Feature

Rock climbing sites as locations for geoheritage and geoscience engagement in mountains

Outdoor activities including trekking and hiking are commonly undertaken in mountains and in other environments where bedrock surfaces or bedrock-controlled landforms are present and where users can enjoy the fresh air and the physical landscape. Information boards and leaflets are often used by scientists and environmental managers in these environments to communicate geoscience issues to the general public along hiking and trekking trails. Rock climbing sites are also prime locations where rock surfaces are exposed and where specific user groups interact with the physical landscape. Here, we describe the relationship between rock climbing and the nature of rock outcrops and the opportunity that this affords for more innovative ways of communicating geoscience information to a physically active and engaged public. As such, rock climbing sites can be considered geoheritage sites, where they represent sites of importance for people and communities (cultural heritage) as well as for their geological and educational value (geological heritage). The characteristics of rock climbing sites as geoheritage sites are discussed in this feature, as are the potential threats to the integrity of these sites.

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Many outdoor activities in mountains such as trekking and hiking have been previously considered as means to communicate geoscience issues to mountain users, managers and the wider public. Such recreational activities are undertaken by millions of people globally, and peoples' interest in and enjoyment and appreciation of the physical landscape may be enhanced when they have a better understanding of the things they see around them. This includes both the biosphere (plants and animals) and the geosphere (rocks and soils). This is also true for all physical environments, whether coastlines, forests, deserts or mountains.

It is mountains, however, that present good opportunities for the intersection of outdoor activities and public communication of geoscience because of the high potential for rock exposure in mountainous regions, which is a primary feature of their often spectacular and impressive landscapes. This means that rock faces are often seen clearly from far away and large-scale rock structures (folds, faults, and bedding planes) can be identified. In addition, mountain landforms include bare and steep bedrock surfaces, sheer cliffs or distinctive glacial or periglacial mountain landforms such as arêtes, cirque basin backwalls, blockfields or scree slopes, all of which arise directly from bedrock weathering and erosion. As such, mountains are an ideal setting to communicate geoscience information to, and to inspire interest in, a range of different user groups. Furthermore, the locations where these activities take place can be considered as geosites and as sites of potential geoheritage value because of the fact that specific user communities (here, rock climbers) interact with and value these locations in those places. It is, therefore, at these climbing sites where there is the opportunity for communicating geoscience information.

In mountains and similar environments, the most common ways of communicating what users can see at certain points in the landscape are through information boards and leaflets found along self-guided hiking or walking trails. These are relatively low-intensity outdoor activities that can be undertaken by many types of people of different ages, physical fitness and according to their interests and convenience. However, a downside is that their interactions with surrounding landscapes or with information boards are often relatively passive and undirected and this does not foster a deeper or more interactive engagement with the landscape or with the information about geoscience that information boards convey. By contrast, there are a great many other physical recreational activities undertaken in mountains in which people interact more directly with the surrounding environment, in particular with rock outcrops and landscape topography. These diverse activities are listed in Table 1. Although there have been a few studies on some of these activities, including the demographics and characteristics of their participants and how they engage with and enjoy the physical landscape, there is a significant research gap on many activities. Having a better understanding of mountain users and the nature of their activities is a potential opportunity to promote geoheritage, to convey geoscience information to undervalued demographic groups and to better appreciate the diversity of mountain recreational activities.

This study explores rock climbing as one mountain activity that is closely related to the physical landscape and that has only recently been examined in detail in terms of its geoheritage and potential for geoscience communication. Many 'energetic' activities undertaken in mountains including rock climbing, bouldering, mountain biking and others (Table 1) are explicitly grounded in land surface topography and relief that is controlled by the distribution and properties of rock outcrops. Indeed, many of these activities would simply not take place if the underlying rocks were not exposed, and where the difficulty or grade of these activities and routes are determined by rock type and structure. The relationships among rock climbing, geology and geoheritage value are explored in this study, including their potential as sites for geoscience communication. This is part of an ongoing project funded by the International Geoscience Programme (IGCP) which is concerned with exploring how outdoor activities such as trekking and climbing can be used as a tool for geoscience communication. This overarching project (IGCP 174) brings together scientists and field case studies from 12 countries on four continents and focuses on developing a consistent and universally applicable methodology for presenting information on geoscience issues, relevant to climbing and trekking users in mountains. This present study is a contribution to project IGCP 174.

Table 1. List of the most common outdoor activities undertaken in mountains in which people may interact with the surrounding environment, in particular with rock outcrops and topography in the landscape

Activities undertaken in mountains	
Abseiling	Mountaineering/alpine climbing
Base jumping/bungee jumping	Nature walking
Birdwatching	Outdoor gyms
Bouldering/free climbing	Orienteering
Camping	Paintballing/laser-tagging
Canoeing/kayaking	Parachuting
Canyoning	Paragliding/parascending
Caving/potholing	Parkour
Cross-country running/fell running	Rock climbing/free climbing
Dog walking	Skiing/snowboarding/alpine skiing
Fishing	Sport climbing/speed climbing
Geocaching	Survival/wilderness training
Geotourism	Trail riding (bicycles, motorbikes)
Heritage/pilgrimage walking routes	Tree climbing
Horse riding/trekking	Trekking/hiking
Ice climbing	Ultrarunning
Kite flying	White water rafting
Long-distance walking or hiking routes	Wild swimming
Mountain/BMX biking	Ziplining

Rock outcrops and climbing activities

Steep or near-vertical natural climbing routes are found in abandoned quarries, sea cliffs, caves or on steep mountain slopes. These routes may vary from a few metres in height (from base to top) to over 900 m in the case of the climbing routes on El Capitan in Yosemite National Park, USA. The grade (difficulty) of specific climbing routes is closely linked to the physical properties of the route (steepness, rock surface roughness, and presence of handholds/footholds), the technical expertise or equipment required and any falling risks. The grade scales used vary between countries and according to climbing type (free climbing, bouldering, etc.). However, the experience enjoyed by a climber while climbing will depend on the characteristics and length of the route, as well as their level of expertise and skill, their fitness level and the weather conditions. The action of climbing also allows users to physically engage with the rock, its touch, its feel and its texture. These sensory interactions with the rock surface help the climber develop their skills and also their appreciation of rocks as an element of the landscape. This means that climbing routes are more than just the physical

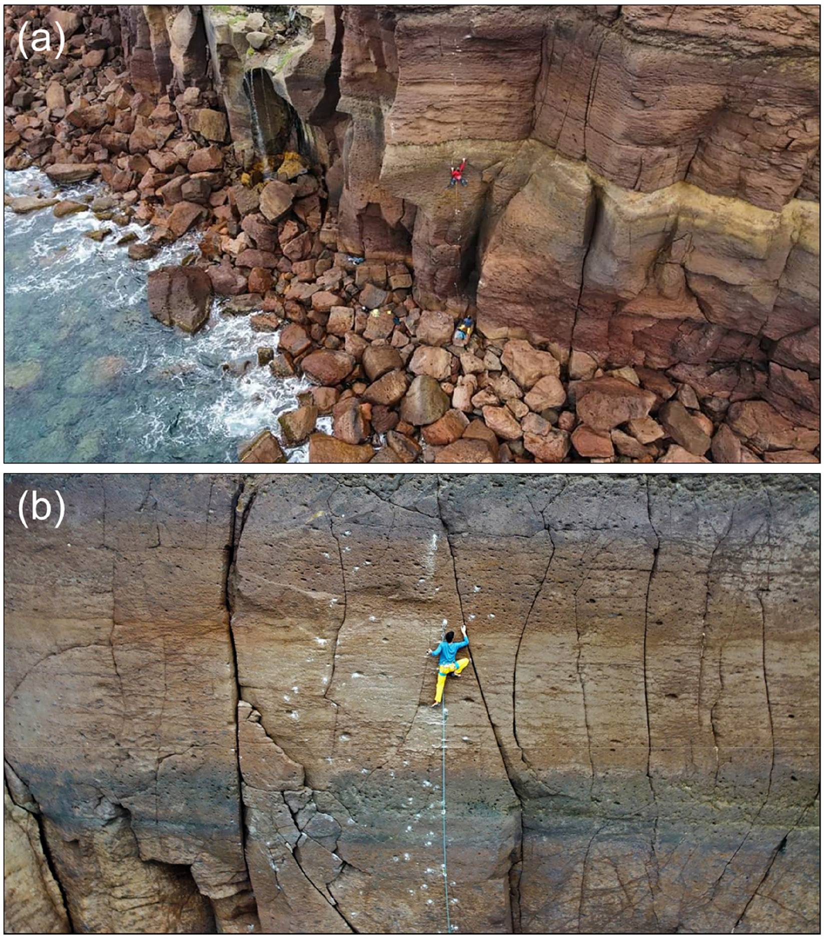

Fig. 1. Examples of handholds and footholds (white patches left by climbers' chalk) on volcanic cliffs at Porto Paglia, Sardinia, Italy (photos by M. Oviglia). Please note the climber in (**b**) is not wearing a helmet, which is an unsafe practice.

features of the rock, as they also include the ways in which different users interact with the rock surface and the wider landscape. This equates to both the geoheritage and cultural heritage values of climbing sites and the rocks displayed there.

The main geological influences on rock climbing routes and grades, and how climbers engage with them, include the presence of primary sedimentary and tectonic structures such as faults, bedding planes and other discontinuities within the rocks that are expressed as lines of weakness across the rock surface. These properties in turn reflect regional rock type and geological history. The most important geological properties that influence rock climbing routes and grades are as follows:

- Rock surface hardness influences the geotechnical strength or deformability of the rock unit. This is related to rock mineralogy and weathering history, discussed below;
- The presence of discontinuities and their orientation, persistence (length) and spatial density across the rock exposure and therefore whether the rock surface offers secure locations for handholds/footholds or for protection where bolted routes with the use of belayed ropes can be developed. As such, specific climbing routes up a rock face may be well marked and worn, with appropriate handholds or footholds, or latching points for pinions and grabs (Fig. 1).

The major controls on the development of these geological properties are as follows:

- Rock mineralogy. This depends on rock type, provenance and evolution. Generally, coarse-grained igneous or rudaceous sedimentary rocks have greater surface roughness (rugosity) and thus high local relief. This provides useful friction for handholds. Fine-grained rocks of all types tend to be smoother and thus more difficult for climbers. Rock type and formation also influence the presence of bedding and cleavage planes, joints, faults, folds and other structures that can variously make climbing routes easier by providing handholds or footholds, or that can reduce the structural integrity of the rock when they are at a high density across the rock surface;
- Weathering and exposure history. Igneous and metamorphic rocks tend to have higher compres-

sive strengths than sedimentary rocks because of the interconnected nature of their mineral crystals, but in all cases, rock mass strength decreases when weathering takes place. Rocks that have experienced subaerial or subsurface weathering over long time periods have weaker intergranular bonds, are more friable, are more permeable for water ingress and thus have lower geotechnical strength. This makes rock surfaces more likely to fail at a granular level and this weathering penetrates deeper into and widens any existing structural weaknesses, making it more likely that bedrock blocks will become detached. This poses a higher hazard risk for climbers. In addition, weathered surfaces are more likely to be affected by lichen growth and shrubs are more likely to penetrate into weathered rock fractures where their roots can split the rock apart. This can obscure climbing routes. By contrast, if an outcrop has been recently glaciated, it may be hard, smooth and fresh when exposed and this strongly influences climbing grade and ascent approach taken. Examples of different rock types, histories and their climbing routes are shown in Fig. 2.

Climbing sites as geoheritage sites

Any area where bedrock is well exposed has the potential to be used for scientific research, where bedrock structures, properties, processes and environments can be deduced through mapping, observation and sampling of the rock. This includes rock climbing sites. In addition, many natural climbing routes have been used by local clubs for decades, for training or instruction of amateurs, competitions and recreation. As such, these may also have wider significance including for their cultural, aesthetic, economic, functional (geosystem) and research/educational values. These are common concepts described in the literature. This means that rock climbing sites may also be considered as multipurpose geoheritage sites. This includes not only sites of local value and interest but also particularly named high-grade routes that are internationally known (or notorious) in the climbing community. These include the 9b + route La Rage d'Adam in the Gorges du Verdon, southwest France, which is a karstic ravine with steep limestone cliffs; or the 5.15d route called Silence in Hanshelleren Cave, Norway, where the route includes a 45 m overhang developed on a granite rock face. Apart from their link to underlying geology, leisure climbing routes may also be of archaeological, ecological and scenic importance and this highlights the multidimensional potential of climbing routes as geoheritage sites and locations for geoscience education.

Another consideration is that the climbing community is very diverse, ranging from professional climbers to amateurs, children and community groups. These climbers have different needs and standards and involve different climbing grades. In addition, rock climbing may be a secondary activity within the wider landscape which may itself be a heritage site or in a protected area. In these areas, climbers as well as other mountain users can be considered as a captive audience for *in situ* engagement about geoscience issues and education in these environments where these users already enjoy spending time. At a very general level, this can include both informing groups about different rock types and their properties and about responsible use and enjoyment of rocks and other elements in the landscape, following professional codes of conduct such as is described by the Geologists' Association in the United Kingdom. More specifically, this can include working with climbers' groups, site owners and managers in providing relevant and focused infor-

Fig. 2. Climbing routes on different rock types with different weathering and erosion histories. **a**. Limestone with chert nodules providing a rough and diverse cliff face at Maggiore Lake, Italy (photo by M. Fossati). **b**. Weathering hollows within sandstone used as convenient footholds at Annot, France (photo by M. Oviglia). **c**. Glacially eroded granite at Mottarone, Italian Alps (photo by M. Fossati). Please note the climber in (b) is not wearing a helmet, which is an unsafe practice.

mation that encourages interaction with the rocks and an understanding of their contexts. The concept of geoheritage sites, as applied to rock climbing sites, can enhance the understanding of the value of such sites to local communities and specific user groups, supporting the key role of geological properties of these sites. Thus, the dual roles of cultural as well as geological heritage have been under appreciated at these sites.

Future developments

Rock climbing is one of many different activities undertaken in mountains (Table 1). As such, there are many opportunities to engage with different mountain users, including climbing groups, which exploit their existing interests in the physical environment. More innovative communication methods for conveying textual and multimedia information can include QR codes near rock surfaces with links to virtual tours, the use of drone imagery and structure from motion photogrammetry. Rock climbing and similar activities like mountain biking have very interactive and dynamic user communities, and information about rocks and the physical environment can be communicated using a Go-Pro camera on climbers' helmets to observe rock outcrops and to upload to social media sites or websites such as YouTube. These are very popular communication forums for these users. Social media influencers and well-known climbers can also communicate geoscience ideas through real-world climbing examples. In addition, interest in climbing in all its forms is growing as both an outdoor and an Olympic sport, and artificial climbing walls are very popular in many different settings, from schools and gyms to cruise ships.

Long-used climbing routes can mean that rock surfaces become degraded and unsafe, and features in the rock that are of geological significance, such as fossils or certain minerals, may become degraded as a result. Climate change and spread of scrubby vegetation can destabilize rock surfaces and may encroach upon climbing routes. These elements may pose threats to climbing sites and increase safety risks. Climbs can now be replicated using 3D printing technology, virtual reality and through gaming. Such artificial routes can also be used as substitutes for sites that cannot be disturbed for safety or access reasons, or to protect fossil sites. Other important aspects to be considered are equitable access by different users, including car parking, emergency equipment, ramps or barriers.

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Suggestions for further reading

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