



Review Article

A Review of the Geochemistry and Processing Pathways for Sulphur Recovery from Ethiopian Volcanic Deposits

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Abstract

The geological architecture of the East African Rift System, specifically within the Afar Triple Junction and the Main Ethiopian Rift, provides a unique tectono-magmatic environment for the formation of extensive volcanogenic sulphur deposits. This review synthesizes the geochemical characteristics and potential processing pathways for Ethiopia's dormant sulphur resources, which are becoming strategically vital as the nation seeks to mitigate its 100% dependency on mineral imports for its agricultural and industrial sectors. Current assessments identify significant native sulphur reserves at Dallol (7 million tons) and Dofan/Chebrit Ale (6 million tons), alongside over 2.5 billion tons of inferred mixed sulphates in the Danakil Basin. Geochemical investigations, supported by stable sulphur isotope systematics ($\delta^{34}\text{S}$), reveal a polygenetic origin for these deposits: primary magmatic degassing of H_2S and SO_2 at centers like Erta Ale ($\delta^{34}\text{S}$ of -0.5‰ to $+0.9\text{‰}$) contrasts with complex hydrothermal recycling and bacterial sulphate reduction in evaporitic sequences. While the study evaluates the technical feasibility of extraction methods including the Frasch process, froth flotation, and solvent extraction it notes that these pathways, despite recovery efficiencies exceeding 90%, must be meticulously adapted to the hyper-arid, high-enthalpy conditions of the Ethiopian Rift. Ultimately, the integration of domestic sulphur recovery with existing geothermal energy projects is proposed as a critical step toward establishing a self-sustaining industrial ecosystem. By addressing existing knowledge gaps in pilot-scale validation and environmental lifecycle assessments, Ethiopia can leverage its volcanic heritage to ensure national food security and regional economic influence.

Keywords

Sulphur Recovery, Geochemistry, Isotope Fractionation, Frasch Process, Fertilizer Industry, Hydrothermal Mineralization

1. Introduction

The global industrial economy relies heavily on sulfur as a fundamental feedstock, primarily for the manufacture of sulfuric acid, which is instrumental in the production of phosphate fertilizers, metal leaching, and various chemical processes. [1] For a nation like Ethiopia, whose economic foundation is built upon agriculture, the availability and affordability of sulfur are direct determinants of national food secu-

urity and developmental stability [2]. Ethiopia currently occupies a precarious position, possessing significant but largely unquantified volcanogenic sulfur reserves while remaining entirely dependent on expensive imports to meet its industrial requirements. [3, 4] This strategic vulnerability is exacerbated by the volatility of the global sulfur market and the logistical complexities associated with maritime transport through the

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Red Sea [5].

The tectonic setting of Ethiopia is the primary driver of its mineral wealth. Situated at the junction of the African, Arabian, and Somali plates, the Afar Triple Junction represents a unique geological laboratory where continental rifting is progressing toward the formation of a new oceanic basin. [6] This crustal thinning and associated asthenospheric upwelling have facilitated intense volcanic activity and the establishment of high-enthalpy hydrothermal systems. [7] These systems are the birthplaces of various mineral deposits, including potash, salt, and notably, elemental sulfur [8].

Historically, the exploration of Ethiopian sulfur was characterized by fragmented missions and inconsistent methodologies. Records from the 1960s, including Japanese and Italian geological missions, provided initial glimpses into the potential of areas like Dallol, Dofan, and Chebit Ale. However, the hostile nature of the Danakil Depression one of the hottest and most acidic environments on Earth coupled with political instability and a lack of infrastructure, left these resources largely unexploited for decades. Recent assessments in 2025 have revisited these historical records, attempting to reconcile estimates that vary by orders of magnitude, from a mere 1,200 tons to a staggering million tons of potential reserves. [3]

This report aims to provide an exhaustive review of the geochemistry and processing pathways for sulfur recovery in Ethiopia. By analyzing the isotopic signatures that reveal the

origin of these minerals and evaluating the technical feasibility of extraction methods such as the Frasch process and solvent extraction, this study provides a roadmap for sustainable resource management. Furthermore, it examines the environmental and logistical hurdles that must be overcome to transform Ethiopia's volcanic potential into a tangible industrial asset that supports its transition toward "fertilizer diplomacy" and regional economic influence. [5]

1.1. A Conceptual Sulfur Genesis Model

In the context of Ethiopian geology, a conceptual sulfur genesis model integrates the nation's unique tectonic and magmatic settings to elucidate diverse sulfur occurrences. Within the Afar Depression and the Main Ethiopian Rift, primary magmatic sulfur originates from the degassing of mantle-derived melts associated with continental rifting. Concurrently, hydrothermal processes within these volcanic systems facilitate the remobilization and precipitation of elemental sulfur, often evidenced by fumarolic deposits. Furthermore, the model must account for biogenic sulfate reduction in sedimentary basins like the Ogaden, where bacterial activity in evaporite sequences generates hydrogen sulfide. Thus, a comprehensive model for Ethiopia frames sulfur formation as an interplay of deep magmatic, shallow hydrothermal, and surficial biological processes, all fundamentally driven by the region's active rift dynamics and varied lithostratigraphy. [9, 10]

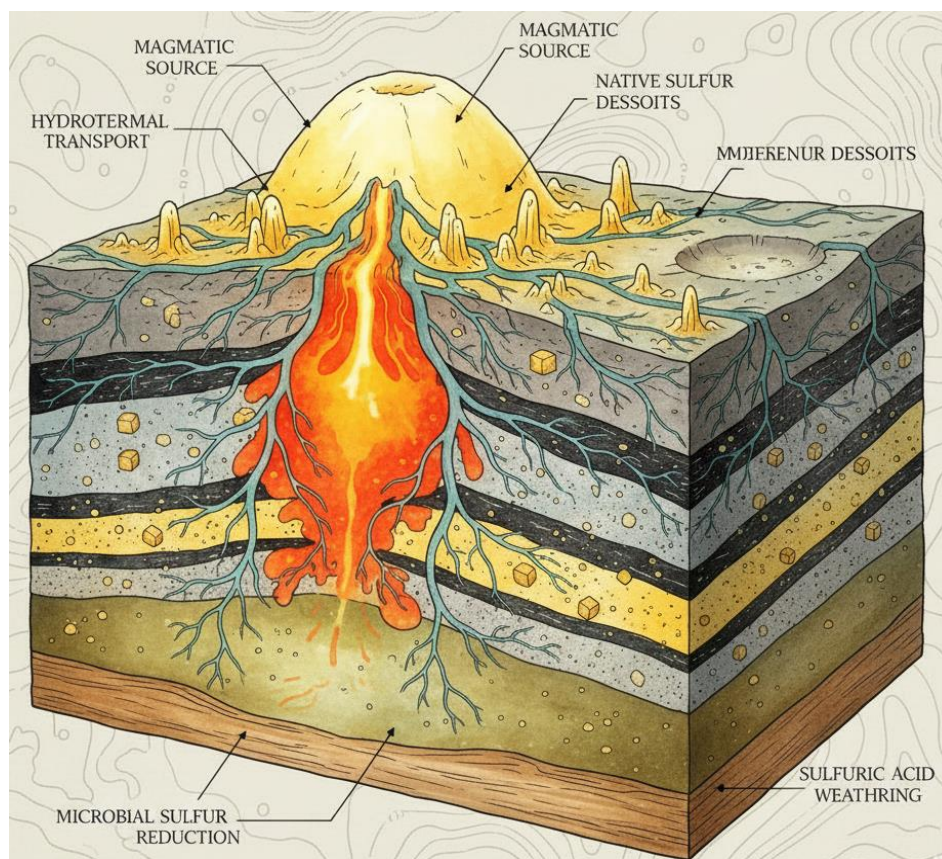


Figure 1. A conceptual sulfur genesis model.

1.2. Geological Map

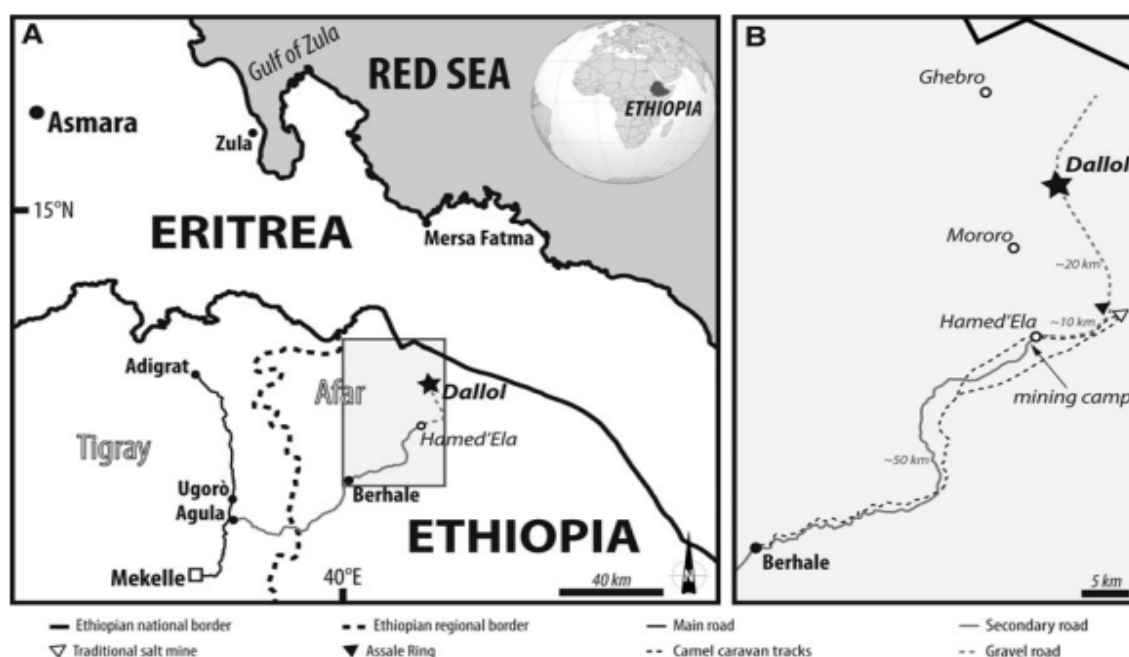


Figure 2. Location of the study area.

Dallol volcano is located in the northern Afar Region, Ethiopia (14°05'28.00" N, 40°17'58.00" E). Roads and tracks extend from Berhale (13°51'46.00" N, 40°01'19.40" E; 67 m a.s.l.) to Hamed'ela (14°05'06.00" N, 40°16'46.00" E; 90 m b.s.l.), leading toward the Dallol geothermal area. The Assale (Skating) Ring (14°07'00.63" N, 40°20'52.59" E) is a phreatic ring structure approximately 20 m high and 110 m in diameter, located about 15 km south of the Dallol volcanic dome [11].

1.3. Geological Setting

The Ethiopian volcanic sulphur deposits are primarily

hosted within the tectonically active East African Rift System (EARS), specifically in the Afar Depression and the Main Ethiopian Rift. This extensional regime creates pathways for mantle-derived magmas and associated volatiles, leading to pervasive hydrothermal activity. Sulphur mineralization occurs in diverse settings, including fumarolic fields, volcanic crater floors (e.g., Dallol), and geothermal alteration zones, where it precipitates from volcanic gases (H_2S , SO_2) upon cooling and oxidation or through acid-sulphate leaching of host rocks [1, 2].

1.4. Ethiopia Sulfur Deposit

Table 1. Major sulfur resources in Ethiopia.

Deposit Location	Estimated Tonnage	Mineral Type	Geological Setting	Resource Status
Danakil Basin (General)	~2.54 Billion	Mixed Sulphates/Potash	Evaporitic Sequence	Inferred Resource
Dallol / Assale	~1,200 - 7M	Native Sulphur (S^0)	Hydrothermal Dome	Indicated / Inferred
Dofan & Chebrit Ale	~6 Million	Native Sulphur (S^0)	Volcanic Fumarolic	Indicated Resource
Zariga & Inkafala	~200,000+	Native Sulphur / Mn	Hydrothermal / Rift	Exploration Stage
Meli / Tigray Range	Significant	Volcanogenic Massive Sulphides (VMS)	Neoproterozoic Basement	Active Prospecting
National (Gypsum)	~57.4 Million	Gypsum / Anhydrite	Sedimentary Basins	Proved / Measured

Ethiopia's Danakil Basin hosts immense inferred resources of mixed sulphates and potash (~2.54 billion tons) in an evaporitic setting. Native sulphur deposits, primarily hydrothermal and fumarolic, are found in areas like Dallol and Dofan, with resources ranging from millions of tons. Additional prospects include volcanogenic massive sulphides (VMS) in the Meli/Tigray Range and national gypsum deposits exceeding 57 million tons. Overall, the country's mineral resources span from advanced exploration to measured reserves across varied geological environments. Despite possessing Ethiopia continues to import the majority of its supply. The country's current domestic demand primarily for the fertilizer and sulfuric acid industries stands at approximately 20,500 tons per year, highlighting a significant opportunity for the development of local volcanic deposits. [12-14]

1.5. Data Sources and Review Framework

This review employs a systematic framework to synthesize existing geological, geochemical, and metallurgical data concerning Ethiopia's volcanic sulphur resources. The methodology ensures that disparate historical records and modern analytical results are integrated to identify strategic processing pathways and critical knowledge gaps.

1.5.1. Geochemical and Analytical Framework

The characterization of Ethiopian sulphur deposits relies on a multi-scale analytical approach to resolve their genetic origins and transformation pathways. Elemental analysis, primarily conducted using ICP-MS and AAS, provides a baseline for quantifying sulphur concentrations and identifying critical trace-element contaminants such as As, Pb, and Ni [15]. To determine specific mineral phases within complex evaporite sequences, including those of the Houston Formation, mineralogical techniques such as X-ray diffraction (XRD) and scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM-EDS) are commonly employed. A critical component of modern studies is the synthesis of stable sulphur isotope systematics ($\delta^{34}\text{S}$). Using gas-source isotope ratio mass spectrometry (G-IRMS) and secondary ion mass spectrometry (SIMS), with results reported relative to the VCDT standard, the literature differentiates between magmatic, marine, and biogenic sulphur sources. [16-18] These high-resolution analytical techniques are essential for constraining fluid rock interactions that govern hydrothermal systems.

1.5.2. Technical Feasibility and Processing Pathway Analysis

The review evaluated various sulfur recovery technologies

through a comparative analysis of their operational parameters and their suitability for Ethiopia's extreme rift environment. **Frasch Process Evaluation:** The physical requirements for the Frasch process, including superheated water volumes, pressure gradients, and depth constraints (50-800 meters), were compared against the geological profile of the Danakil salt domes. [19] **Flotation and Solvent Extraction Modeling:** Technical feasibility was assessed by reviewing pilot plant studies on sulfur flotation (achieving 85–90% concentrate) and solvent extraction using trichloroethylene or heavy naphtha (achieving 90%+ recovery). [20] **GIS-Based and Environmental Modeling:** Geographic Information Systems (GIS) were used to analyze landslide susceptibility and the proximity of resources to industrial hubs. [21] **Environmental impact modeling** focused on the transport and storage risks of granulated sulfur and the potential for acid mine drainage. [22]

The synthesis process explicitly mapped the density and quality of available information. Gaps were identified where: geochemical characterization was insufficient to inform process design; proposed methods lacked pilot-scale validation for the specific ore types; or socio-economic and full lifecycle assessments were absent. This analysis forms the basis for the recommendations for future research presented in the conclusion.

This review of geochemical and processing pathways is framed within a critical national economic objective: reducing Ethiopia's foreign exchange expenditure on fertilizer imports. The analysis of deposit characteristics and recovery methods is therefore contextualized against macro-economic assessments of national fertilizer demand and the viability of localized sulphur production to support the domestic fertilizer blending initiative. [2]

2. Results

The assessment of Ethiopian volcanogenic sulfur resources reveals a landscape of immense potential but significant geological and quantitative variability. Results are categorized by geographical location, geochemical profile, and mineralogical composition. Exploration activities have confirmed the presence of native sulfur at several key volcanic centers within the East African Rift. The most prominent sites include the Dallol hydrothermal field in the northern Danakil Depression, the Dofan volcano in the northern Main Ethiopian Rift, and the Chebrit Ale area. [3]

Table 2. Regional Resource Distribution and Reserve Estimates.

Deposit Location	Estimated Reserves (Metric Tons)	Geological Context	Observed Sulfur Form
Dallol	~7,000,000	Hydrothermal field in thick evaporites	Mounds, precipitates, fumarolic crusts
Dofan and Chebrit Ale	~6,000,000	Rhyolitic shield volcano; flank craters Volcanic-sedimentary interface	Fumarolic sulfur, steam deposits Native sulfur in evaporite sequences
Non-Volcanic Areas	Significant (Unquantified)	Mesozoic and Tertiary sediments	Gypsum, Anhydrite, Kieserite

The largest known resources of elemental sulfur are concentrated in the volcanic regions of the Afar Depression, particularly the hydrothermal field at Dallol (~7 million tons) and the volcanic craters at Dofan and Chebrit Ale (~6 million tons). These deposits form as mounds and crusts from volcanic and fumarolic activity. Additionally, significant sulfur reserves are present in non-volcanic areas as mineral compounds like gypsum and anhydrite within sedimentary basins, though these resources remain unquantified. [13, 14]

2.1. Geochemical Composition of Hydrothermal Fluids

The hydrothermal systems driving sulfur mineralization in Ethiopia are characterized by extreme chemical parameters, particularly in the Dallol area. The fluids are anoxic, hyper-acidic ($\text{pH} \approx 0$), and hyper-saline, containing significant concentrations of dissolved metals. [13] Analysis of eight water samples from hot spring-associated ponds in Dallol provided the following geochemical indicators: Total Organic Carbon (TOC): 94 to 902 ppm, suggesting the presence of hydrocarbon fluids at depth or lateral migration. Sulfate (SO_4^{2-}): 19 to 60 ppm (generally low, except for one outlier at 117 ppm). Sulfide (S^{2-}): 27 to 111 ppm (generally low, except for one outlier at 965 ppm). Iron (Fe): Exceeding 26 g/L in the hyper-acidic brines. The low concentrations of dissolved sulfate and sulfide in surface ponds suggest that these complexes are rapidly being converted into solid elemental sulfur or sulfide minerals through bacterial reduction or degassing processes. [15, 23]

2.2. Isotope Geochemistry and Genetic Origins

Stable sulfur isotope analysis ($\delta^{34}\text{S}$) provides critical evidence for the origin of the sulfur. The variations in isotopic composition are caused by fractionation during oxidation, reduction, and degassing events. [16] Erta Ale Range: Gases and scoria exhibit ($\delta^{34}\text{S}$) values between -0.5‰ and $+0.9\text{‰}$ indicating a primary, deep-seated magmatic source with minimal crustal contamination. [24] Dallol Hot Springs: Isotopic ratios for ($\delta^{34}\text{S}$) and ($\delta^{33}\text{S}$) predict complex pathways involving both magmatic SO_2 and the bacterial reduction of seawater-derived sulfates. [14] Sarnak/Northern Ethiopian Basement: Pyrite samples show a wide ($\delta^{34}\text{S}$) range from -25.78 to $+12.11$, reflecting a history of fluid boiling, cooling, and the mixing of deep hydrothermal fluids with shallow, oxidized meteoric waters. [16]

These results indicate that while some sulfur is purely magmatic, the economically significant deposits in the Danakil and Rift Valley are often polygenetic, involving the recycling of ancient marine sulfates through modern hydrothermal circulation.

2.3. Trace Element and Heavy Metal Associations

Volcanogenic sulfur deposits in Ethiopia are not isolated but occur alongside a suite of trace elements. While some elements add potential byproduct value, others present significant environmental challenges. [25]

Table 3. Trace Element Concentrations and Risks.

Trace Element	Concentration/Prevalence	Implications
Arsenic (As)	Up to 405 mg/L in Rift surface waters	High toxicity; human health risk (arsenicosis)
Nickel (Ni)	Average 106.3 mg/L in tailings water	Exceeds WHO drinking water guidelines
Lead (Pb)	Up to 24.6 mg/L in community wells	Geogenic and mining-related contamination
Selenium (Se)	Present in mafic-associated sulfides	High Co, Ni, and Se in specific massive sulfides

Trace Element	Concentration/Prevalence	Implications
Aluminum (Al)	30% of samples above MAC	High concentration in acid mine drainage areas

In mining-impacted areas such as Adola, Arsenic concentrations in community drinking water were found to be up to 36 times the WHO health-based guideline. These trace elements are often associated with the sulfides in the ore aggregate, which are the ultimate source of the metals when exposed to oxidation. [26]

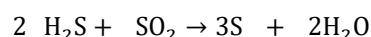
3. Discussion

The integration of geochemical, mineralogical, and technical data reveals that Ethiopia's sulfur potential is intimately tied to its unique tectonic evolution. However, transforming this potential into a productive industry requires addressing significant scientific and engineering challenges.

3.1. Genetic Models for Sulphur Mineralization

The formation of sulfur deposits in the Ethiopian Rift can be explained through two primary mechanisms: magmatic degassing and hydrothermal recycling. In high-temperature volcanic systems like Erta Ale, sulfur is primarily transported

as H₂S and SO₂ gas. Upon reaching the surface or mixing with cooler groundwater, these gases undergo oxidation:



This mechanism is responsible for the pure, bright yellow fumarolic sulfur observed at Dofan and the crests of Dallol.

In contrast, the larger, bedded deposits within the evaporite sequences are likely the result of a salt volcano model. In this scenario, the emplacement of an igneous intrusion beneath the thick Danakil evaporites (specifically the Houston Formation) destabilizes hydrated minerals. [27] This drives the circulation of hyper-acidic brines that leach sulfur from the bedrock. The presence of hydrocarbons, indicated by the moderate TOC levels (up to 902 ppm), provides the necessary energy source for anaerobic, sulfur-reducing bacteria. [20] These bacteria facilitate the transformation of gypsum and anhydrite into elemental sulfur and limestone, a process similar to the formation of sulfur-containing salt domes in the Gulf of Mexico. [19]

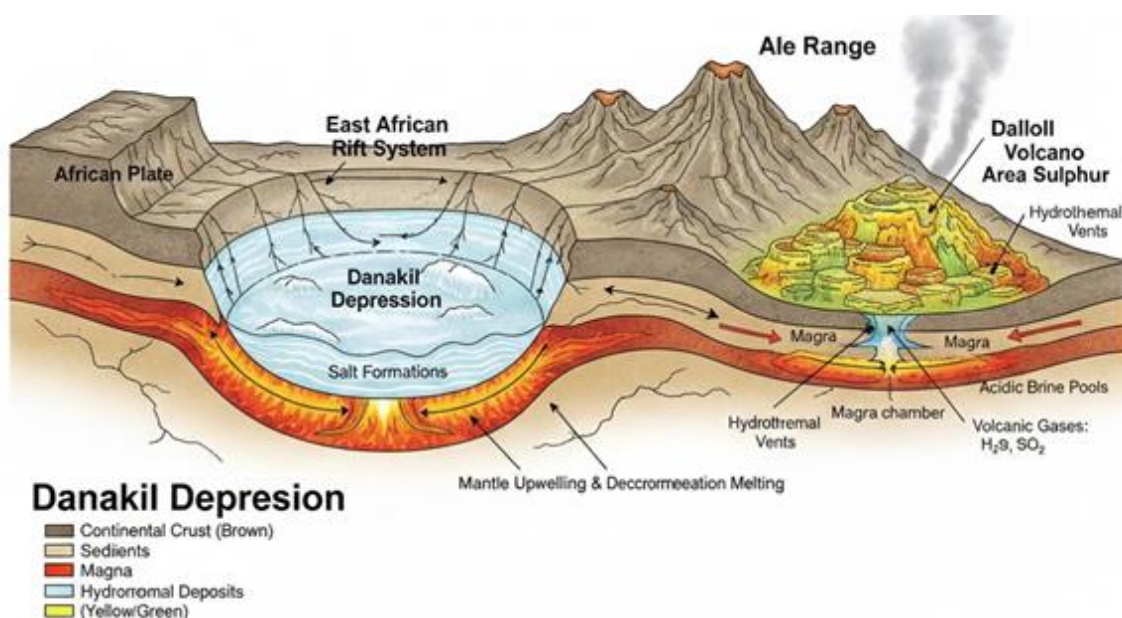


Figure 3. Genetic origin of sulphur mineralization in the Danakil Depression: Ale Range-Dallol area.

3.2. Technical Evaluation of Recovery Pathways

The selection of a processing pathway for Ethiopian sulfur

depends heavily on the depth, grade, and environmental context of the deposit. The Frasch process is the only industrial method for recovering sulfur from deep elemental deposits. While it produces high-purity sulfur (99.7%), its re-

quirement for vast quantities of superheated water (up to 38 m³ per ton of sulfur) is a significant hurdle in the arid Afar region. [19] Furthermore, the process relies on the presence of an impermeable caprock to maintain pressure, a condition that may be compromised by the extensive faulting and tectonic instability of the Danakil Depression. [8] However, if applied to the deeper salt domes of the Danakil, the process could leverage the existing geothermal energy potential of the region to heat the water, thereby reducing fuel costs [28].

For near-surface or low-grade deposits, froth flotation offers a robust alternative. Ores can be crushed and ground to 20 mesh, then processed in Sub-A flotation machines to yield an 85-90% sulfur concentrate. The highly acidic nature of the Ethiopian volcanic ores (pH 2-3) necessitates the use of acid-proof equipment, such as rubber-covered shafts and wooden tanks. [29] The primary advantage of flotation is its ability to handle complex ores containing base metals (Cu, Zn, Ni), allowing for the recovery of multiple mineral products from a single stream. [30]

Solvent extraction using heavy naphtha or trichloroethylene has demonstrated high recovery efficiencies (90%+) and superior product purity (99.9%). Heavy naphtha is par-

ticularly effective at temperatures around 90°C, which are easily maintained in the Danakil environment with minimal additional heating. [25] The feasibility of solvent extraction in Ethiopia is further supported by the local availability of petroleum-based solvents as the country develops its own natural gas and refining capabilities in the Ogaden Basin. [5]

3.3. Sulphur Extraction Technologies

Recovery technologies must adapt to the remote location and specific mineralogy of these volcanic deposits. Traditional artisanal mining involves manual collection and crude melting. Industrial Frasch-process analogues, which use superheated water or steam to melt subsurface sulphur *in situ* for pumping, are conceptually applicable but face challenges due to complex geology and high water stress. Recent research focuses on hydrometallurgical and solvent extraction methods for processing sulphur-bearing ores, alongside flue-gas desulfurization (FGD)-inspired capture from geothermal vent gases. The economic viability hinges on integrating extraction with geothermal energy co-production to offset costs [5, 6].

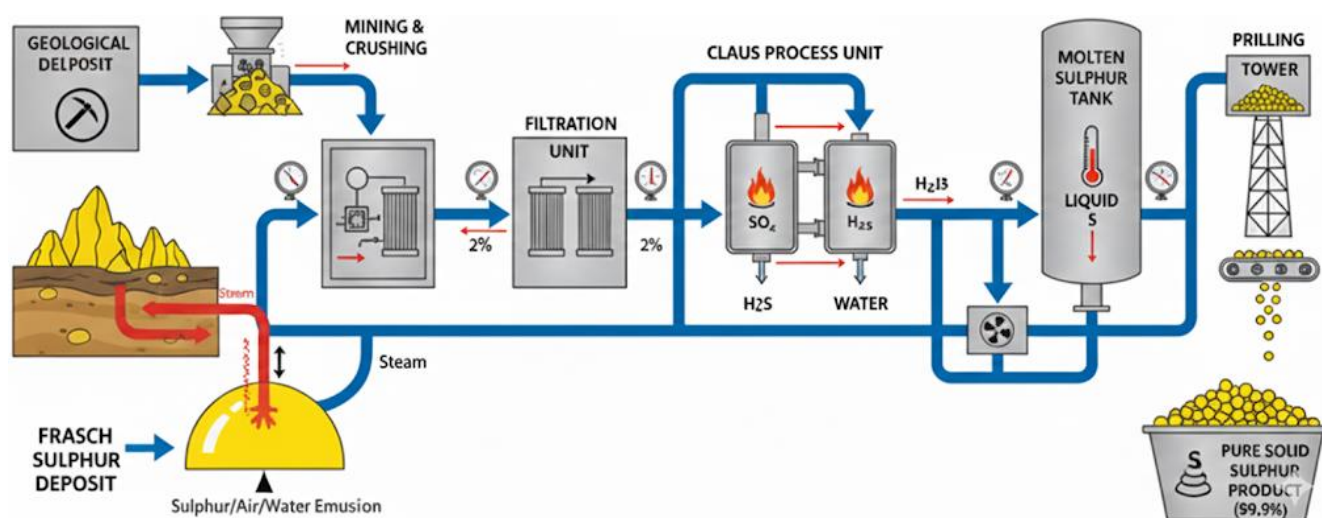


Figure 4. Sulphur processing.

3.4. Economic and Strategic Implications for Ethiopia

The development of domestic sulfur is not merely an in-

dustrial goal but a pillar of Ethiopia's national security strategy. The current dependency on imports for the 20,500 tons of sulfur required annually by the fertilizer industry creates a significant financial burden and strategic vulnerability. [3]

Table 4. Economic Impacts of Local Production.

Economic Factor	Impact of Domestic Production	Strategic Value
Foreign Exchange	Conservation of hard currency reserves	Reduces pressure on national currency [5]
Fertilizer Cost	Lower farm-gate prices for farmers	Enhances agricultural productivity and food self-sufficiency [2]

Economic Factor	Impact of Domestic Production	Strategic Value
Industrial Base	Growth of sulfuric acid and chemical plants	Facilitates broader industrial modernization [5]
Regional Trade	Export potential to the Horn of Africa	Strengthens fertilizer diplomacy and regional influence [5]

The \$3 billion Gode fertilizer plant deal highlights the scale of this ambition. Integrating sulfur recovery with other rift resources such as the 14 identified geothermal sites (including Aluto Langano and Tendaho) and the vast potash deposits would create a self-sustaining industrial ecosystem. [28]

3.5. Environmental and Logistical Constraints

The harshness of the Danakil Depression remains the single greatest barrier to entry. Temperatures exceeding 50 °C and a hyper-arid climate make large-scale industrial operations physically demanding and technically complex. [31] The logistics of transporting sulfur from the remote depression to the central highlands or ports require the development of resilient infrastructure. [8]

Furthermore, the environmental risks associated with sulfur mining must be managed. The potential for sulfur dust explosions and the release of toxic H₂S gas poses risks to both workers and the local Afar communities. [22] Geochemical monitoring is essential to prevent the contamination of the Awash River with heavy metals like Arsenic and Nickel, which are already present at elevated levels due to geogenic weathering. [32] Sustainable remediation using native plants shows promise for stabilizing mining tailings and protecting local water resources. [33]

3.6. Historical Lessons and Future Outlook

The history of sulfur mining, from the closure of Japan's Matsuo Mine to the decline of traditional Sicilian methods, teaches that economic viability is a balance between recovery costs and global market prices. [34] Ethiopia's advantage lies in its geographical proximity to its own burgeoning demand. The Passive Option of continued imports is increasingly untenable as global fertilizer prices remain volatile. [2]

Modern exploration must move beyond the hasty visits and erroneous diagrams of the past. [35] Systematic 3D geological modeling of the rift structure, combined with advanced isotopic tracers, will allow for more accurate reserve quantification. [36] The integration of sulfur recovery into the national development goals specifically the Plan for Accelerated and Sustained Development to End Poverty (PASDEP) marks a transition toward a more scientifically grounded resource policy. [37]

4. Conclusion

The geological synthesis presented in this review underscores Ethiopia's profound potential to transition from a total

reliance on mineral imports to becoming a self-sustaining industrial hub within the East African Rift System. The tectono-magmatic architecture of the Afar Triple Junction and the Main Ethiopian Rift has facilitated the formation of substantial volcanogenic sulphur reserves, notably at Dallol (~7 million tons) and Dofan/Chebrit Ale (~6 million tons). These deposits, characterized by complex polygenetic origins involving magmatic degassing and hydrothermal recycling, represent a strategic asset for the domestic fertilizer and sulphuric acid industries, which currently face an annual demand of approximately 20,500 tons.

Technical evaluations indicate that while the Frasch process remains the industrial standard for deep-seated deposits, its implementation in the arid Danakil region is contingent upon navigating extreme water stress and tectonic instability. Alternatively, near-surface recovery via froth flotation and solvent extraction offers promising efficiencies exceeding 90%, provided that acid-proof infrastructure is utilized to withstand the hyper-acidic environments characteristic of the Ethiopian rift. The integration of these extraction pathways with the nation's vast geothermal energy potential provides a viable roadmap for reducing operational fuel costs and fostering a circular industrial ecosystem.

Despite the clear economic incentives including the conservation of hard currency and enhanced regional fertilizer diplomacy significant barriers remain. The hyper-arid climate of the Danakil Depression, logistical infrastructure deficits, and geogenic environmental risks, such as arsenic and nickel contamination, necessitate rigorous geochemical monitoring and sustainable remediation strategies. Future research must prioritize systematic 3D geological modeling and pilot-scale validation of processing methods to refine reserve quantification and ensure environmental safety.

In summary, the strategic development of Ethiopia's volcanic sulphur deposits is not merely a matter of industrial expansion but a fundamental pillar of national food security and economic sovereignty. By bridging existing knowledge gaps through advanced isotopic tracing and integrated resource management, Ethiopia can successfully transform its unique geological heritage into a tangible driver for the Plan for Accelerated and Sustained Development to End Poverty (PASDEP).

Abbreviation

ICP-MS	Inductively Coupled Plasma Mass Spectrometry
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AAS	Atomic Absorption Spectrometry
G-IRMS	Gas Source Isotope Ratio Mass Spectrometry
SIMS	Secondary Ion Mass Spectrometry
VCDT	Vienna Canyon Diablo Troilite
XRD	X-ray Diffraction
SEM-EDS	Scanning Electron Microscopy with Energy-Dispersive X-ray Spectroscopy
GIS	Geographic Information Systems
EGI	Ethiopian Geological Institute
TOC	Total Organic Carbon
PASDEP	Plan for Accelerated and Sustained Development to End Poverty

Acknowledgments

The authors sincerely thank the Mineral Industry Development Institute of Ethiopia for its institutional support and for providing access to facilities, technical expertise, and research resources that enabled the successful completion of this article. The professional cooperation and assistance of the institute's staff are gratefully acknowledged.

Author Contributions

Wakjira Tesfaye is the sole author. The author read and approved the final manuscript.

Data Availability Statement

The datasets generated and analyzed during this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflict of interest.

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