traced back through the geological history of the loess plateau which extends back over several million years. The influence of the last factor only appeared in the historical period. The period of human history is generally considered to extend back over 4000–5000 years.

The sediment of Yellow River has formed the Huang-Hai-Huai Plain (3H Plain) over hundreds of thousands of years (Dai, 1983). At present, the total amount of sediment aggradation on the plain is about 38×10^{12}t. The area of the 3H plain is about 25×10^4km^2, and the depth of sedimentation is about 60 m). According to textural investigations, the Yellow River formed a large united river system during the late Pleistocene epoch of the Quaternary period. This was 100 000 years ago.

EROSION OF THE LOESS AREA DURING THE GEOLOGICAL PERIOD

From the above data, we can estimate the mean annual sediment yield of the Yellow River during the geological period as 0.38×10^9t. This is much smaller than the 1.6×10^9 t contemporary mean annual sediment yield of the Yellow River. The sediment yield of the loess region of the Yellow River has therefore experienced great changes through its history.

The loess deposition in the loess region of Middle Yellow River began during the early Pleistocene epoch of the Quaternary period. At present the depth of the loess deposits is about 100–200 m.

During the Quaternary period there were four periods of increased erosion. They occurred respectively $1.2–1.5 \times 10^6$ years ago, $5–7 \times 10^5$ years ago, $1–2 \times 10^5$ years ago and $1–2 \times 10^4$ years ago. The erosion during the later periods was more intense than during the earlier periods. The third and fourth erosion periods exerted a considerable influence on sedimentation in the Lower Yellow River. Between these two periods of increased erosion there was a period of reduced erosion. After the formation of the united Yellow River system, its sediment yield experienced great variations.

EROSION OF THE LOESS REGION IN THE HISTORIC PERIOD (BEFORE 1855 AD)

In the historic period, human activities exerted a major effect on sediment yields in the loess region. Ye *et al.* (1983) have assessed the rate of aggradation of the alluvial fan (3H) Plain) of the Yellow River from geological evidence (see Table 1). They considered that practically all of the sediment on the alluvial fan was derived from the loess region. They estimated the mean annual erosion rates for different periods. They considered that the effect of human activity on sediment yield before the Tan Dynasty (618 AD–907 AD) was smaller than after the Tan Dynasty. Before the Tan Dynasty there was primarily naturally accelerating erosion in the loess region. According to the evidence of alluvial fan aggradation during the middle Holocene epoch and the period between 1020 BC and 1194 AD,

Table 1 *Rates of aggradation of the alluvial fan of the Yellow River during the Holocene epoch*

Period		*Aggradation amount* $10^9 t\ year^{-1}$	*Rate of erosion acceleration % per 100 year*
Middle Holocene epoch (3000–6000 years ago)		*1.075*	
			0.71
Late Holocene epoch	*1020 BC–1194 AD*	*1.160*	
			2.07
	1494 AD–1855 AD	*1.330*	

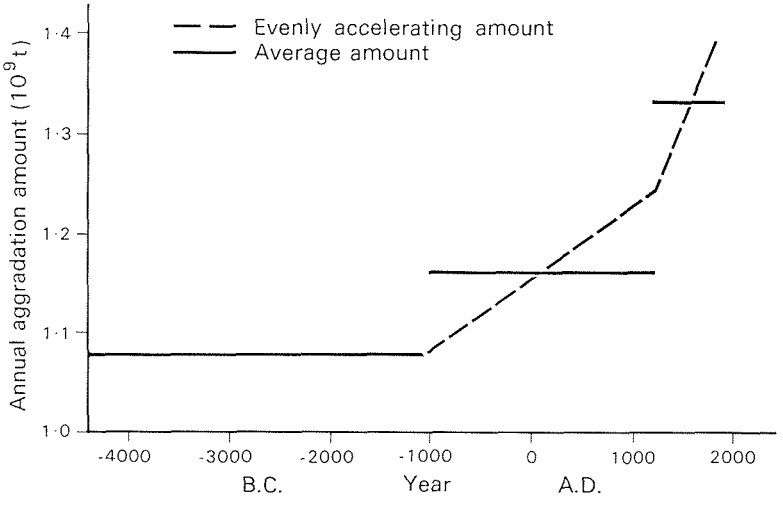

Fig. 1 Changes in the amount of aggradation on the alluvial fan of the Yellow River during the historical period.

erosion rates during the period 1020 BC–1194 AD increased by 7.9% over those during the Middle Holocene epoch. This figure could be regarded as a criterion for distinguishing naturally accelerating erosion rates. They also estimated that erosion rates during the period 1494 AD–1855 AD increased by 14.6% over those operating during the period 1020 BC–1194 AD They therefore estimated that the natural erosion rate increased by 7.9% and acceleration of erosion due to human activity account for an increase of 6.7%. We consider that in their conclusion they neglected the time factor, so that they underestimated the effect of human activity in accelerating erosion during the period 1494 AD–1855 AD. Taking account of the time factor and the linear

acceleration of erosion, we find that the rate of acceleration of the erosion rates during the period 1020 BC–1194 AD should be 0.71% per hundred years (see Fig. 1). This figure can be regarded as the criterion for distinguishing naturally accelerating erosion rates. Then we consider that the level of human activity during the period 1194 AD–1494 AD was the same as that during the period 1494 AD–1855 AD. Therefore, the overall rate of acceleration of erosion rates during the period 1194 AD–1855 AD was 2.07% per hundred year. Thus, the rate of acceleration due to human activity during the period 1194 AD–1855 AD was 1.36% per hundred year (2.07% – 0.71% = 1.36%). This figure indicates that the impact of human activity in accelerating erosion rates was greater than that of natural factors during the period 1194 AD–1855 AD.

REMARKS

Studies of the sediment yield of the loess region of the Yellow River in the geological period are helpful in interpreting modern observations and in emphasising the important impact of human activity.

As indicated above, the acceleration of erosion rates ascribed to human activity is greater than that associated with natural controls. The effects of human activity on sediment yields during the modern period possess two aspects, leading to both increase and decrease of sediment yield. Deforestation and the reclamation of wasteland could increase sediment yields, but water and soil conservation could decrease it. At present, the mean annual sediment yield of Yellow River is about 1.6×10^9 t. On the basis of the naturally accelerating erosion rate (0.71% per hundred years), the natural sediment yield of the Yellow River should be about 1.31×10^9 t. The 0.3×10^9 t difference between the two figures represents the aggregate effect of human activity, including both increase and decrease effects. The decrease effect of human activities on sediment yields should be expanded so that the sediment yields from the loess region of the Yellow River will increase more slowly and even decrease over the years.

REFERENCES

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