The effect of mineral composition in the compound soil of soft rock and sand on special surface area and cation exchange capacity

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Abstract. The X-ray diffraction method and gas adsorption method were used to investigate the mineral composition and special surface area of different soft rocks, sands, and composed soil. The results showed that (1) Montmorillonite, kaolinite, potash feldspar, calcite, quartz, plagioclase and illite, constitute the soft rock. Quartz, potash feldspar, plagioclase, calcite, montmorillonite, illite, and kaolinite constitute the soft rock in the Mu Us sandy land. There are several types of soft rocks, and there are some differences in the mineral composition of different types. The highest primary mineral content is 94.6\% and the lowest 41\%; the secondary mineral content is the highest 59\% and the lowest is 5.4\%; (2) The special surface area of different types of soft rock is quite different, and the special surface area is up to 17.14 m\textsuperscript{2}g\textsuperscript{-1}, the lowest is 3.12 m\textsuperscript{2}g\textsuperscript{-1}, and the average content is 9.98 m\textsuperscript{2}g\textsuperscript{-1}. The cation exchange capacity is up to 7.25 cmol(+)kg\textsuperscript{-1}, and the lowest is 3.36 cmol(+)kg\textsuperscript{-1}; (3) The fitting formula of secondary minerals and specific decomposition of arsenic sandstone, aeolian sandy soil and composite soil is $y = 2.423e^{0.0871x}$, and the correlation coefficient $R^2 = 0.8258$. The fitting formula for the exchange capacity of secondary minerals and cations is $y = 3.105e^{0.0348x}$, and the correlation coefficient $R^2 = 0.9235$.

Keywords: Soft rock, mineral composition, special surface area, cation exchange capacity.

1. Introduction
Mu Us Sand is situated in the edge zone of the Loess Plateau and the Ordos Plateau. It has the characteristics of flat geographical conditions, abundant solar energy resources, and no environmental pollution. It has huge ecological and economic potential and can be used as a reserve resource for cultivated land [1].
A large number of soft rocks are also distributed in frontier areas such as Shaanxi, Ningxia and Inner Mongolia. Soft rock means mudstone, sandstone and conglomerate that are prone to soil erosion. Predecessors have conducted a lot of research on the following aspects, the nature of soft rock [4], type [5] and distribution [6], soil erosion characteristics [7] and vegetation management, ecological Safety evaluation [8]. As for the formation technology of soft rock-sand composite soil, a great deal of research has been done on water and sand fixation of soft rock-sand composite soil [8]. Zhang et al. found that when soft rock and sand are compounded in a ratio of 1:2~1:5, the structure, texture, capillary porosity and saturated hydraulic conductivity of the compound soil have been significantly improved compared to aeolian sandy soil [7]. She and other studies have shown that soft rock could effectively reduce the infiltration rate and saturated water conductivity of aeolian sand, increase the saturated and retained water content of aeolian sand, and improve the water-holding capacity of aeolian sand [9]. Sun et al. found that the composite soil of soft rock and sand can improve the hydraulic parameters of soft rock soil and significantly increase the crop yields of wheat and corn [10].

Theoretically, the specific surface area and charge characteristics of soft rock directly affect the fertility of the composite soil. There is a mutual influence between the mineral composition of soft rock and the specific surface area and charge characteristics, but there are no experiments and studies to show both a clear quantitative relationship between. In this paper, through a correlation study on the mineral composition, specific surface area, and charge characteristics of soft rock, the quantitative relationship between the mineral composition, specific surface area and charge characteristics of soft rock, soft rock soil, and composite soil is obtained, and then proposed. In order to fully explore the scientific mechanism of soft rock and sand composite soil, maximize the farmland quality of soft rock and sand composite formation, and explore new natural composite materials, it is necessary to in-depth study of the scientific mechanism of composite soil mineralogy.

2. Methods and materials

The test samples in this study are different types of soft rock. There are all from Ordos City, Inner Mongolia, and Yulin City, Shaanxi Province (Fig.1). The Composite soil is a mixture of brown soft rock and sand in a fixed proportion (brown soft rock: 20%, 33% and 50%) to form soft rock-sand composite soil. The mineral content detection of Soft rock, aeolian sandy soil and compound soil is X-ray diffraction method. Samples of clay minerals with particle sizes less than 10 microns and less than 2 microns will be extracted first. The 10-micron sample is used to test the total rock mineral content

Figure 1. The picture of soft rocks and sands.
and the total relative content of clay minerals in the original rock. The relative content of various clay minerals is determined by the clay mineral samples under 2 microns.

This time, the specific surface area mainly adopts the gas adsorption method. After dragging the sample under vacuum, use the ASAP-2000 rapid surface instrument from MIC Company to fill the liquid nitrogen, monitor its pressure and adsorption capacity, and use the BET theoretical model formula to calculate the specific surface area of samples. The amount of cation exchange this time adopts acid-base titration. Titrate the acetic acid prepared from the sample with sodium hydroxide standard solution to calculate the cation exchange capacity of the sample.

3. Results

3.1. Mineral composition of soft rock, aeolian sandy soil and composite soil

The soft sandstone mainly contains quartz, potassium feldspar, plagioclase, calcite, montmorillonite, illite and kaolinite. The mineral composition of different colored soft rock varies greatly, with quartz content ranging from 17% to 88%, potassium feldspar content from 4% to 16%, plagioclase content from 0% to 38%, calcite content from 0.7% to 52.7%, montmorillonite content from 0% to 51.33%, illite content from 0.2% to 13.6%, and kaolinite content from 0.3% to 12.5%. The content of secondary minerals in grayish-white soft sandstone is the lowest, accounting for only 5.4%. The secondary mineral content of light brown soft tite sandstone is the highest, up to 59%. Wind-sand soil is composed of quartz, potassium feldspar, plagioclase, calcite, amphibole, montmorillonite and illite, among which the primary mineral content accounts for 93.5% and the secondary mineral content accounts for 6.5%. The specific content is shown in Figure 2.

![Figure 2. Mineral content of Composite soil, various Soft rock and Aeolian sandy soil.](imageURL)

In the process of soil formation, quartz, potassium feldspar, plagioclase, calcite, dolomite, pyrite, amphibole belong to primary minerals, while montmorillonite, illite, kaolinite belong to secondary minerals. The content of primary minerals in the soft rock can reach up to 94.6% and 41% respectively, with an average of 72.8%. The content of secondary minerals was up to 59%, the content of secondary minerals was up to 5.4, and the average content was 27.1%. The primary mineral content of sandstorm soil is 93.5% and the secondary mineral content is 6.5%. The specific contents of primary and secondary minerals of each type of soft rock and sand soil are shown in Figure 3.
Figure 3. Primary and secondary mineral content of Composite soil, various Soft rock and Aeolian sandy soil.

3.2. Correlation analysis of mineral composition and specific surface area and cation exchange capacity of soft rock, aeolian sandy soil and composite soil

The specific surface area of different types of soft rock is quite different, the highest is 17.14 m$^2$/g, the lowest is 3.12 m$^2$/g, and the average is 9.98 m$^2$/g. The specific surface area of various soft rock and aeolian sandy soil is shown in Table 1. Through the analysis of the correlation between the secondary minerals of soft rock and the specific surface area (Fig. 4), it can be found that the two have an exponential relationship, and the correlation is high, the correlation coefficient is 0.8258, and the fitting formula is $y = 2.423e^{0.0871x}$.

The charge of different types of soft rock is quite different. The highest cation exchange capacity can reach 7.25 cmol(+)/kg and the lowest is 3.36 cmol(+)/kg. The specific surface area of various types of soft rock and aeolian sand is shown in Table 1. Through the analysis of the correlation between the secondary minerals of soft rock and the cation exchange capacity (Fig. 4), it can be found that the two have an exponential relationship, and the correlation is high, the correlation coefficient is 0.9232, and the fitting formula is $y = 3.105e^{0.0348x}$.

| Name                        | Specific surface area (m$^2$/g) | Cation exchange capacity (cmol(+)/kg) |
|-----------------------------|---------------------------------|--------------------------------------|
| Grayish white soft rock     | 3.12                            | 3.36                                 |
| Pink soft rock              |                                 |                                      |
| Grayish yellow soft rock    | 15.62                           | 7.25                                 |
| Grayish green soft rock     | 12.585                          | 5.54                                 |
| Purple soft rock            | 12.46                           | 6.33                                 |
| Yellow soft rock            | 4.4                             | 4.33                                 |
| Gray soft rock              | 4.01                            | 4.25                                 |
| Light brown soft rock       | 10.48                           | 4.66                                 |
| Brown soft rock             | 17.14                           | 6.21                                 |
| Yellow brown soft rock      |                                 |                                      |
| Aeolian sandy soil          |                                 |                                      |
| Composite soil (25%)        |                                 |                                      |
| Composite soil (33%)        |                                 |                                      |
| Composite soil (50%)        |                                 |                                      |

Table 1. Specific surface area and cation exchange capacity of soft rock and sand
4. Discussion

Through the above analysis, it is known that there is a good correlation between the content of secondary minerals in soft rock, aeolian sand and composite soil with specific surface area and cation exchange capacity, and can be used as $y=2.423e^{0.0871x}$ and $y=3.105e^{0.0348x}$ equivalent conversion. In the "Technical Specification for Soil Reconstruction Engineering of soft rock and Sand Compound" (DB61/T 1088-2017), the requirements for the clay content in the soft rock are actually the requirements for secondary minerals [10]. Secondary minerals are the key factor for the water retention and fertilizer retention of soil [9]. Through the above analysis, it is known that the content of secondary minerals directly affects the specific surface area of the soil, because the specific surface area of secondary minerals is many times larger than that of primary minerals. In the cation exchange capacity, the large specific surface area can absorb more ions, and meanwhile the large specific surface area can increase ion exchange capacity.

The sedimentary environment with weak hydrodynamic force is easy to enrich clay minerals, such as yellow-brown soft rock, brown soft rock, and gray-yellow soft rock. The sedimentary environment with strong hydrodynamic force is easy to enrich stable minerals such as quartz and feldspar, such as gray-white soft rock and gray-brown soft rock. In the process of arsenic and sand compounding, the soft rock should be selected in the sedimentary environment with weak hydrodynamic conditions, such as yellow-brown soft rock, brown soft rock, and gray-yellow soft rock. The specific surface area and cation exchange capacity of the composite soil have been significantly increased, which can greatly improve the farmland quality of the arsenic and sand composite soil.

5. Conclusion

(1) Montmorillonite, kaolinite, potash feldspar, calcite, quartz, plagioclase and illite, constitute the soft rock. There are several types of soft rocks, and there are some differences in the mineral composition of different types. The highest primary mineral content is 94.6% and the lowest 41%; the secondary mineral content is the highest 59% and the lowest is 5.4.

(2) The specific surface area is as high as 17.14 m$^2$g$^{-1}$, the lowest is 3.12 m$^2$g$^{-1}$ of soft rock in the aeolian sandy soil and composite soil, and the average is 9.98 m$^2$g$^{-1}$. The secondary mineral content determines the specific surface area, and the two have an exponential relationship in the soft rock, aeolian sandy soil and composite soil. The fitting formula is $y=2.423e^{0.0871x}$, and the correlation coefficient $R^2=0.8258$.

Figure 4. Relationship between secondary mineral content and special surface area and cation exchange of various color soft rocks and sands
The cation exchange capacity can reach up to 7.25 cmol\(^{(+)}\) kg\(^{-1}\), and the lowest is 3.36 cmol\(^{(+)}\) kg\(^{-1}\) in soft rock, aeolian sandy soil and composite soil in the Mu Us sandy land. The secondary mineral content of soft rock, aeolian sandy soil and composite soil determines the cation exchange capacity. The fitting formula for the secondary mineral and cation exchange capacity is \(y=3.105e^{0.0348x}\), and the correlation coefficient \(R^2=0.9235\).

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