Dolomite Phenomenon

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The so-called dolomite phenomenon, also known as dolomite edaphism or dolomitophily, occurs globally and is evidenced through the appearance of an endemic flora on nutrient-poor soils with high levels of magnesium. It occurs when dolomitic rocks emerge, especially with high Mg content, and when tectonic or weathering processes generate skeletal soils, predominantly sandy or gravelly in texture. These types of habitats are associated with a specific flora, also accompanied by other tolerant species.

Keywords: glade ; dolostone ; serpentine ; edaphism ; barren soil ; dolomite flora

1. Plants on Rich-Magnesium Dolomite Barrens: A Global Phenomenon

Dolomite rocks or dolostones are widely distributed over the planet's surface [4], although they do not always appear clearly differentiated from limestone in available geological cartography. This imprecision does not affect other types of rock such as gypsum or ultramafic rocks, which are much better registered in geological cartography [5], but it does hinder the study of dolomitic flora and vegetation (e.g., [6][7]). Despite this, there are numerous publications that mention plant communities associated with dolomite and dolomitic limestone (e.g., [1]). All of them recognize the influence of this type of rocks both on flora and vegetation, and on the landscape [8]. However, the study of what some researchers have called the "dolomitic phenomenon" [9][10][11] is not an easy task, considering the heterogeneity of habitats included. Indeed, Mota [12] distinguishes up to seven rocky environments with dolomite-associated vegetation. Among all of them, perhaps cliffs are the most universally widespread and homogeneous, because gravity is the prevailing ecological factor, due to its verticality [13]; such environments also comprise several associated microenvironments (overhangs, vaults, and ledges) which harbour different types of plant communities. Debris or stony grounds are frequent at the foot of these cliffs, more or less mobile depending on the slope, caused by mechanical weathering, which give rise to highly specialized plant communities [14]. Although not as markedly as in cliffs, gravity plays a very important role in these habitats, especially because it reduces the availability of water, thus the chemical composition of the rock is not as decisive as in other places [12]. However, so-called sweeps or glades are those habitats in which the link between plants and dolostone is most exacerbated. The difficulty of using these terms, in an international context, lies in that they have been used imprecisely and almost always to refer to vegetation types in North America [8][15]. The "typical" dolomite barrens (an extent of land sparsely vegetated) are well defined by their lithology (dolostone, marly dolomites or dolomitic marbles), tectonics (affected by strike-slip faults), the predominant texture of their soils (fragmented rocks ranging from centimetre to micrometre sizes) and by the frequent effect of strong erosive and meteorization processes (thermal cycles, karstic dissolution) which often leads to ruiniform reliefs [16]. Flora extraordinarily rich in endemic species appears in association with these strongly weathered bedrock outcrops, as in gypsum and serpentine areas, although it has been much less studied.

2. Definition of the Dolomite Phenomenon

Despite their geographical amplitude and geomorphological and climatic heterogeneity, there are a number of features that are common to all descriptions of the vegetation associated with dolomite. These traits can assist in delimiting the dolomite phenomenon (dolomitophily or dolomite edaphism, sensu Mota, and colleagues [17][18]).

- There are patches of exposed dolomite (or dolomitic marble or dolomitic limestone) bedrock, associated with thin and undeveloped soils, on which they become frequently disaggregated rock fragments providing a gravelly or even sandy appearance to their surface [19][20][21]. The pebble or even sandy appearance of these soils results from the fact that they occur in heavily tectonized areas [17]. This geological process is associated with another climate process that also contributes to generating such debris by the mechanical breakdown of the rock, promoting brecciation, disintegration, and the formation of dolomitic sands. Frost shattering [22] and the thermal expansion of these rocks at high temperatures [23] appear to be the dominant local weathering processes. These features lead to strong edaphical stress and prevent the surrounding vegetation, usually conifer forests, from succession and closure.

- As dolomite rocks are relatively slowly weathered, these soils are usually shallower, can thus hold less water and by way of consequence, have a lower capacity for nutrient supply. This feature is accentuated in south-facing, and frequently steep slopes and ridges which, together with the textural characteristics of the soil (from pebbly silt loam to coarse rubble) and high insolation, promotes erosion and drainage. At least in areas with a Mediterranean climate, summer soil moisture levels are extremely low. In general, glades are drought-prone, which offers conditions hostile to not adapted plants; consequently, they represent sharp and obvious discontinuities with the nearby vegetation [24].

- Dolomite soils show a soil exchange complex which is dominated by Ca and Mg, but they differ chemically from their non-carbonate counterparts primarily in that they have a higher pH, and lower Fe, P and K. Moreover, these soils are unlike limestone-derived ones in their highest proportion of Mg [10][17]. In general, these are nutrient-poor soils with low water retention capacity, which makes these communities unproductive in relation to the surrounding vegetation.

- Such a habitat calls for specialized adaptations, promoting endemism [25][26]. In these microclimate-soil areas, there are species which are very rare or absent in other places and, in many cases, have a marked relic character, likely due to a lack of severe competition. This is because they disproportionally contribute to regional plant diversity [27], especially in biodiversity hotspots [17][28][29][30].

- This type of communities is, almost always, easily identifiable due to the physiognomic features and the adaptations shown by the plants composing them. Such adaptations are a consequence of an adaptive convergence process. In most cases, these are open dwarf communities dominated by tough perennial herbs which form flat mats and cushions, frequently silvery white-haired. Some authors have highlighted their convergent adaptive appearance with the dune vegetation [31][32].

3. The Extent of the Dolomite Phenomenon

According to the references found, edaphism on dolomite is widespread, as is the case with that related to gypsum and serpentine. In the USA, several authors have used terms such as barren, glades, limestone prairies, and xeric limestone prairies (XLPs) to refer to different types of open communities associated with exposed bedrock among which dolomites are frequent (e.g., [24]). Baskin and colleagues [15] attempted to resolve inconsistencies in the use of such terms by restricting them to those substrates developed on calcareous bedrock and adding that many of them are extremely high in magnesium. In addition, so as to distinguish these barrens from those derived from serpentine and diabase, with comparable or higher Mg levels, they mention the alkaline pH of the dolomites in contrast to that acidic of serpentines.

Curiously, American barrens and glades have not been clearly related to one of the most iconic forests in North America, the bristlecone pine forests, developed mostly on dolomite [8]. The reason for this may be that these are forests in the Alpine region, subjected to very different climatic conditions from other types of barrens and glades. However, that relationship is undeniable, as Billings [33] recognized when pointing out the “desert-like” dolomite barrens as the sharp distinction in vegetation and flora of the White Mountains. Plant communities linked to dolomites have also been mentioned in Central Europe. This relationship was baptized as the “dolomite phenomenon”, including the vegetation types which were formed under the influence of dolomite [9][11][34]. To the south, in the circum-Mediterranean area, especially in middle and high mountain areas, this geobotanical phenomenon is clearly visible from the Baetic ranges to the Taurus Mountains [35][36], with extraordinary representations in the Balkans [37][38][39], Crete [40] and also in the Rif and the Middle Atlas [21][41]. The Alps, the Apennines and the Madonia (Sicily) show many endemisms restricted to this type of habitat [42]. Interestingly, this phenomenon has not been expressly mentioned in the Dolomitic Alps [43], perhaps since it is not as accentuated as in the rest of the mountains mentioned, of a more xeric and Mediterranean nature. In all these territories, the areas richest in endemic plants, associated with dolomite, coincide with those of great tectonic activity. In the Baetic ranges (Spain), the coincidence that exists between the dolomitic outcrops richest in endemisms, many of them local, and the distribution of the Tortonian and Quaternary faults [44] is surprising; the same occurs throughout the Mediterranean basin [45].

In the southern hemisphere, the dolomite phenomenon or dolomitophily (according to Mota and colleagues [17]), has been noted in South Africa [7][26][46] and, to a lesser extent, in Australia and Tasmania [31]. There are also allusions to South America, although not very precise [47]. In Asia there are no excessively specific references, but it seems to occur in some mountains in eastern Anatolia, in the Irano-turanian region [48], and also in Tibet and Himalaya [49][50][51]. However, in the latter territories it is not easy to separate the presence of dolomite and dolomite marbles from that of various types of ultramafic igneous rocks. In the eastern part of Asia, vegetation associated with different types of karst related to limestone and dolomite is mentioned, although under a tropical climate [6]. This circumstance highlights the importance of not only lithology, but also geomorphology and weathering, to explain the relationship between plants and magnesium rocks [17][34].

Therefore, climate is another element to take into account when considering edaphism on dolomite, and not merely in terms of rainfall. This geobotanical phenomenon has been alluded to in the White Mountains of California, in the Alps, and in several Mediterranean mountains. All these territories are characterized by their very cold winters, a trait they share with the so-called "alvars". Alvars are globally uncommon ecosystems distinctive for their unusual plant species' composition and natural openness (open scraped alvar) [52]. They are present on thin or nearly absent soils underlain by flat limestone or dolomitic bedrock [52]. They are documented in Scandinavia, the northern parts of the United States, and Canada [53]. Despite the northern latitude of these ecosystems, they contain a good number of threatened and endemic species [54]. Due to their special features, bedrock that restricts drainage, they are subject to extreme variations in moisture availability that range from drought conditions to periodic flooding [52]. Alvars are widely distributed, including areas of Greenland [55]. Definitely, although the data for dolomite edaphism are much more imprecise than for serpentine or gypsum, there is no doubt that it is a global phenomenon (see above references; Figure 1).

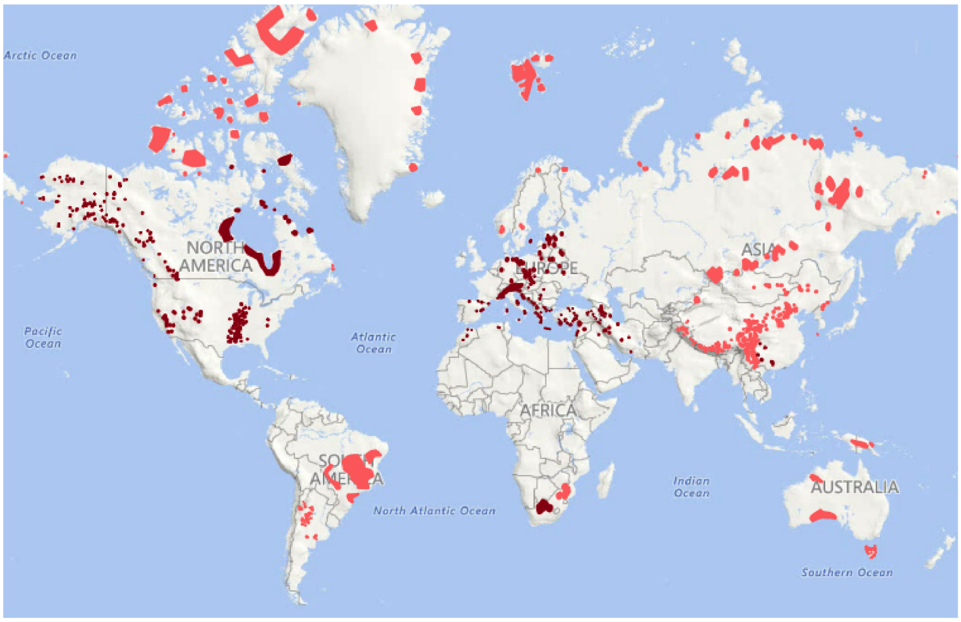

Figure 1. Worldwide distribution of dolomite outcrops; in dark those in which there is associated dolomiticolous flora (based on [56][57][58] and other references in the main text).

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