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Preliminary Evaluation of Blockiness Characteristics in Obsidian Rock Masses: A Case Study from Eastern Anatolia

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Anahtar Kelimeler

Kaya Düşmesi
Obsidyen Kaya
Kütlesi Bloklanma
Kaya Yamacı
Duraysızlığı

Graphical/Tabular Abstract (Grafik Özet)

This study presents a preliminary engineering geological assessment of an obsidian rock slope located along the Sarıkamış–Karakurt road. Field observations and ImageJ-based scaled photograph analyses were used to evaluate block size distribution and potential rockfall behavior. /Bu çalışma, Sarıkamış–Karakurt yolu boyunca yer alan bir obsidiyen kaya yamacının ön mühendislik jeolojisi değerlendirmesini sunmaktadır. Blok boyutu dağılımı ve olası kaya düşmesi davranışı, arazi gözlemleri ve ImageJ tabanlı ölçekli fotoğraf analizleri kullanılarak değerlendirilmiştir.



Figure A: *General view of the obsidian rock slope and ImageJ-based block size measurements used for preliminary rockfall assessment. /* ***Şekil A:*** *Ön kaya düşmesi değerlendirmesi için kullanılan obsidiyen kaya yamacının genel görünümü ve ImageJ tabanlı blok boyutu ölçümleri.*

Highlights (Önemli noktalar)

- *Field observations revealed a highly fractured and blocky obsidian rock mass. /Arazi gözlemleri yüksek derecede kırıklı ve bloklu bir obsidiyen kaya kütlesi ortaya koymuştur.*
- *Rock block sizes ranged between 52.9 cm and 192.7 cm. /Kaya blok boyutları 52.9 cm ile 192.7 cm arasında değişmektedir.*
- *Rockfall was identified as the dominant instability mechanism in the slope. /Kaya düşmesi yamactaki baskın duraysızlık mekanizması olarak belirlenmiştir.*
- *Large detached blocks may generate high-energy rockfall events. /Büyük kopmuş bloklar yüksek enerjili kaya düşmesi olayları oluşturabilir.*

Aim (Amaç): *This study aims to preliminarily evaluate the blockiness characteristics and rockfall potential of an obsidian rock slope using field observations and photograph-based measurements. /Bu çalışma, arazi gözlemleri ve fotoğraf tabanlı ölçümler kullanılarak bir obsidiyen kaya yamacının bloklanma özelliklerini ve kaya düşmesi potansiyelini ön değerlendirme amacıyla gerçekleştirilmiştir.*

Originality (Özgünlük): *The study provides one of the limited preliminary engineering geological assessments focusing on rockfall behavior in brittle obsidian rock masses in Eastern Anatolia. /Çalışma, Doğu Anadolu'daki kırılgan obsidiyen kaya kütlelerinde kaya düşmesi davranışına odaklanan sınırlı sayıdaki ön mühendislik jeolojisi değerlendirmelerinden birini sunmaktadır.*

Results (Bulgular): *The results indicate that the obsidian slope contains medium to very large rock blocks controlled by discontinuity systems, and rockfall is the dominant instability mechanism. /Sonuçlar, obsidiyen yamacın süreksizlik sistemleri tarafından kontrol edilen orta ve çok büyük kaya blokları içerdiğini ve baskın duraysızlık mekanizmasının kaya düşmesi olduğunu göstermektedir.*

Conclusion (Sonuç): *Field observations combined with simple image-based analyses can provide valuable preliminary insights into rockfall hazards in steep volcanic rock slopes. /Arazi gözlemleri ile basit görüntü tabanlı analizlerin birlikte kullanılması, dik volkanik kaya yamaçlarındaki kaya düşmesi tehlikelerinin ön değerlendirilmesi açısından değerli bilgiler sağlayabilmektedir.*

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Abstract

This study presents a preliminary assessment of the blockiness characteristics and potential rockfall behavior of an obsidian rock slope located along the Sarıkamış–Karakurt road in Eastern Anatolia. Field observations and scaled photograph analysis were used to estimate the approximate dimensions of rock blocks exposed on the slope. Using a 30 cm reference object placed in the field, the sizes of fallen blocks accumulated at the toe of the slope were measured and analyzed. The results show that block lengths vary between 52.9 cm and 192.7 cm, indicating a wide distribution of block sizes. Most blocks exceed 70 cm, and several are larger than 1 m, suggesting the presence of relatively large fractured obsidian fragments within the slope. The slope height is approximately 7–8 m, and the slope faces are characterized by a steep geometry. Considering the brittle nature of obsidian and the observed discontinuity patterns within the rock mass, rockfall is interpreted as the dominant instability mechanism in the study area. The accumulation of detached blocks at the slope toe further supports the occurrence of previous rockfall events. The findings highlight the role of block size distribution and slope geometry in controlling rockfall processes in obsidian rock masses. The study demonstrates that field observations combined with simple photographic analysis can provide useful preliminary insights into potential rockfall hazards in steep volcanic rock slopes.

Doğu Anadolu'daki Obsidiyen Kaya Kütlelerinde Bloklanma Özelliklerinin Ön Değerlendirilmesi: Bir Vaka Çalışması

Makale Bilgisi

Araştırma makalesi
Başvuru: 06/04/2026
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Anahtar Kelimeler

Kaya Düşmesi
Obsidyen Kaya Kütlesi
Bloklanma
Kaya Yamacı Duraysızlığı

Öz

Bu çalışma, Doğu Anadolu'da Sarıkamış–Karakurt karayolu boyunca yer alan bir obsidiyen kaya yamacının bloklanma özellikleri ve potansiyel kaya düşmesi davranışının ön değerlendirmesini sunmaktadır. Arazi gözlemleri ve ölçeklendirilmiş fotoğraf analizleri kullanılarak yamaç üzerinde gözlenen kaya bloklarının yaklaşık boyutları belirlenmiştir. Arazide yerleştirilen 30 cm yüksekliğindeki referans bir nesne kullanılarak yamaç eteğinde birikmiş düşmüş blokların boyutları ölçülmüş ve değerlendirilmiştir. Sonuçlar, blok uzunluklarının 52,9 cm ile 192,7 cm arasında değiştiğini ve blok boyutlarının geniş bir dağılım gösterdiğini ortaya koymaktadır. Blokların büyük bir kısmı 70 cm'den büyük, bazıları ise 1 m'den daha büyük olup, bu durum yamacın nispeten büyük kırıklı obsidiyen blokları içerdiğini göstermektedir. Çalışma alanındaki yamaç yüksekliği yaklaşık 7–8 m olup, yamaç yüzeyi dik bir geometri sergilemektedir. Obsidiyenin kırılgan yapısı ve kaya kütlesi içerisinde gözlenen süreksizlik sistemleri dikkate alındığında, çalışma alanındaki baskın duraysızlık mekanizmasının kaya düşmesi olduğu değerlendirilmektedir. Yamaç eteğinde biriken blokların varlığı da geçmişte kaya düşmesi olaylarının meydana geldiğini göstermektedir. Elde edilen bulgular, obsidiyen kaya kütlelerinde kaya düşmesi süreçlerinin kontrolünde blok boyutu dağılımı ve yamaç geometrisinin önemli rol oynadığını ortaya koymaktadır. Bu çalışma, arazi gözlemleri ile basit fotoğraf analizlerinin birlikte kullanılmasının dik volkanik kaya yamaçlarında potansiyel kaya düşmesi tehlikelerinin ön değerlendirilmesi açısından faydalı bilgiler sağlayabileceğini göstermektedir.

1. INTRODUCTION (GİRİŞ)

Rock slope instability and rockfall processes constitute a major geohazard in mountainous and steep terrain, frequently threatening transportation corridors, settlements, and critical infrastructure. Rockfalls are commonly characterized by the detachment of single blocks or rock masses from a steep slope, followed by falling, bouncing, rolling, and fragmentation during impacts, often resulting in

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high mobility and substantial kinetic energy that limits response time and increases potential damage [1]. In engineered and natural slopes, the hazard is governed not only by the slope geometry but also by the structural condition of the rock mass, including the presence of multiple joint sets, discontinuity persistence, and weathering-related weakening. Many unstable rock masses remain in a state of limited equilibrium and may lose stability under gravity alone or following external triggers such as rainfall and earthquakes, producing rapid downslope movement and impact hazards [2]. Consequently, robust assessment frameworks are needed to characterize slope conditions, identify plausible failure mechanisms, and support mitigation decisions.

A key challenge in rock slope assessment is that failures are commonly controlled by discontinuities rather than intact rock strength. The orientation and persistence of joint sets, their intersection patterns, and their relationship to slope face orientation can strongly constrain the kinematically feasible modes of instability (e.g., planar sliding, wedge sliding, or toppling) and can dictate whether a given failure mechanism is geometrically possible before any force–equilibrium calculation is attempted [3,4]. This structural control becomes even more critical in steep rock faces where small variations in discontinuity orientation may lead to markedly different outcomes in terms of detachment likelihood, block size distribution, and runout. Several studies emphasize that reliable hazard evaluation requires explicit consideration of local rock mass conditions and site-specific structural features, particularly when assessing susceptibility to earthquake-induced or rainfall-related rockfalls [5,6]. In practice, engineering geological assessments therefore benefit from integrating field-based structural characterization with analytical or numerical modeling approaches to provide a defensible interpretation of instability potential.

In the literature, a wide range of approaches has been applied to evaluate rock slope stability, reflecting differences in data availability, slope type, and project objectives. Limit equilibrium method (LEM) analyses remain widely used due to their conceptual clarity and practical efficiency; they are frequently adopted in case studies where geometry, discontinuity-controlled failure surfaces, and shear strength parameters can be reasonably defined [7-9]. Complementary approaches include rock mass classification-based stability rating systems and probabilistic frameworks that attempt to incorporate uncertainty and variability in geological and geotechnical inputs [10,11]. Numerical methods (e.g., finite element-based approaches) are also employed in site-specific studies, particularly where stress redistribution, complex geometry, or material heterogeneity must be represented more explicitly [12]. Across these approaches, an important recurring theme is that the credibility of any computed stability metric depends strongly on the adequacy of field characterization and on the appropriateness of the assumed failure mechanism and parameter set.

Rock slopes developed in geologically complex settings—where faults, thrusts, and multiple lithological units coexist—often exhibit strong spatial variability in rock mass structure and weathering conditions. Studies from diverse mountainous regions describe how tectonic discontinuities, lithological contrasts, and weathering can create localized instability-prone zones, even along short slope segments [13-15]. For volcanic and volcaniclastic terrains in particular, discontinuity patterns and weathering processes can produce blocky rock masses that are susceptible to detachment and progressive slope degradation [16]. However, despite the broad attention given to rock slope hazards in general, case studies that explicitly address uncommon or highly brittle lithologies remain comparatively limited within standard engineering geological workflows. This motivates targeted assessments that document the rock mass structure, interpret plausible failure modes, and evaluate stability using transparent assumptions tailored to the lithological and structural context.

Obsidian, as a volcanic glass, is characterized by pronounced brittleness and fracture-dominated behavior, and it may form steep outcrops where discontinuities and cooling-related fracturing govern block formation. In such settings, slope instability may be strongly controlled by discontinuity geometry and by surface conditions that influence shear resistance along potential release planes. Given the importance of structural controls highlighted across engineering geological and hazard-oriented studies [17], an obsidian rock slope constitutes a compelling case for an integrated assessment focused on (i) detailed description of site conditions and rock mass characteristics, (ii) identification of plausible instability mechanisms guided by structural relationships, and (iii) stability evaluation using established analytical frameworks (e.g., LEM) under clearly stated assumptions [18,19]. Such an approach supports both scientific understanding of instability controls in brittle volcanic materials and practical decision-making for hazard management where steep slopes interact with human activity.

Accordingly, this study presents an engineering geological assessment of an obsidian rock slope through a case-study framework. The work compiles field observations and site descriptions, summarizes the regional geological context that influences rock mass structure, and applies stability modeling to evaluate instability potential. The modeling component is organized to remain consistent with established rock slope assessment practice linking failure mechanism interpretation to analytical evaluation—while maintaining transparency regarding assumptions and parameter choices [20,21]. The outcomes are intended to provide a structured basis for discussing instability drivers, expected failure modes, and implications for risk reduction in brittle volcanic rock slopes.

2. DESCRIPTION OF THE STUDY AREA (ÇALIŞMA ALANININ TANIMI)

The most comprehensive study in the study area was conducted by Kamanlı (1977) [22]. In his detailed investigation of the perlites located south of Sarıkamış, Kamanlı (1977) also reported the presence of obsidians associated with these deposits. Obsidian outcrops are best observed along the Sarıkamış–Karakurt highway (Figure 1). Along the road corridor, the most reliable observations of the obsidian occurrences can be made in road cuts reaching approximately 7–8 m in height. The obsidians are generally observed in the form of dikes (veins). These veins are predominantly steep to near-vertical, although a limited number of low-inclined veins are also present. In rare cases, obsidian veinlets conformable with the stratification within debris deposits can also be observed. Since such veinlets are relatively thin and mostly consist of small-sized obsidian fragments, they are not considered economically significant [23].

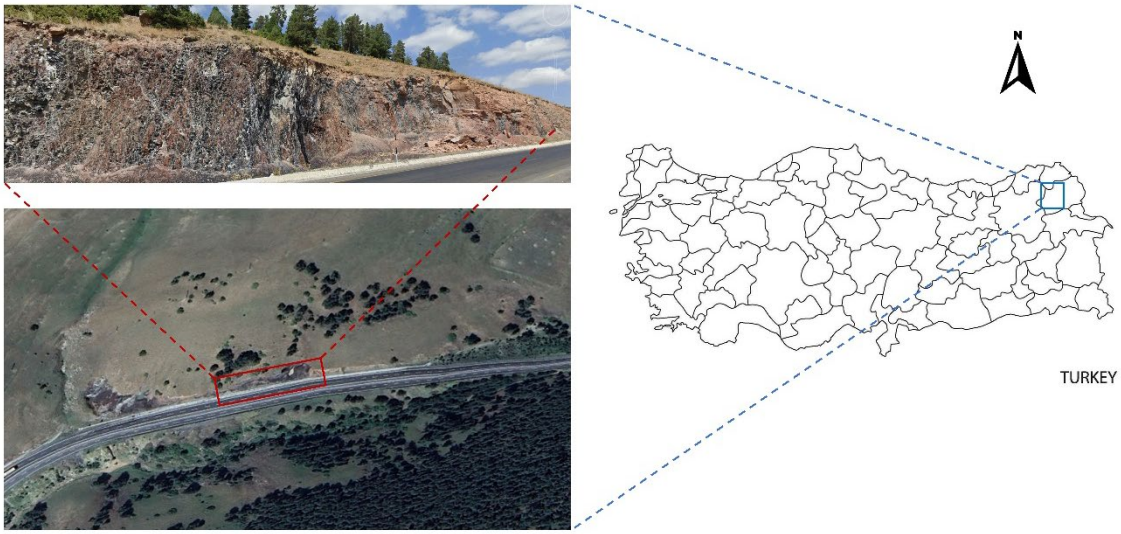


Figure 1. Geographical location of the study area (Google Earth 2024) [29] (Çalışma alanının coğrafi konumu)

3. REGIONAL GEOLOGY (BÖLGESEL JEOLOJİ)

The basement of the study area consists of metamorphic rocks known as the Paleozoic-aged Keklik Formation. Overlying this unit are the Sarıkamış volcanics, which are widely distributed in the region and dated to the Miocene–Quaternary period (6.9 ± 0.9 and 1.3 ± 0.2 Ma). The youngest units in the study area are Quaternary slope debris deposits [24–27].

The Sarıkamış volcanics and the associated obsidians observed in the field occur in three distinct lithological levels within the study area. The lower level begins with rhyolitic agglomerates, dacitic and rhyolitic tuffs, and locally obsidian-bearing layers. The middle level consists of welded tuffs that form resistant outcrops in the field. The upper level is composed of basaltic–andesitic and rhyolitic lavas, agglomerates, tuffs, and locally perlite layers [24–27].

In the lower volcanic level, a vitrophyric texture is commonly observed, while spherulitic textures occur locally. Volcanic glass is the dominant component, accompanied by low-temperature silica phases and minor amounts of biotite, plagioclase, amphibole, and opaque minerals. The spherulitic crystals are generally composed of silica (cristobalite). Due to the dominance of volcanic glass, these rocks are classified as vitric tuffs [24–27].

In the middle-level welded tuffs, flow structures are well developed. These welded tuffs consist of volcanic glass shards together with crystal and lithic components. The rocks typically display a vitrophyric texture, while locally microlitic

alignment and hyalopilitic textures can also be observed. The main minerals include plagioclase (oligoclase), sanidine, ± pyroxene (augite), ± biotite, ± amphibole, and opaque minerals. These rocks are generally classified as crystal–vitric tuffs. In addition to crystal fragments, the welded tuff samples also contain minor lithic components [24–27].

The upper-level tuffs consist of volcanic glass together with crystal and lithic components. These tuffs generally exhibit vitrophyric textures, while local alignment of microlites can also be observed. The main mineral phases include plagioclase (oligoclase) and pyroxene (augite) microlites, together with ± sanidine, ± biotite, and opaque minerals. Lithic fragments commonly display a hypocrystalline texture. Fine-grained crystals are dispersed within the volcanic glass matrix. The tough samples are typically classified as crystal–vitric tuff and vitric tuff.

In the upper-level lava samples, the dominant textures are pilotaxitic and hyalopilitic, and locally microlitic pilotaxitic textures are observed. Sanidine and pyroxene (augite) occur as phenocrysts, while plagioclase, pyroxene, opacitized biotite, and opaque minerals are present as microlites within the matrix. Based on petrographic characteristics, these rocks are identified as andesitic and trachyandesitic lavas (Figure 2) [24–27].

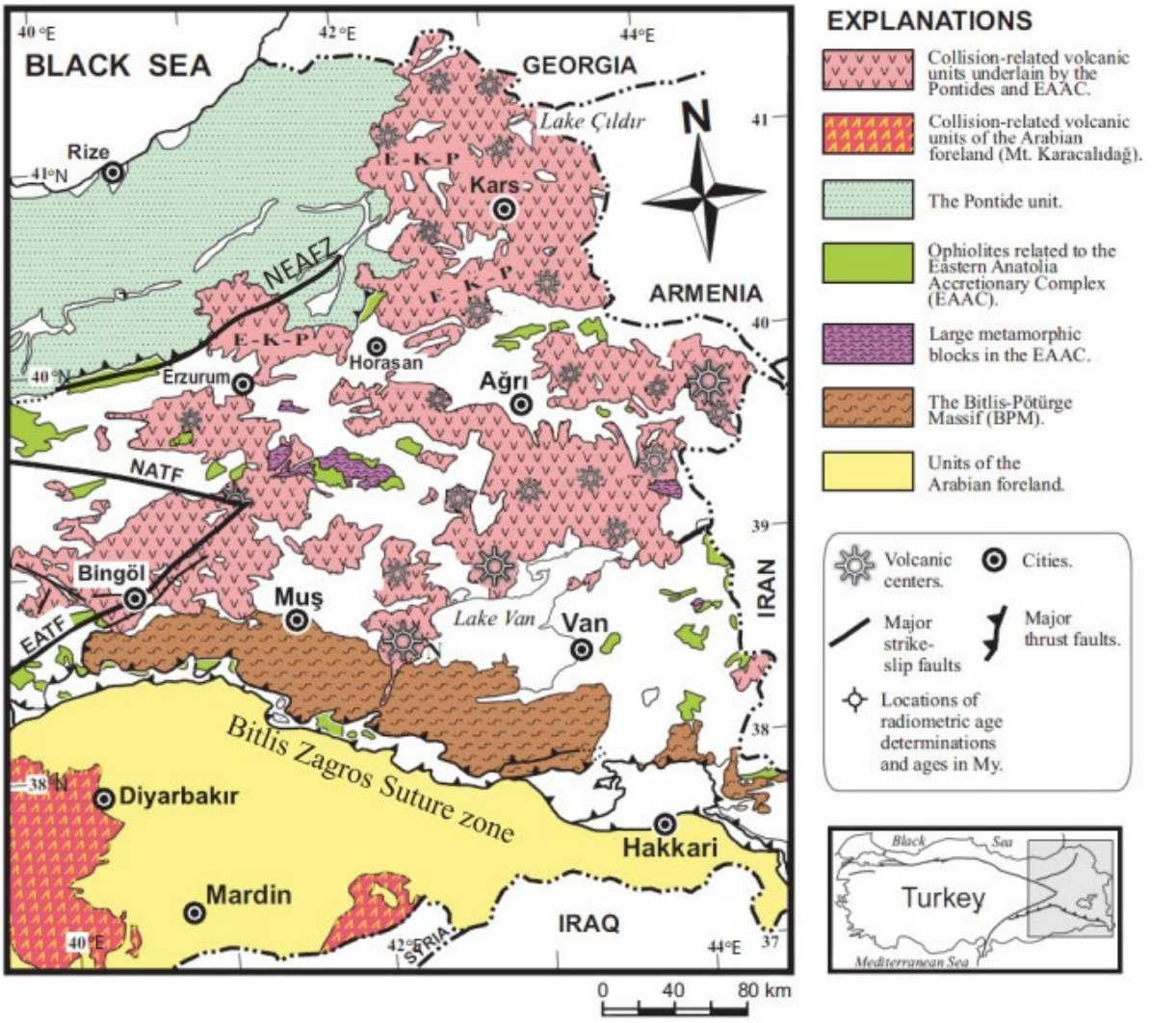


Figure 2. Simplified geologic map of Eastern Anatolia [26] (Doğu Anadolu'nun basitleştirilmiş jeoloji haritası)

4. METHODS (YÖNTEMLER)

Within the scope of this study, the blockiness characteristics of an obsidian rock slope were preliminarily evaluated using field observations and photograph-based analyses. For this purpose, obsidian and surrounding rock samples collected from the field were photographed and visually documented (Figure 3). In addition, discontinuity patterns, block geometries, and fragmentation

characteristics observed along the slope surface were qualitatively assessed during field investigations. Representative photographs obtained from the study area were further examined to identify the general distribution and dimensions of rock blocks within the slope mass.



Figure 3. Obsidian and surrounding host rock samples were collected from the study area (Obsidiyen ve çevresindeki ana kaya örnekleri çalışma alanından toplanmıştır)

During the field investigations, the slope was examined in detail, and discontinuities and block separations within the rock mass were visually assessed. In addition, photographs taken from different points of the slope and including a reference scale were used to estimate the approximate dimensions of the blocks (Figure 4).



Figure 4. Field photographs of the investigated obsidian rock slope showing the slope face and rock blocks accumulated at the slope toe due to rockfall (İncelenen obsidiyen kaya yamacına ait şev yüzeyini ve kaya düşmesi sonucu yamaç eteğinde biriken kaya bloklarını gösteren arazi fotoğrafları)

Block dimensions were estimated from field photographs using a scaled image analysis approach in the ImageJ software [30]. A 30 cm reference object (Block No. 1) placed in the field was used for scaling, and the visible dimensions of the fallen blocks accumulated at the slope toe were approximately measured. Based on these measurements, the blocks were classified according to their size ranges.

The results indicate that a significant portion of the blocks within the study area fall into medium and large size classes. Smaller blocks generally

range between 0.2–0.5 m, medium-sized blocks between 0.5–1.0 m, and large blocks between 1.0–1.5 m. In addition, several blocks exceed 1.5 m, indicating the presence of very large detached fragments within the slope.

Measurements obtained from the photographs show that, excluding the reference object used for scaling, block lengths vary between approximately 52.9 cm and 192.7 cm, with an average block size of about 94 cm (Figure 5). This size distribution indicates that the discontinuity systems within the rock mass allow not only small-scale fragmentation but also the detachment of relatively large rock blocks. The presence of large blocks bounded by distinct discontinuities suggests that block detachment is primarily controlled by discontinuity-driven mechanisms within the brittle obsidian rock mass.

Furthermore, the accumulation of blocks at the slope toe provides clear field evidence that rockfall events have occurred in the past and that rockfall is an active geomorphological process in the area. The classification of block sizes, therefore contributes to a preliminary assessment of the degree of blockiness of the obsidian rock mass and provides a basis for the qualitative interpretation of potential rockfall behavior.

The presence of large and very large blocks indicates that potential detachments could generate high-energy rockfall events along the slope. Consequently, block size distribution not only reflects the fragmentation characteristics of the rock mass but also serves as an important indicator for the initial evaluation of slope instability and rockfall hazard in the study area.

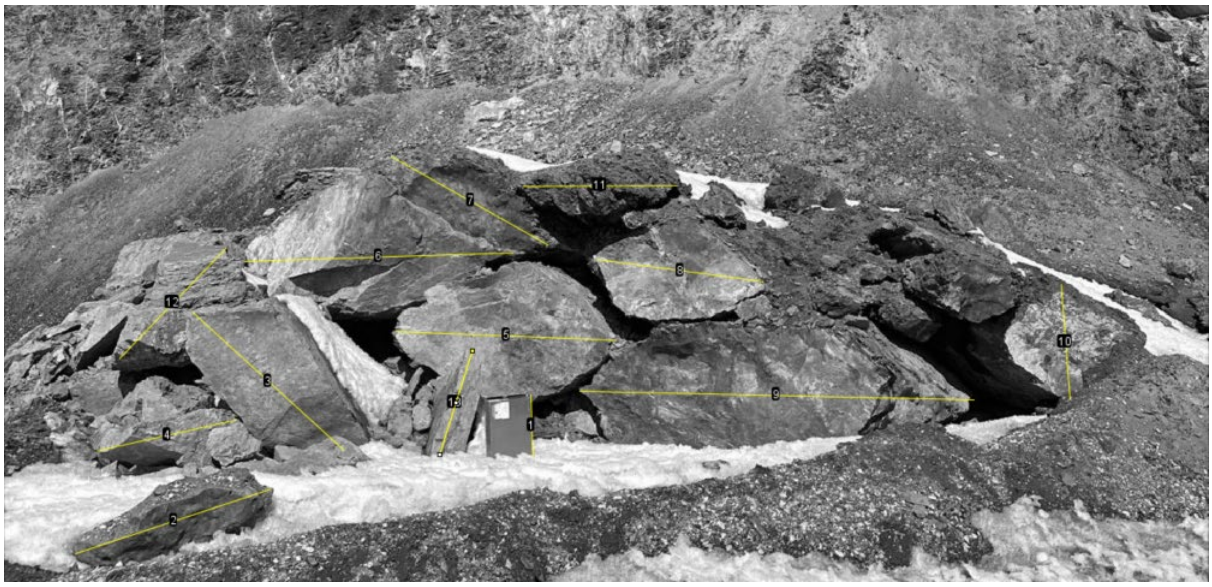


Figure 5. Field photograph of the obsidian rock mass exposed along the Sarıkamış–Karakurt road cut. The yellow lines indicate the measured dimensions of individual obsidian blocks used for the block size analysis based on the reference scale placed in the field (Sarıkamış–Karakurt yol yarması boyunca yüzeylenen obsidiyen kaya kütlesine ait arazi fotoğrafı. Sarı çizgiler, arazide yerleştirilen referans ölçeğe göre blok boyutu analizinde kullanılan bireysel obsidiyen bloklarının ölçülen boyutlarını göstermektedir)

The predominance of blocks close to or exceeding 1 m in length indicates the presence of relatively large fractured rock fragments within the slope. Such block sizes are typical for highly jointed volcanic rock masses and may play a critical role in controlling potential rockfall processes. Larger detached blocks are likely to generate higher impact energy during downslope movement, which may increase the potential hazard associated with rockfall events in the investigated obsidian slope (Table 1).

Table 1. Measured lengths of obsidian rock blocks identified from the field photograph.

Block No	Length (cm)
2	100.4
3	99.8
4	69.5
5	106.9
6	130.5
7	87.8
8	82.1
9	192.7
10	56
11	75
12	74.9
13	52.9

5. PRELIMINARY STABILITY ASSESSMENT (ÖN DURAYLILIK DEĞERLENDİRMESİ)

A preliminary assessment was conducted to evaluate the potential instability behavior of the obsidian rock slope. Within this framework, the slope geometry, block size distribution, and potential block movement directions were qualitatively analyzed based on field observations and photograph-based measurements.

Field investigations indicate that the obsidian rock mass is characterized by a well-developed discontinuity system and pronounced blocky structure. The interaction between these discontinuities and the steep slope geometry creates favorable conditions for block detachment from the slope face. Considering the observed discontinuity patterns and block dimensions, it is interpreted that block failures within the obsidian rock mass are primarily governed by a rockfall mechanism.

Once detached from the slope surface, blocks are expected to move downslope through a combination of free fall, bouncing, and rolling motions until reaching the slope toe. The accumulation of detached blocks observed at the base of the slope provides clear field evidence supporting the occurrence of such rockfall processes.

6. RESULTS AND DISCUSSION (BULGULAR VE TARTIŞMA)

Field observations combined with scaled photograph analyses performed using ImageJ indicate that the obsidian rock mass within the study area exhibits a distinctly blocky structure. Block dimensions were estimated using a 30 cm reference object placed in the field. The measurements obtained from the photographs show that block lengths vary between 52.9 cm and 192.7 cm, with an average block size of approximately 94 cm.

The results demonstrate that a large proportion of the blocks fall within the medium to large size classes, generally ranging between 0.5 m and 1.5 m, while several blocks exceed 1.5 m in length. This size distribution suggests that the discontinuity systems within the obsidian rock mass facilitate the formation and detachment of relatively large rock blocks. The presence of such large blocks is particularly important in terms of slope stability, as larger detached blocks are capable of generating higher kinetic energy during downslope movement, thereby increasing the potential hazard associated with rockfall events.

The obsidian outcrops in the study area are exposed along a steep road-cut slope morphology. Field observations indicate that the slope height is approximately 7–8 m, and the slope face exhibits a very steep inclination. Such geometric conditions significantly increase the likelihood of block detachment and facilitate the initiation of rockfall processes.

The accumulation of numerous detached blocks at the slope toe further indicates that rockfall events have occurred previously in the area. These block deposits represent clear geomorphological evidence that rockfall processes are active along the slope.

Considering the block size distribution, slope geometry, and discontinuity systems together, rockfall is interpreted as the dominant instability mechanism affecting the obsidian slope within the study area. The brittle mechanical behavior of obsidian, combined with the presence of discontinuities that define individual blocks, facilitates the separation of rock fragments from the slope face.

Following detachment, blocks are expected to travel downslope through free fall, bouncing, and rolling movements, eventually accumulating at the slope toe. This interpretation is consistent with the block deposits observed during the field investigations.

Overall, the findings indicate that the obsidian slope investigated in this study presents a potential rockfall hazard, particularly due to the presence of large and very large blocks. The detachment of such blocks could result in high-energy rockfall events, which may pose risks to nearby infrastructure such as the Sarıkamış–Karakurt road.

From an engineering geology perspective, the results highlight the importance of block size distribution, slope geometry, and discontinuity characteristics in controlling rockfall processes in obsidian rock masses. The study demonstrates that field observations combined with simple image-based measurements can provide valuable preliminary insights into slope instability and rockfall hazards, particularly in steep volcanic rock slopes where detailed geotechnical data may not be readily available.

DECLARATION OF ETHICAL STANDARDS (ETİK STANDARTLARIN BEYANI)

The author of this article declares that the materials and methods they use in their work do not require ethical committee approval and/or legal-specific permission.

Bu makalenin yazarı, çalışmada kullanılan malzeme ve yöntemlerin etik kurul onayı ve/veya özel yasal izin gerektirmediğini beyan etmektedir.

AUTHORS' CONTRIBUTIONS (YAZARLARIN KATKILARI)

***Ahmet ERDAĞ*:** He conducted the field investigations, performed the photograph-based analyses, interpreted the results, and carried out the writing process.

Arazi incelemelerini gerçekleştirmiş, fotoğraf tabanlı analizleri yapmış, sonuçları yorumlamış ve makalenin yazım sürecini yürütmüştür.

CONFLICT OF INTEREST (ÇIKAR ÇATIŞMASI)

There is no conflict of interest in this study.

Bu çalışmada herhangi bir çıkar çatışması yoktur.

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