Master's Thesis♣

Petrology of Saprolites in Central Hesse

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December 17, 2024

Submitted to the University of Freiburg

Geology - Institute of Mineralogy and Petrology

Faculty of Environment and Natural Resources

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Editing Time	June 20, 2024 - December 17, 2024
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Declaration

I hereby declare, that I am the sole author and composer of this Thesis and that no other sources or learning aids, other than those listed, have been used. Furthermore, a full list of works used to develop this work, to which I cannot claim ownership, has been referenced.

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Abstract

The comprehensive analysis of saprolites from various lithologies endemic to Central Hesse has provided valuable insights into the weathering processes and products of Tertiary Europe. Through the integration of petrology, micromorphology, grain size analysis, and geochemistry, a detailed picture of formation conditions has emerged. Geochemical analyses reveal a consistent enrichment of immobile elements and depletion of alkali components, highlighting the intensity of chemical weathering. Secondary mineralizations of hematite, goethite, and siderite further confirm the transformative effects of weathering on the original rock compositions. Petrographic observations complement these findings, showcasing fine-grained textures, clay coatings, and flow structures indicative of fluid activity. Collectively, these features point to weathering as the dominant alteration mechanism, with little evidence of hydrothermal interference.

The observed alteration patterns provide valuable insights into past climatic conditions, suggesting a history of intense weathering regimes. These results have broader implications for reconstructing paleoenvironments and understanding the mobility of elements during weathering. Additionally, the study highlights the need for methodological advancements in grain size analysis, particularly for fine-grained materials, to improve measurement accuracy. By integrating multidisciplinary approaches, this research contributes to unraveling the complexities of weathering processes and their implications for geological and environmental sciences.

In conclusion, this study underscores the transformative impact of weathering on saprolites, driven by a combination of chemical, physical, and mineralogical processes. Past climatic conditions have facilitated intense chemical weathering, aided by fluid transport, resulting in highly altered mineral assemblages enriched in immobile elements, some of which hold economic significance. These findings enhance our understanding of weathering dynamics and provide a foundation for future investigations into the interplay between geology, climate, and surface processes.

Zusammenfassung

Die umfassende Analyse von Saproliten aus verschiedenen in Mittelhessen vorkommenden Lithologien hat wertvolle Einblicke in die Verwitterungsprozesse und -produkte des tertiären Europas geliefert. Durch die Integration von Petrologie, Mikromorphologie, Korngrößenanalyse und Geochemie ist ein detailliertes Bild der Bildungsbedingungen entstanden. Geochemische Analysen zeigen eine konsistente Anreicherung von immobilen Elementen und eine Verarmung von Alkalibestandteilen, was die Intensität der chemischen Verwitterung verdeutlicht. Sekundäre Mineralisierungen von Hämatit, Goethit und Siderit bestätigen die transformativen Auswirkungen der Verwitterung auf die ursprüngliche Gesteinszusammensetzung. Petrographische Beobachtungen ergänzen diese Ergebnisse und zeigen feinkörnige Texturen, Tonüberzüge und Fließstrukturen, die auf flüssige Aktivitäten hinweisen. Insgesamt deuten diese Merkmale auf Verwitterung als vorherrschenden Alterationsmechanismus hin, wobei es kaum Anzeichen für hydrothermale Störungen gibt.

Die beobachteten Alterationsmuster bieten wertvolle Einblicke in die klimatischen Bedingungen der Vergangenheit und lassen auf eine Geschichte intensiver Verwitterungsregime schließen. Diese Ergebnisse haben weitreichende Auswirkungen auf die Rekonstruktion von Paläoumgebungen und das Verständnis der Mobilität von Elementen während der Verwitterung. Darüber hinaus unterstreicht die Studie den Bedarf an methodischen Fortschritten bei der Korngrößenanalyse, insbesondere bei feinkörnigem Material, um die Messgenauigkeit zu verbessern. Durch die Integration multidisziplinärer Ansätze trägt diese Studie dazu bei, die Komplexität von Verwitterungsprozessen und ihre Auswirkungen auf die Geologie und die Umweltwissenschaften zu entschlüsseln.

Zusammenfassend unterstreicht diese Studie die transformativen Auswirkungen der Verwitterung auf Saprolite, die durch eine Kombination von chemischen, physikalischen und mineralogischen Prozessen angetrieben werden. Die klimatis-

chen Bedingungen der Vergangenheit haben eine intensive chemische Verwitterung begünstigt, die durch den Flüssigkeitstransport unterstützt wurde und zu einer stark veränderten Mineralzusammensetzung führte, die mit immobilen Elementen angereichert ist, von denen einige wirtschaftliche Bedeutung haben. Diese Ergebnisse verbessern unser Verständnis der Verwitterungsdynamik und bieten eine Grundlage für künftige Untersuchungen des Zusammenspiels zwischen Geologie, Klima und Oberflächenprozessen.

Acknowledgments

I am deeply grateful to my supervisor, Prof Dolejs, for his invaluable guidance, support, and encouragement throughout this research. His expertise and dedication have been instrumental in shaping the direction and success of this work.

To my classmates, especially Nico Nöthen and Edwin Wambicho, I appreciate your camaraderie and insightful discussions, which made this journey both intellectually stimulating and enjoyable. To the wonderful staff at the department that lent me their wisdom, expertise and precious time.

On a personal note, I owe a heartfelt thanks to my family for their unwavering support, patience, and encouragement. Your belief in me has been my greatest source of strength.

Finally, I dedicate this work to Alethea Harrison, my muse and my inspiration.

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Chapter 1

Introduction

Saprolites, which are also known as “Weathering mantles” or “Grus” (especially concerning weathering granites), are a widespread feature of landscapes on every continent, occurring at or near the earth’s surface. They are most prominent in tropical to subtropical regions where they regularly exceed depths of 50 m Stoops, Marcelino, and Mees (2018), however, saprolites are not restricted to these locations as they can be as small as a few millimetres thick in temperate regions. In Europe, the distribution of saprolites is varied but is of significant quantities as they are present in central, western, and northern Europe. Locations where the presence of saprolites is well documented include the Iberian Peninsula, the Massif Central in France, parts of the Rhenish Massif in Germany (our study area), the British Isles, the Scandinavian Mountains, and the Fennoscandian Shield Migoń and Lidmar-Bergström (2001); Vazquez (1981).

The word “Saprolite” was coined from the Greek for “rotten rock” (*/sapros lithos/*) by G.F. Becker (1895) to describe bedrock still in the process of pedogenesis and delineate it from the layers further down the line of decomposition. They are the weathering remains of preexisting rocks exposed to atmospheric conditions such as precipitation, diurnal temperature changes, microbial activity, and high oxygen fugacity. They are the product of mineral transformations driven by thermodynamics, as the formation conditions at depth significantly differ from the conditions they encounter after their host rocks are exhumed. Saprolites differ from other weathering products because they remain in situ, meaning they develop as a covering, lying directly on top of the unweathered rock, like an outer skin. Due to this lack of mobilization, they also retain their rock fabric, even though the degree to which the fabric preservation varies with depth. The exact rate of weathering and thickness of the weathering mantle depends on the time spent at or close to the surface, the climate, and the rock type Ehlen (2005).

Saprolites frequently constitute a part of a more extensive stratigraphic sequence and usually only serve as a subordinate layer within the weathered profile. The weathered profile or regolith, as a whole, is an aggregate of layers of rock pieces in various stages of disintegration and originating from multiple sources. The A-B-C scheme was first introduced by Orth (1873, 1875) and later evolved by Dokuchaev, Vasily (1879a, 1879b). Improvements by Fowler (1925) brought the scheme to what is recognized today as the most widely accepted approach to the description of soil profiles Tandarich, Darmody, Follmer, and Johnson (2002). However, even though there is a unification of the scheme, there is no unification of the terms within the scheme, and the components are modified by authors to represent a variety of features studied, as evidenced by the review of Tandarich Tandarich et al. (2002).

The German soil classification scheme, as defined in the KA5 Eckelmann et al. (2006), begins the weathered profile with a layer littered with organic material that has just begun to humify and is known as the "O Horizon." Below this layer is a completely disaggregated and unstructured layer which has lost all structure due to some varying combinations of biological and environmental processes and is known as the "A Horizon" or topsoil. The next layer, called the "E Horizon," is where acids formed during humification of the organic matter in the previous layers, strip elements from the minerals in its layer and precipitates them further down, in a process called podzolization. Next is the "B Horizon," which is structurally similar to the A Horizon but includes precipitates formed from the leaching processes in the layers above and less organic material. After that is the "C Horizon," which has begun to weather but still preserves the structure of the bedrock below it. This layer corresponds to the titular saprolites and can be characterized as being the closest in density to the unaltered bedrock and the least affected by soil-forming processes of all the horizons.

Saprolites are studied by geochemists, civil engineers, hydrologists, geomorphologists, soil scientists, and exploration geoscientists for different purposes. They can serve as aquifers from which groundwater can be tapped or may form hosts for economic deposits through secondary or supergene enrichment for resources such as gypsum, clays, aluminium, manganese, nickel, copper, uranium, iron, gold, and other heavy minerals. Saprolites also serve as a window to the past, through which the events that led to their formation can be observed. Therefore, their study is important to understanding and predicting the effects of current geo-climatic processes.