Postprint: Quantitative Mineral Analysis of Mu Us Sandy Land Samples by Scanning Electron Microscopy

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Abstract

Mineral quantitative analysis experiments were conducted using the MLA650F Mineral Liberation Analyzer manufactured by Czech FEI Company. The MLA raw sample method and MLA heavy mineral method were employed to analyze the mineral composition and content of typical sand samples from the southwestern and southeastern regions of the Mu Us Sandy Land. The results indicate that the MLA650F instrument demonstrates good repeatability and high precision, detecting a more comprehensive range of mineral species than optical microscopy; however, it cannot directly provide the most primitive mineral characteristics such as color, shape, transparency, luster, and surface fracture in the same manner as optical microscopy. Although certain differences exist in the individual mineral contents and mineral analysis indices measured by scanning electron microscopy and optical microscopy, the trends in mineral content variation are fundamentally consistent, both concluding that the primary light minerals in the Mu Us Sandy Land are dominated by quartz-feldspar, while heavy minerals are dominated by amphibole-garnet. Additionally, the trends in mineral analysis indices for the same sample measured by scanning electron microscopy and optical microscopy are essentially consistent, with the Q/TF and ATi indices from the MLA raw sample method and optical microscopy aligning with the chemical weathering index CIA results, collectively indicating that weathering intensity is greater in the southwestern region than in the southeastern region of the Mu Us Sandy Land. Although both scanning electron microscopy and optical microscopy can reflect the sedimentary environment of sediments, it is essential in practical work to ensure that the data utilized are established within the same measurement system, and experimental data obtained from different laboratories or experimental methods should be cited with caution.

Full Text

Quantitative Mineral Analysis of Mu Us Sandy Land Samples Using Scanning Electron Microscopy

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Abstract

This study employs optical microscopy and MLA650F mineral liberation analyzer (using both original sample and heavy mineral methods) to conduct mineral analysis of sand samples from the Mu Us Sandy Land. The findings reveal that MLA650F exhibits excellent repeatability and high precision, detecting a richer variety of minerals than optical microscopy, including altered minerals. Due to differences in testing principles and sample preparation procedures between optical microscopy and MLA650F, discrepancies exist in individual mineral content measurements, yet the overall trends in mineral variation remain consistent. Both methods conclude that the main light minerals are quartz and feldspar, while heavy minerals are dominated by hornblende and garnet. Although mineral analysis indices differ between the two methods for the same sample, their variation trends are fundamentally consistent. Specifically, the Q TF and ATi indices from MLA original sample method and optical microscopy align with the chemical weathering index (CIA), both indicating stronger weathering in the southwestern region compared to the southeastern region of the Mu Us Sandy Land. Optical microscopy and MLA650F each possess distinct advantages and limitations, allowing researchers to select appropriate methods based on their needs. Notably, data used in practical work should be established within the same measurement system, and experimental data from different laboratories or methods should be cited with caution.

Keywords: QEMSCAN; mineral analysis; Mu Us Sandy Land

1. Study Area Overview

The Mu Us Sandy Land is one of China' s four major sandy lands, located between 107°20 -111°30 E and 27.5 -39°22.5 N, primarily situated in the southeastern depression of the Ordos Plateau. The area features diverse aeolian landforms, including fixed, semi-fixed, and mobile dunes. Characterized by a temperate arid to semi-arid continental monsoon climate with typical transitional features, the region has an average annual temperature of 6–9°C, average annual precipitation of 200–490 mm, average wind speed of 2.5–4 m · s^{-1}, and annual evaporation of 1,800–2,500 mm. Following Lancaster' s sampling standards for desert environments, we selected sand surfaces of approximately 20 cm × 20 cm and uniformly collected surface samples from 0–10 cm depth. This study focuses on sample MLA-YY from the southwestern region and sample MLA-ZK from the southeastern region [Figure 1: see original paper].

2. Research Methods

Mineral analysis was performed using the Czech-made MLA650F mineral liberation analyzer, which combines scanning electron microscopy with X-ray energy dispersive spectroscopy to identify minerals based on elemental composition. The experimental procedure includes: (1) Sample preparation: For the original sample method, 100 g of sand was divided, washed to remove organic debris, and prepared for analysis; for the heavy mineral method, samples were initially screened with a pan and heavy minerals extracted using tribromomethane. (2) Resin embedding: Samples were embedded in 30 mm diameter molds using resin and hardener with a Danish Struers CitoVac vacuum cold mounting system. (3) Grinding and polishing: Samples were polished using a Danish Struers Tegramin-25 automatic grinder through multiple stages. (4) Carbon coating: All samples were carbon-coated using an American Anatech carbon coater.

3. Results

3.1 Test Result Accuracy Repeated test results for the original sample method are presented in Table 1. Both pretreatment methods yielded identical mineral types in replicate experiments, including quartz, various feldspars, micas, fayalite, and 21 total mineral species. Repeated testing on the MLA650F analyzer shows standard deviations of 0–0.87% for the original sample method and 0–2.39% for the heavy mineral method, with variation amplitudes below 3%, demonstrating high precision. The original sample method shows smaller standard deviations, likely because it avoids artificial mineral removal, whereas the heavy mineral method may leave light mineral residues during screening, diluting heavy mineral content. Operator experience may affect heavy mineral method accuracy, so the same technician should process each batch.

3.2 Light Mineral Content Comparison Light minerals are defined as rock-forming minerals with specific gravity less than 2.86 $g \cdot cm^{-3}$. Since heavy mineral pretreatment removes most light minerals, comparison focuses on sample MLA-YY. Statistical results show optical microscopy identified five light mineral types (quartz, feldspar, chlorite, carbonates), while MLA650F detected additional minerals including minor mica, talc, and kaolinite. Both methods indicate quartz and feldspar dominate light mineral content, with other minerals below 1%. MLA650F original sample method measured quartz at approximately 44.72% (5.91% lower than optical microscopy) and feldspar at approximately 50.63% (5.91% higher). This discrepancy arises because MLA650F grinding and polishing removes altered mineral surfaces, eliminating altered mineral content. Feldspar is less stable than quartz and more susceptible to alteration, causing optical microscopy to underestimate feldspar and overestimate quartz. Despite content differences, variation trends remain consistent between methods [Figure 2: see original paper].

3.3 Heavy Mineral Content Comparison Heavy minerals in terrigenous clastic rocks have densities exceeding 2.86 $g \cdot cm^{-3}$, are abrasion-resistant and stable, and preserve parent rock information effectively, with different provenance areas exhibiting distinct heavy mineral assemblages. Analysis of all samples reveals optical microscopy identified 21 heavy mineral types, while MLA650F detected 50 types, including minor tremolite, olivine, zoisite, allanite, diopside, goethite, andalusite, jadeite, and spinel not found by optical microscopy. This demonstrates MLA650F' s superior capacity for heavy mineral identification.

Table 3 shows inter-method differences for the same samples. MLA650F calculates mineral proportions by area multiplied by specific gravity, whereas optical microscopy counts mineral particles. Optical microscopy shows significantly higher hornblende content, likely because MLA650F' s broader heavy mineral spectrum dilutes hornblende percentages. Despite these differences, both methods show consistent overall trends, indicating hornblende-garnet dominance in heavy mineral assemblages [Figure 3: see original paper].

4. Discussion

Mineral analysis indices, including heavy mineral assemblage analysis and ratios of specific minerals, effectively reflect provenance issues. Regional variations in these indices indicate transport distance from source areas and weathering intensity. Based on geographic differences, we compare mineral maturity (Q TF) and characteristic heavy mineral indices (ATi, GZi, ZTR) between southwestern MLA-YY and southeastern MLA-ZK samples. Higher Q TF values indicate stronger weathering; ATi index (apatite $\times$100%/tourmaline) is source-sensitive; GZi index (garnet $\times$100%/zircon) reveals garnet parent rock composition; ZTR index (zircon + tourmaline + rutile) indicates heavy mineral maturity and transport distance.

Table 4 shows optical microscopy and MLA650F original sample method yield consistent trends for Q TF, ATi, and GZi indices, though ZTR trends differ. Heavy mineral method GZi values contradict other methods, likely due to mineral loss during pretreatment. Overall, optical microscopy and MLA650F original sample method show consistent trends, both indicating stronger weathering in the southwestern region. To verify accuracy, we used the Chemical Index of Alteration (CIA), calculated from Al_2O_3, CaO, Na_2O, and K_2O molar ratios, which correlates positively with weathering intensity. According to Nesbitt and Young, CIA values of 50–65 indicate low chemical weathering under cold, dry conditions. Southwestern and southeastern Mu Us Sandy Land CIA values range 49.28–51.06, indicating low-grade chemical weathering, with higher values in the southwest confirming stronger chemical weathering there—consistent with optical microscopy and MLA650F Q TF and ATi results.

5. Conclusions

This study using optical microscopy and MLA650F (original sample and heavy mineral methods) to analyze Mu Us Sandy Land samples reveals:

1. MLA650F demonstrates excellent repeatability and high precision, detecting richer mineral varieties than optical microscopy, including altered minerals.

2. Due to different testing principles and sample preparation, individual mineral content differs between methods, but variation trends are consistent, both concluding that light minerals are dominated by quartz-feldspar and heavy minerals by hornblende-garnet.

3. Mineral analysis indices differ between methods for the same sample but show consistent trends. MLA650F original sample and optical microscopy Q TF and ATi indices align with CIA, both indicating stronger weathering in the southwestern region.

4. Optical microscopy and MLA650F each have advantages and limitations. Researchers should select methods based on needs, but must use data from consistent measurement systems, citing data from different laboratories or methods with caution.

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