Characteristics of Loess Magnetic Susceptibility and Its Influencing Factors analysis in Hebei Country

YUAN Jie1, CAO Guangchao1, E Chongyi1, YUAN Youjing2, WU Chengyong1, YU Ming1, YANG Rongrong1

1 Key Laboratory of Qinghai Province Physical Geography and Environmental Process, Qinghai Normal University, XiNing 810008, P.R. China;
2 Environmental Geological Prospecting Bureau of Qinghai Province, XiNing 810000, P.R. China

The corresponding author’s e-mail: caoguangchao@qhnu.cn

Abstract. Taking the loess profile of Hebei countryside area as the research object, the magnetic susceptibility, particle size, SOC and chroma were measured respectively. The following conclusions are drawn from the analysis of the above indicators: Xhf value is between $20.56 \times 10^{-8}$ m$^3$ kg$^{-1}$ and $107.81 \times 10^{-8}$ m$^3$ kg$^{-1}$, Xfd value is between 0.31% and 8.74%. The content of silt (4~63μm) is the largest in the particle size composition, followed by the clay content (<4μm), the sand content (>63μm) is the least. The SOC content of the whole profile was less, with an average of 8.69 g/kg. Among the chroma values, $a^*$ is between 6.65 and 10.3, $L^*$ is between 43.34 and 63.79, and $b^*$ is between 15.66 and 22.58. The correlation analysis showed that the correlation between grain size and Xhf was not significant (P>0.05), but has a significant correlation with Xfd (P<0.01); SOC has a significant correlation with magnetic susceptibility (P<0.01); There was a significant positive correlation between Xfd and chromaticity (P<0.01), but there was no correlation between Xfd (P>0.05).

1. Introduction

In recent decades, the study of Chinese loess deposits, the particle size and magnetic susceptibility of sediments have been used to reflect the two substitutes of climate change widely. Because of its simple, rapid, targeted, strong sensitivity to climate change and other characteristics, it is widely used in a variety of depositional environment analysis [1], and the particle size is one of the important characteristics of sediments [2]. The sediment size distribution can reflect the source of the material, hydrodynamic environment of the sedimentary area, transport capacity and transport routein the sedimentary facies [3]. The characteristic of river grain size reflects the river hydrodynamic environment [4,5], but the different particle size components related closely to the sediment source area in the sediments [6], so it is used as a substitute index to reflect the changes of climate and environment. Similarly, the magnetic susceptibility of sediments is also used as an important substitute indicator for the study of loess strata. Lu Huayu found the magnetic susceptibility of loess sediments was sensitive index of climate in the study of loess section of Luochuan[7, 8]; Xia Dunsheng [9]and Song Youjia [10] pointed out that the loess deposition magnetic susceptibility and wind theory and the characteristics of soil in Xinjiang Yili area loess deposition study; Yuan Shengyuan pointed out that the magnetic susceptibility of sediments in the lacustrine area is closely related to the intensity of water and the intensity of precipitation in study of Jianghan Plain Temple section, and it has the characteristics of reflecting paleoclimatic environment.
and paleohydrological events [11]. However, there are few studies on the magnetic properties of loess deposits in the northwestern Qinghai area, and it has a great ecological significance for the further exploration of the magnetic and particle size of loess in this area as a natural barrier for desertification [12]. In this research, the loess profile which was selected as the object of study in Hebei County of Qinghai Province to contrast and analyze the grain size, magnetic susceptibility and other soil physical and chemical indexes, and discuss the magnetic susceptibility and particle size characteristics of loess deposits in this area. In order to provide some scientific basis for loess sediment magnetic change mechanism and the environmental evolution in Qinghai.

2. Materials and methods

2.1 Soil Sampling Methods
Hebei loess profile (34°43′47″N, 100°48′19″E) is located southeast of Qinghai Province, and the altitude is 3424 m; Soil samples were collected in July, 2014. Sampling from the surface down when sampling (sampling interval of 5 cm), a total of 97 samples. All soil samples were brought into laboratory and dried naturally and cleaned. After it was under grind through a 200 mesh sieve, it would be arranged, collected and set aside.

2.2 Determination of soil magnetic susceptibility
Magnetic susceptibility was measured with MS-2B type magnetic susceptibility instruments made by the British company. Measurement process mainly includes: the dried sample was poured into 10 mL volume plastic cylindrical cartridge and weighed sample mass; the magnetic susceptibility meter background value was measured for a time, and the continuous measurements for three times was made after the samples were put. Meanwhile, the measurement sample is removed from its background value for one time. The change of both of the background measurement value should be under 0.3. The low frequency is 470 Hz, the high frequency is 4700 Hz, the unit gear of measuring for the SI is 0.1 tear [13]. Finally, the frequency and high-frequency magnetic susceptibility were calculated through magnetic susceptibility test results, samples low (high) frequency magnetic susceptibility value = (average of 3 measurements of the sample-around twice the average background value) × 10 sample mass, units 10⁻⁵ m³ kg⁻¹. Frequency magnetic susceptibility (X₀₀%) = (low frequency magnetic susceptibility X₀ - high-frequency magnetic susceptibility X₉₀) / low-frequency magnetic susceptibility X₀ × 100. (Note: According to the measured low-frequency and high-frequency magnetic susceptibility magnetic susceptibility, the overall trend is consistent. However, the overall value of the low-frequency magnetic susceptibility values are higher than the high-frequency magnetic susceptibility. So, just low frequency magnetic susceptibility and the frequency magnetic susceptibility compared analysis were selected here.)

2.3 Determination of soil Chroma
Chroma was taken from Minolta spectrophotometric colorimeter measurement produced by Japan. When the sample was dried naturally in the laboratory, and then it was through 200 mesh sieve. Then, the sample was placed on the test board, flatten. Three areas of smooth surface were randomly selected to be measured for three times, and the instrument automatically determined three measurements of L *, a *, b * mean, and it was ensured that the error was less than 0.1. (L * value: psychometric lightness; a *value: psychometric red-green chromaticness; b * value: psychometric yellow-blue chromaticness)

2.4 Determination of Soil particle size and SOC
After all samples were dried naturally and through 2 mm sieve, 0.4 g soil samples were accurately weighed and placed in a beaker of 50 mL. And then, the samples was processed as follows: 1) 10 mL 10% hydrogen peroxide was added and heated when it was to boil so that it could react calmly in order to remove soil organic matter ease of oxidation salts; 2) after the beaker was cool, 10 mL 10% hydrochloric acid (HCl) was added and shaken sufficiently when it was to boil so that it could be reacted freely and
carbonates could be removed; 3) the distilled water was put into the samples, and it would be kept for 12 hours; 4) 10mL of 10% sodium hexametaphosphate was added and it was placed in an ultrasonic shaker test [14]. Among this, the particle size analysis instruments was Mastersizer2000 Malvern laser particle size analyzer produced by a British production company. In process of measurement, the degree of shading existed between 17% and 20%, and then, the same measurement would be done for three times, and the final result was accorded to the average value. The SOC content of a random selection of 97 samples was analyzed using the wet oxidation method (Wakley Black).

3. Results and analysis

3.1 The changes trend of the indicators on study profile

The study of the cross-sections are shown in Fig. 1, where $X_{mf}$ is between $20.56 \times 10^{-8}$ m$^3$kg$^{-1}$ and $107.81 \times 10^{-8}$ m$^3$ kg$^{-1}$ with an average value is $38.99 \times 10^{-8}$ m$^3$ kg$^{-1}$ and the maximum is about the minimum of 5 times. $X_{mf}$ is between 0.31% and 8.74% with an average value is 4.30% and the maximum value is about 3 times of the minimum value. The silt (4~63μm) is the largest, which total value is between 65.12% and 76.69% and the proportion is 69.78%, the clay (<4μm) is between 11.25% and 26.88% and the proportion is 17.72%, and the sand (63~1000μm) is between 2.43% and 21.08% with the proportion is 12.50% in the composition of particle size. The average particle size is between 5.42Φ and 6.96Φ, with average value is 5.97Φ, so the grade is silt. The average value of SOC is 8.69g/kg with the maximum appears in the distance to the surface 30 cm to 35cm and the minimum appears in 280cm to 285cm, however, the content of SOC is high in surface and the remaining content is less. In the value of Chroma, $a^*$ is between 6.65 and 10.3 with average value is 7.69, $L^*$ is between 43.34 and 63.79 with average value is 55.20, $b^*$ is between 15.66 and 22.58 with an average value is 18.63.

![Fig.1 The basic indicators variation of profile](image)

3.2 Analysis of soil magnetic susceptibility and soil particle size

The results show that: 1) There is a correlation between the high frequency mass susceptibility and the grain size, but not significant ($P <0.05$); 2) There is a correlation between frequency magnetic susceptibility and grain size ($P <0.01$) significantly (Figure 2). Specifically, the particle size of the clay particles (<4.00μm) and the silt (4.00μm~63.00μm) is positively correlated with the high frequency mass susceptibility, but it is weak for the high frequency mass susceptibility and the coefficient are only 0.191 and 0.186. At the same time, the sand (63.00μm~1000.00μm) with high frequency mass
susceptibility is negatively correlated, the significant relationship is weak and the correlation coefficient is -0.278. Then from the above analysis results, the effects is weak for high frequency mass susceptibility in the area regardless of the grain component size is how much. There is significant correlation between the clay (<4.00μm) and the silt (4.00μm–63.00μm) particle size components and frequency susceptibility for the frequency susceptibility, the correlation coefficients are 0.362 and 0.473, which indicates that the clay and silt contributes to the frequency susceptibility, but it is not significant. While the sand (63.00μm–1000.00μm) is significantly different from the frequency susceptibility negative correlation and the correlation coefficient is -0.612, so it indicates that the sand may affect the frequency of the magnetic susceptibility changes.

Fig. 2 The correlation analysis of Xhf and Xfd with particle size

The average particle size represents characteristics of grain size change in the longitudinal direction or in the transverse direction. The more larger of the Φ value the more finer of the particle size, and vice versa. From the analysis of the correlation between the average particle size and Xhf and Xfd of the sediments in the loess section of Hebei Village (Fig. 3), the average particle size is positively correlated with the Xhf, but the correlation is weak and the correlation coefficient is 0.235, and it is correlates with Xfd and the correlation coefficient is 0.517.
Fig. 3 The correlation analysis of Xhf and Xfd with $\phi$

3.3 Analysis of soil magnetic susceptibility and SOC
The average value of the SOC is 8.69g×kg$^{-1}$ in HeBei lengthways profile, in addition to the surface layer 30cm, the entire profile of the SOC content is low. From the correlation between the SOC and Xhf of the entire profile, both of them were very significant relationship ($P<0.01$), the correlation coefficient is achieved 0.905; the SOC and Xfd were significantly related ($P<0.05$), the correlation coefficient is 0.692; For the relationship between SOC and the magnetic susceptibility, there are the following conclusions: 1) Organic matter itself has a certain magnetic [15]; 2) There is a significant positive correlation between the content of organic matter and the magnitude of magnetic susceptibility [16]; 3) To a certain extent organic matter can prevent some magnetic minerals from magnetic attenuation [17]; 4) When the amorphous iron into iron oxide, the organic matter as a catalyst to facilitate the formation of magnetic hematite [18]; In summary, from the correlation results analysis point of view, the total profile of the SOC and Xfd were significant positive correlation, may indicate that SOC contributes greatly to the formation of magnetic minerals. So there is a significant positive correlation with the magnetic susceptibility.

Fig. 4 The correlation analysis of Xhf and Xfd with SOC

3.4 Analysis of soil magnetic susceptibility and chroma
Purely for the brightness, the organic matter content and the carbonate content are the main factors affecting its size. Generally, the accumulation of organic matter in the soil will depend on the amount of precipitation in the region, the more precipitation the high organic content, and vice versa. There is a significant negative correlation between the magnetic susceptibility and the organic matter content, While the brightness in the soil is mainly controlled by the organic matter content, it’s will be reduced with the increase of organic matter. So the brightness can also indirectly reflect the soil precipitation in the study area. There was a significant negative correlation between lightness and Xfd and Xhf ($P<0.01$), the correlation coefficients were -0.789 and -0.914, respectively. Indicating that the area of brightness
and magnetic susceptibility in a certain extent can reflect the regional precipitation changes. At the same time, the relationship between brightness, magnetic susceptibility and organic matter can be used to indicate the regional vegetation development.

As can be seen from Figure 5, there was a significant correlation between $X_{\text{hf}}$ and redness ($P < 0.05$), the correlation coefficient is $-0.437$; while the correlation coefficient between $X_{\text{fd}}$ and redness did not reach significant level ($P > 0.05$). The redness of the soil is mainly controlled by hematite content, and the redness increases with the increase of hematite. The correlation between the $X_{\text{fd}}$ and the redness is not significant maybe because of $X_{\text{fd}}$ as an alternative to the identification of superparamagnetic minerals, indicating the amount of ultrafine paramagnetic particles formed by the natural wind into ferromagnetic particles under natural soil formation and the intensity of soil formation. On the other hand, the ancient soil of Hebei profile due to pedogenesis to formation a very small amount of hematite, while there is almost no superparamagnetic particles in the loess, so the frequency between the magnetic susceptibility and redness did not reach a significant level. While the correlation coefficient between high frequency mass susceptibility and redness is $-0.437$, it is shown that hematite which in addition to ultrafine component particles other than the soil particles will affects the change of magnetic susceptibility in this region.

There was a significant correlation between yellowness and $X_{\text{fd}}$ and $X_{\text{hf}}$ ($P < 0.05$), the correlation coefficients were $-0.683$ and $-0.773$, respectively(Figure 5). Yellowness related to the amount of goethite in the soil[19], while the formation of goethite depends on the climatic conditions of different periods, the climate more humid, the goethite is more conducive to formation. There was a significant negative correlation between yellowness and $X_{\text{fd}}$ and $X_{\text{hf}}$ in this study, indicating that in the process of loess accumulation of yellowness will also affect the area of the magnetic susceptibility changes. In addition, the analysis of the yellowness and the magnetic susceptibility can reflect, to a certain extent, the change in precipitation, but it is not accurate only using yellowness to reflect changes in precipitation.
4. Conclusions

(1) For high frequency mass susceptibility, the grain size of this region has a weak effect on the magnetic susceptibility of high frequency in this area; For the frequency susceptibility, the clay and silt components has contribute to the frequency susceptibility, but the contribute is little, while the sand content (63μm~1000μm) and the frequency of magnetic susceptibility has a significant negative correlation, indicating that the sand components may affect the frequency of magnetic susceptibility changes in this area.

(2) SOC and magnetic susceptibility have a very significant positive correlation, indicating that SOC contributes greatly to the formation of magnetic minerals, it directly determine the size of the magnetic susceptibility of the area. From the correlation between chroma and magnetic susceptibility, the chroma indicate can reflect the water-heat condition of the loess accumulation in different periods, the brightness and the magnetic susceptibility can reflect the change of the regional precipitation to some extent. At the same time brightness, magnetic susceptibility and organic matter can be used to indicate the regional vegetation development. The size of the chroma indicator will affect the change of the magnetic susceptibility in this study area, but it is not accurate only using chroma to reflect changes in precipitation in the area.

Acknowledgements

This paper is co-sponsored by National Natural Science Foundation of the People’s Republic of China (41361005) and Qinghai Province Key Laboratory of Physical Geography and Environmental Process (2014-Y24, 2015-Z-Y01). The authors thank them and the anonymous reviewers.

References

[1] WANG WEI, LI A C, XU F J, et al. Distribution of surface sediments and sedimentary environment in the north yellow sea [J]. OCEANOLOGIA ET LIMNOLOGIA SINICA, 2009, 40(5):526-531.

[2] YING Z Q, QING X G, WU J S, et al. The multimodal grain size distribution characteristics of Loess, Desert, Lake and River sediments in some areas of Northern China [J]. ACTA SEDIMENTO LOGICA SINICA, 2009, (2):343-351.

[3] LIU J L, LI L Q, LIN H N, et al. Characters of gain size of sediments from mangrove wetlands of China [J]. Journal of Xiamen University (Natural Science). 2008, 47(6):891-893.

[4] LIU HONG, HE QING, WANG Y Y, et al. Temporal and spatial characteristics of surface sediment grain-size distribution in Chang jiang Estuary [J] . ACTA SEDIMENTO LOGICA SINICA, 2007, 25(3):45-448.

[5] PENG X T, ZHOU H Y, YE YING, et al. Characteristics of sediment grain size and their implications for bottom hydrodynamic environment in the Pearl River Estuary. ACTA SEDIMENTO LOGICA SINICA, 2004, 22(3):487-493.

[6] ZHANG Z N, DONG Z B. The effect of wind erosion on the surface particle size [J]. Journal of Arid
Land Resources and Environment. 2012.26 (12): 86-89.
[7] HELLER F, TUNG S L. Magnetism of Chinese loess deposits [J]. Geophysical Journal International, 1984, 77(1): 125-141.
[8] KUKLA G, HELLER F, LIU X M, et al. Pleistocene climates in China dated by magnetic susceptibility [J]. Geology, 1988, 16: 811-814.
[9] XIA D H, CHEN F H, MA J Y, et al. Magnetic characteristics of loess in the ILI area and their environmental implication [J]. QUATERNARY SCIENCES, 2010, 30(5): 902-910.
[10] SONG Y G, SHI Z T, FANG X M, et al. Loess magnetic properties in the IlI Basin and their correlation with the Chinese Loess Plateau. Sci China Earth Sci, 2010, doi: 10.1007/s11430-010-0011-5.
[11] YUAN S Y, LI C A, ZHANG Y F, et al. Grain sizes and magnetic susceptibility of the XIAOSI section in the JiangHan plain and their environmental significance. TRANSACTIONS OF OCEANOLOGY AND LIMNOLOGY, 2011, (4): 169-176.
[12] DONG LI, LI Y H. Comparative study on magnetic variations of eolian and alluvial-proluvial sediments from Lop Nur area [J]. Journal of Arid Land Resources and Environment, 2013, 27(11): 111-116.
[13] ZENG F M, LAI Z P, LIU X J. Discussion on sedimentary characteristics of the Paleogene salt-bearing formation and salt forming model of the Paleo-Saline in Hoh Xil Area [J]. JOURNAL OF SALT LAKE RESEARCH, 2014, 22(3): 21-25.
[14] E C Y, CAO G C, HOU G L, et al. The environmental change recorded in Jiang Xi Gou loess sections in Qinghai Lake region [J]. Marine Geology & Quaternary Geology, 2013, 4(33): 193-200.
[15] DENG S F, YANG T B, E C Y, et al. Magnetic Susceptibility and Influencing Factors of Loess From Bole, Xinjiang Province [J]. Chinese Journal of Soil Science, 2012, 43(5): 1054-1059.
[16] HU X F. Influence of iron oxides and organic matter on magnetic susceptibility in the Loess-Paleosol sequence [J]. ACTA PEDOLOGICA SINICA, 2004, 41(1): 7-12.
[17] LU S G. Relationship between frequency magnetic susceptibility and ferromagnetic mineral grain size in soils and its environmental implication [J]. Journal of basic science and engineering, 2005, 8(1): 9-15.
[18] Feng Z D, Khosbayar P. Paleosubarctic Eolian environments along the southern margin of the North American Ice sheet and the southern margin of Siberia during the Last Glacial Maximum [J]. Paleogeography, Paleoclimatology, Paleoecology, 2004, 212(3): 265-275.
[19] RESENDE M. Mineralogy, chemistry, morphology and geomorphology of some soils of the central plateau Brazil [D]. Indiana: Purdue University, 1976.