

Reduction of real hematite ore to magnetite in CH₄ atmosphere: the critical role of gangue minerals, particle size, and microcracks

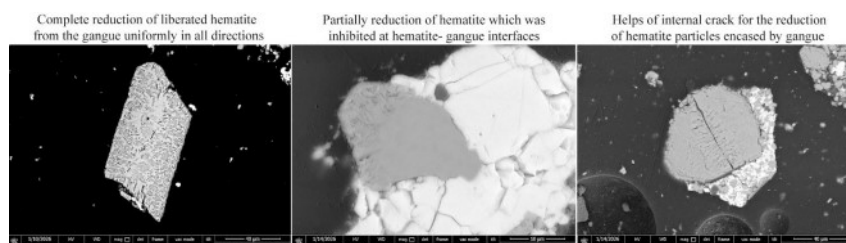
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HIGHLIGHTS

- Direct contact with gangue fully arrests the reduction front.
- Pre-existing microcracks provide internal gas diffusion pathways for CH₄.
- Complete hematite-to-magnetite conversion requires 600 °C in methane.
- Fine particles (38–53 μm) reduce fully; coarse (75–106 μm) retain hematite cores.
- XRD overestimates reduction; cross-sectional FESEM-EDS reveals true gangue-limited extent.

GRAPHICAL ABSTRACT



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ABSTRACT

For decades, hematite reduction has been studied almost exclusively on pure synthetic samples, missing a key reality: real iron ores contain gangue minerals intergrown with hematite. We close this gap using a natural hematite ore (~40 wt% quartz and barite gangue). The ore was crushed into three size fractions (38–53, 53–75, 75–106 μm) and reduced in methane at 400–600 °C in a fixed bed reactor. Rather than relying on bulk techniques like XRD -which can be deeply misleading- we examined polished cross-sections by FESEM-EDS to see exactly where reduction progressed and, more importantly, where it stopped. Three findings stand out: First, temperature is decisive: no reduction occurs at 400 °C, and complete conversion to magnetite requires 600 °C. Second, particle size matters: fine fractions fully reduce within 35 min, whereas coarse particles retain hematite cores. Third and most striking: wherever hematite directly contacts non-reactive gangue (quartz or barite), the reduction front does not cross that interface, even after 35 min at 600 °C. This “gangue-induced arrest” is invisible to XRD but fundamentally limits reduction extent in real ores. Conversely, pre-existing microcracks – inherited from geology or comminution – act as internal gas diffusion pathways, enabling partial reduction even in poorly liberated particles. Our cross-sectional FESEM-EDS approach provides a reliable method to evaluate such effects. Maximizing reduction efficiency in real ores therefore requires either complete hematite liberation or engineered microcrack networks that supply the reducing gas with alternative routes.

1. Introduction

The reduction of hematite (Fe₂O₃) to magnetite (Fe₃O₄) is a reaction

of central importance in the iron and steel industry, but its significance extends well beyond ironmaking alone. In the context of ironmaking – whether via the blast furnace route or direct reduction processes such as

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