Mineral Composition of Soft Rock in Mu Us Sandy Land, China

Biao Peng1,2,3, 4,* and Yulu Wei1,2,3, 4

1Shaanxi Provincial Land Engineering Construction Group Co., Ltd., Xian, China
2Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd., Xian, China
3Key Laboratory of Degraded and Unused Land Consolidation Engineering, the Ministry of Land and Resources, Xian, China
4Shaanxi Provincial Land Consolidation Engineering Technology Research Center, Xian, China

*Corresponding author e-mail: 43493022@qq.com

Abstract. Minerals are the main composition of soils. Soil minerals, especially secondary minerals, determine physical and chemical properties of soils. In this study, the X-ray diffraction ray experiments were carried out to study the mineral composition of eleven different color soft rocks and sands. The study found that the soft rock in Mu Us Sandy Land is mainly composed of quartz, potassium feldspar, plagioclase, calcite, montmorillonite, illite and kaolinite. The soft rock has various color types, such as yellow, grayish white, purple, grayish green. Different color soft rocks have different mineral composition. The grayish white soft rock has the lowest secondary mineral, accounting for only 5.4%; the light brown soft rock has the highest secondary mineral, up to 59%. The sands are composed of quartz, potassium feldspar, plagioclase, calcite, hornblende, montmorillonite, illite, of which the original mineral accounted for 93.5%, and the secondary mineral accounted for 6.5%.

1. Introduction
Mu Us Sandy Land is located in the border area of Shaanxi, Ningxia and Inner Mongolia with an area of about 40,000km². It is located in the transition area between the Ordos Plateau and the Loess Plateau. It has flat terrain, heavy rainfall, good light and heat resources, no environmental pollution, and development potential. It is huge and has the potential for the development of cultivated land reserve resources [1-2]. However, the main problems restricting the development of the area are desertification of land and erosion of soft rocks [3].

Soft rock is a general term for mudstones, sandstones, and conglomerates that are easy to lose water and soil, and are formed in the border areas of Shanxi, Shaanxi, and Mongolia. The researches on the soft rock mainly focus on the properties, the species and the distribution, the characteristics of soil and water loss, the ecological security evaluation [4], and it is relatively rare to utilize the soft rock as resources. Mu Us sandy land is one of the areas where desertification is severe in China, and it is also one of the key areas for desertification research. It is located in a semi-arid climate area [5].

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

Published under licence by IOP Publishing Ltd
At present, the land remediation and development and utilization of the Mu Us Sandy land have been achieved through the rapid soil formation technology of soft rocks and sands. The predecessors have carried out fruitful work on the moisture, sand fixation and crop productivity of the soft rock-sand mixed soil [6-7].

There is a rich literature on the effects of mixed soft rock and sand composite soil, but the research on the scientific mechanism of mixed soft rock and sand composite soil appears to be inferior, especially for the mineralogical composition of mixed soft rock-sand composite soil. Minerals are the main constituents of soil. Soil minerals, especially soil secondary minerals, determine many physical and chemical properties of the soil, such as soil water holding capacity, adsorption, expansion and contraction, adhesion, and soil structure [8]. In order to explore the mechanism of the formation of soil from soft rock and sand, to improve the quality of farmland formed by soft rock and sand, and to explore new types of natural materials, it is necessary to thoroughly study the mineral composition of soft rock and sand.

2. Methods and materials
The soft rock and aeolian soil were collected from Ordos, Inner Mongolia and Yulin, Shaanxi. Among them, gray white soft rock, pink soft rock, grayish yellow soft rock, gray-green soft rock, purple soft rock, yellow soft rock, gray soft rock are collected from Ordos City, Inner Mongolia, brown soft rock, gray brown soft rock, yellow brown soft rock Aeolian sand soil was collected from Yulin City, Shaanxi Province (Figure 1).

![Various colour soft rocks and sands.](image)

Figure 1. Various colour soft rocks and sands.

The X-ray diffraction method is mainly used for the identification of the minerals of soft rock and sandy soil. According to the Stokes settlement theorem in fluid mechanics, clay suspension samples or centrifugal separation methods were used to extract clay mineral samples with particle sizes smaller
than 10 microns and smaller than 2 microns, respectively. Clay mineral samples with a particle size of
less than 10 microns are used to determine the total relative content of clay minerals in raw rocks; clay
mineral samples with a particle size of less than 2 microns are used to determine the relative content of
various clay minerals. Mineral crystals all have specific X-ray diffraction patterns. The characteristic
peak intensity in the pattern is positively correlated with the content of the mineral in the sample. The
positive correlation between the content of a mineral and the intensity of its characteristic diffraction
peak can be determined experimentally. K value, and further determine the content of the mineral by
measuring the characteristic peak intensity of the mineral in the unknown sample.

3. Results
The soft rock of Mu Us Sandy Land is mainly composed of quartz, potash feldspar, plagioclase,
calcite, montmorillonite, illite and kaolinite. The mineral composition of soft rocks with different
colors is quite different. The specific content is shown in Table 1 and Figure 2.

Table 1. Mineral composition of soft rock and sand (%).

| Name                  | quartz | orthoclase | plagioclase | calcite | dolomite | pyrite | hornblende | montmorillonite | goethite/nazrite | kaolinite |
|-----------------------|--------|------------|-------------|---------|----------|--------|------------|-----------------|-----------------|-----------|
| grayish white soft rock| 88.8   | 5.1        | 0.7         | /       | /        | /      | /          | 0.2             | 5.2             |
| pink soft rock        | 17.1   | 8          | 3.7         | 52.7    | 1.6      | /      | /          | 15.5            | 1.1             | 0.3       |
| grayish yellow soft rock| 30     | 16.4       | 2.3         | 4.8     | /        | /      | /          | 45.1            | 0.9             | 0.5       |
| grayish green soft rock| 55     | 10.1       | 0.3         | 3.9     | /        | /      | /          | 24.8            | 0.7             | 5.2       |
| purple soft rock      | 38.1   | 12.9       | 4.3         | 7.8     | /        | /      | /          | 22.8            | 1.6             | 12.5      |
| yellow soft rock      | 21.4   | 5.4        | 12.2        | 21.5    | /        | /      | /          | 37.525          | 1.185           | 0.79      |
| gray soft rock        | 59.4   | 5.6        | 0.4         | 10.6    | /        | /      | /          | 22.32           | 0.72            | 0.96      |
| light brown soft rock | 29.7   | 4.3        | 0.2         | 2.7     | 4.1      | /      | /          | 51.33           | 1.18            | 6.49      |
| brown soft rock       | 27.8   | 15.1       | 8.6         | 25.1    | /        | 0.7    | /          | 17.7            | 2.2             | 2.6       |
| grayish brown soft rocks| 32.9   | 8.8        | 30.2        | 12.1    | /        | 0.5    | /          | 3.3             | 9.6             | 2.7       |
| yellow brown soft rock| 26.1   | 3.7        | 20.9        | 26.1    | /        | 0.6    | /          | 5.4             | 13.6            | 3.6       |
| sands                 | 35.5   | 13.6       | 38.2        | 5.2     | /        | /      | 1          | 1.8             | 3.9             | 0.8       |

In the process of soil formation, quartz, plagioclase, potash feldspar, amphibole, pyrite, calcite,
dolomite, are primary minerals, and kaolinite, illite, and montmorillonite are secondary minerals. The
content of soft rock minerals can be as high as 94.6%, the lowest can be 41%, with an average of
72.8%; the secondary mineral content can be up to 59%, the lowest can be 5.4, and the average content
is 27.1%. The content of original minerals in sandy soil is as high as 93.5%, and the content of
secondary minerals is only 6.5%. See Table 2 for the specific content of primary and secondary
minerals in various types of soft rock and sandy soil.

Table 2. Primary mineral content and secondary mineral content of soft rock and sand (%).

| Name                       | Original mineral | Secondary mineral |
|----------------------------|------------------|-------------------|
| grayish white soft rock    | 94.6             | 5.4               |
| pink soft rock             | 83.1             | 16.9              |
| grayish yellow soft rock   | 53.5             | 46.5              |
| grayish green soft rock    | 69.3             | 30.7              |
| purple soft rock           | 63.1             | 36.9              |
| yellow soft rock           | 60.5             | 39.5              |
| gray soft rock             | 76               | 24                 |
| light brown soft rock      | 41               | 59                 |
| brown soft rock            | 77.5             | 22.5              |
| grayish brown soft rocks   | 84.5             | 15.5              |
| yellow brown soft rock     | 77.4             | 22.6              |
| sands                      | 93.5             | 6.5               |
a-grayish white soft rock, b-pink soft rock, c-grayish yellow soft rock, d-grayish green soft rock, e-purple soft rock, f-yellow soft rock, g-gray soft rock, h-light brown soft rock, i-brown soft rock, j-grayish brown soft rocks, k-yellow brown soft rock, l-sands

Figure 2. X-ray diffraction patterns of various soft rocks and sands.

4. Discussion
Soil secondary minerals have a decisive influence on soil water and fertilizer retention performance [8]. Montmorillonite and illite are 2:1 type layered aluminosilicate minerals. Such minerals have strong swelling and shrinking properties, high water holding capacity, low permeability, and are good at forming a stable combination with calcium humate. And such minerals have a larger specific surface. In the ion exchange reaction, the larger specific surface not only increases the charge density of the soil, but also directly affects the rate of the exchange reaction. According to the above analysis, the content of montmorillonite and illite in the secondary minerals of sandy soil only accounts for 6.5%, while the content of montmorillonite and illite in the secondary minerals of soft rock ranges from 5.4% to 59%. The content of secondary minerals was all greater than 20%. Therefore, the combination of shoal soft rock with higher secondary mineral content and sandy soil can significantly improve the water and fertilizer retention capacity of sandy soil. And soft rock is a natural material. It
is widely distributed in the Mu Us sandy land, with high reserves and low difficulty in obtaining. Therefore, the soft rock is an ideal material to help "sand" to "soil" in the Mu Us sandy land.

The difference in mineral composition of sedimentary rocks is affected by the parent rocks and the sedimentary environment[9-10]. According to the above analysis, it is known that the mineral types of soft rocks of different colors in the Mu Us sandy land are basically the same. The original minerals are mainly quartz and feldspar, and the secondary minerals are mainly montmorillonite and illite, which indicates that the parent rocks of the soft rock are basically the same. The mineral content of soft rock of different colors is different, which indicates that the sedimentary environments formed by soft rock of various colors are slightly different. Dark and green soft rocks are formed in reducing environments, and light and brown soft rocks are formed in oxidizing environments.

5. Conclusion
The soft rock of Mu Us sandy land is mainly composed of quartz, potash feldspar, plagioclase, calcite, montmorillonite, illite and kaolinite. The mineral composition of soft rock of different colors is quite different. The quartz content is from 17.1% to 88.8%, the potassium feldspar content is from 3.7% to 16.4%, the plagioclase content is from 0% to 38.2%, and the calcite content is from 0.7% to 52.7% the montmorillonite content is from 0% to 51.33%, the illite content is from 0.2% to 13.6%, and the kaolinite content is from 0.3% to 12.5%. The gray-white soft rock has the lowest secondary mineral content, accounting for only 5.4%; the light-brown soft rock has the highest secondary mineral content, up to 59%. Aeolian sand is composed of quartz, potash feldspar, plagioclase, calcite, amphibole, montmorillonite, and illite. The content of primary minerals is 93.5%, and the content of secondary minerals is 6.5%. The results of the study of the mineral composition of soft rock and sandy soil have important reference significance for exploring the mechanism of soil formation from soft rock and sand and exploring new types of natural composite materials.

Acknowledgments
This work was financially supported by the project of Shaanxi Provincial Land Engineering Construction Group (DJNY2019-23).

References
[1] Han, J. C., Liu, Y. S., and Luo, L. T., 2012, Research on the core technology of remixing soil by soft rock and sand in the Maowusu sand land region, China Land Science 26 (8): 87-94.
[2] Li, Z., Schneider, R. L., Morreale, S. J., Xie, Y., Li, C., and Li, J., 2018, Woody organic amendments for retaining soil water, improving soil properties and enhancing plant growth in desertified soils of Ningxia, China, Geoderma 310: 143-152.
[3] Mi, J., Gregorich, E. G., Xu, S., McLaughlin, N. B., Ma, B., and Liu, J., 2017a, Effect of bentonite amendment on soil hydraulic parameters and millet crop performance in a semi-arid region, Field Crops Research 212: 107-114.
[4] Ni, H., Zhang, L., Zhang, D., Wu, X., and Fu, X., 2008, Weathering of Pisha-sandstones in the wind-water erosion crisscross region on the Loess Plateau, Journal of Mountain Science 5 (4): 340-349.
[5] Sun, Z., and Han, J., 2018, Effect of soft rock amendment on soil hydraulic parameters and crop performance in Mu Us Sandy Land, China, Field Crops Research 222: 85-93.
[6] Tahir, S., and Marschner, P., 2016, Clay amendment to sandy soil—effect of clay concentration and ped size on nutrient dynamics after residue addition, Journal of soils and sediments 16 (8): 2072-2080.
[7] Xu, S., Zhang, L., McLaughlin, N. B., Mi, J., Chen, Q., and Liu, J., 2015, Effect of synthetic and natural water absorbing soil amendment soil physical properties under potato production in a semi-arid region, Soil and Tillage Research 148: 31-39.
[8] Zhang, K., Xu, M., and Wang, Z., 2009, Study on reforestation with seabuckthorn in the Pisha Sandstone area, Journal of Hydro-environment Research 3 (2): 77-84.
[9] Veron, S. R., Paruelo, J. M., and Oesterheld, M., 2006, Assessing desertification, Journal of Arid Environments 66 (4): 751-763.

[10] Miščević, P., and Vlastelica, G., 2017, Estimation of embankment settlement caused by deterioration of soft rock grains, Bulletin of Engineering Geology and the Environment: 1-11.