Origin of Northern Gondwana Glaciofluvial Deposit Revealed by Coupling Rare-earth Element and Trace Element Geochemistry


Abstract

Objectives/Scope: The Sarah Formation is a glaciofluvial sedimentary formation that was formed along the Gondwana Margin during the end of the Ordovician ice age. The short-lived ice age resulted in the initial incision and large-scale paleo valley generation. It forms part of an extensive but discontinuous belt of outcrop deposits that extends from westernmost North Africa to the Arabian Peninsula. Notably, the glaciogenic Sarah Formation is a potential tight gas sandstone reservoir in the Rub’ al Khali Basin and other basins in Saudi Arabia. However, on a more global scale, the geochemical data, depositional settings, and spatial distribution correlation of the Late Ordovician glaciofluvial sedimentary formation in several different localities have been poorly reported. Therefore, this study aims to focus on geochemical records to unravel the provenance and tectonic settings of the Late Ordovician Northern Gondwana glaciofluvial sedimentary formation.

Methods, Procedures, Process: Here, we performed inductively-coupled plasma mass spectrometry (ICP-MS) analysis from six outcrops in two paleo valleys of the Sarah Formation in NW Saudi Arabia. The geochemical composition combined with the detailed stratigraphic measurement to capture the clear variance of the provenance, paleoenvironment, and tectonic settings related to the glacial events. Our results were also compared with previous Late Ordovician glaciofluvial sedimentary formation studies in several localities to inform the sediment provenance and tectonic settings.

Results, Observations, Conclusions: The concentration of trace elements showed that Sarah sandstone is rich in Ba, Zr, Sr, Zn, and Rb. The total REE (ΣREE) of the samples varies from 24.7 to 215.9 ppm. Meanwhile, the ΣLREE and ΣHREE range 18.4-196.9 ppm and 2.7-20.9 ppm, respectively. The Europium anomalies (Eu/EuCN) are as low as 0.4, with an average value of 0.7. The Sarah sandstones show high LREE/HREE ratios of 11.9. The high Zr content, high ratio LREE/HREE, and Eu anomalies of Sarah sandstone match the condition that sediment was derived mainly from the felsic igneous rock. Furthermore, the low (Gd/Yb)CN ratios of 1.8 in Sarah sandstone indicate the provenance is from the Post-Archean strata. The Ti/Zr and La/Sc ratios of the samples suggest that the Sarah Formation in NW Saudi Arabia is deposited in the passive continental margin setting. On a broader regional scale, the Late Ordovician glaciofluvial sediments from several localities are consistently derived from the exact provenance but deposited in slightly different tectonic settings.
**Novel/Additive Information:** Our results highlight that major, trace, and rare earth elements (REEs) combined with the detailed stratigraphic measurement are considered effective tracers of the lithosphere and hydrosphere geological processes and encompass the understanding of the several processes involved in their formation. More importantly, the results might be essential to provide guidelines for exploration, development, and tight gas sandstone reservoir quality prediction of the glaciofluvial sedimentary formation.