

Desert Rocks – A Habitat Which Supports Many Species That Were New to Science in the Last 40 Years

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Abstract: Hard limestone, dolomite, sandstone, and granite constitute, under certain conditions, smooth-faced outcrops in desert areas of SW Asia. This habitat supports the most rare plant species in the desert including most of the desert endemics of Israel, Sinai, and Jordan. The smooth-faced outcrops efficiently contribute runoff water to the rock crevices and events when water is available for plant utilisation take place at a higher frequency than in the other habitats in the desert. In many sites plants are isolated and protected by impermeable rocks from competition from other plants. The rare and special plants found in this habitat include many relicts of mesic floras that prevailed in the past when the climate was moister than that of the present. Many such events of climatic shifts had occurred in the area during the Tertiary and the Quaternary. The soil pockets in these rocks are rich in silt and clay particles transported as air-borne dust and trapped by mosses and lichens that are confined to rocks. The existence of relatively moist soil pockets in this habitat enables it to function as a refugium for plants that adapt to the desert with difficulty. The relatively small areas of rock outcrops of Israel and Sinai may be looked upon as an archipelago of minute and small islands in the "desert ocean". They support occasional species of the Mediterranean flora together with shrub-steppe species surrounding the refugia. The large areas of sandstone outcrops of SW Jordan function as large islands with many relict species that are typical to almost all the habitats and fulfil most functions of the Mediterranean woodlands. The archipelago situation seems to have functioned in speciation in a few genera. Discovering 5 of the 6 species in *Origanum* L. sect. *Campanulatocalyx* Letsw. may serve as a test-case to display the "archipelago situation". Occasional events of survival and speciation of taxa in unpredictable sites increase the chances of finding species that were not observed previously locally or internationally, i.e. new to science.

Key Words: Desert, smooth-faced rocks, rare, relicts, mesic moisture regime, refugium

Introduction

At the beginning of my academic activity, I became involved in a project of vegetation mapping of the Negev Highlands, the shrub-steppe area of the Israeli desert (Danin, 1983) led by the late Prof. Gideon Orshan. I was surprised to discover in the Negev Desert typical Mediterranean geophytes such as *Sternbergia clusiana* Ker Gawl. ex Schult., *Delphinium ithaburense* Boiss., and *Narcissus tazetta* Ker Gawl. in crevices of smooth-faced calcareous rock outcrops. In an excursion with my colleagues Uri Gavish and Ilan Borovitch, I discovered a population of a scented Lamiaceae that could not be named by anybody. Eventually it became the first species new to science I discovered and described (Danin, 1967). This discovery drew my attention to further investigations in this habitat type. My studies on the nature of smooth-

smooth-faced rock outcrops in the deserts of Israel, Sinai, and Jordan enabled me to discover later an additional 16 of the species that became new to science and carry my "signature". They were accompanied by rare plants that were first found in desert areas of the study area. The search for good answers about how mesophytes can survive isolated in the desert brought me to the fields of biogenic weathering, moisture regime in desert, soil formation, and climatic changes in the Near East.

The environmental conditions, flora, and vegetation of the study area were described in detail in our previous publications (Danin et al., 1975; Danin, 1983, 1999a, 1999b, 2001). In the present article an attempt is made to generalise from the findings history and to summarise it as a method for studying vegetation and flora of arid lands.

Materials and Methods

The first aim of the study we carried out from 1962 through 1967 was mapping of the vegetation of the Negev Desert of Israel. The first obstacle was the missing method fitting the desert conditions. Two patterns of vegetation distribution in desert were declared by Monod, (1954). Under extreme drought conditions the vegetation is contracted (mode contracté – Monod, 1954)—confined to dry water courses. Under less extreme conditions it is “diffused vegetation” (mode diffus – Monod, 1954; cf. Danin, 1983: p. 26). Lipkin (1971) and later Rudich and Danin (1978) dealt with methods of investigations in the contracted vegetation. Danin et al. (1975) and Danin and Solomeshch (1999) dealt with the investigation methods in the diffused vegetation.

Aerial photograph interpretation became an essential part of our investigations. We did not inherit a method from another knowledgeable entity and had to find our own way. Reconnaissance excursions took place for a long time, until certain rock types and their vegetation became familiar. Since we look in the present paper on the way to discover species new to science, the following Results section contains some “methods” type information.

Results

Mapping of diffused desert vegetation

One of the most important problems in delimiting desert vegetation in the Braun-Blanquet (1951) method is the paucity of exclusive characteristic species. Danin et al. (1975), in continuation of the “Jerusalem School” (Whittaker, 1962) method of vegetation studies, used the dominant species and plants with high constancy in the vegetation records as “markers” or diagnostic species of the association (Danin & Solomeshch, 1999). The dominance is often correlated with soil or rock type, and delimiting proper edaphic-ecologic entities. The interpretation of aerial photographs and hence the method of work in the field depend on the ability to see and determine actual plants in the aerial photographs. When no plants can be detected, the photointerpreter has to delimit edaphic-ecologic units that are correlated with vegetation distribution.

Mapping vegetation by plants observed in the aerial photographs

The areas where plants could be used as diagnostic features for aerial-photo-interpretation are the sands, salt

marshes, and single trees. Sand vegetation, which often has a prominent contrast with the background, was determined, mapped, and published in Danin et al. (1964). Salt marsh vegetation was discussed in the Hebrew-written MSc thesis of Bourvine (1963). Single trees were studied together with the vegetation mapping of the Negev Highlands. The *Pistacia atlantica* Desf. investigation is part of it (Danin & Orshan, 1970) and is discussed later.

Mapping vegetation by edaphic units delimitation

During the first stages of desert vegetation investigations (Danin et al., 1964) we followed the earlier tradition of the “Jerusalem School in Phytosociology” (Whittaker, 1962). We used dominance as the first diagnostic feature to delimit plant communities in the field. Later, similar vegetation records sharing the same dominant and second companion were clustered together to construct an association table (cf. Danin et al., 1975; Danin & Solomeshch, 1999). The distribution of most associations confined to desert lithosols could be correlated with an edaphic character that is detectable in aerial photographs.

The smooth-faced calcareous rocks

The investigations of the vegetation of smooth-faced rocks (Danin, 1972, 1999a, 1999b) led to the discovery of many species with narrow ecological ranges. Many of these species became new records for the flora of the area investigated. This type of terrain is easy to delimit in aerial photographs. The discovery of *Origanum ramonense* Danin increased greatly the investigative value of this edaphic-ecologic entity (Danin, 1967), and it became the first vegetation unit to be recognised and delimited via aerial-photo-interpretation. There is an outcrop of such rocks in the middle part of the slope in Figure 1. The runoff water from these rocks to the area below it enables the development of dense vegetation there. The other strip of dense vegetation is that of the wadi, where runoff water from all slopes accumulates.

Steppe-forest vegetation

P. atlantica trees seen on hill slopes in proximity to the smooth rock outcrops, in the Negev Highlands near Mt. Ramon, drew special attention. The varying size of the catchment area contributing runoff water to the trees and covered by shrub-steppes called for special investigation. The basic hypothesis for explaining the varying size of the catchment area was related to the edaphic factor.



Figure 1. An aerial view of a shrub-steppe area at the Negev Highlands near Sede Boqer. For explanations see text.

However, found in an area hard to access, preliminary investigations had to be done on similar rock outcrops in areas easier to access. Finding rare plants, in the desert vegetation context, led to a search for the frequency of specimens of rare species in relation to the nature of the rock outcrop. There are many relicts from events when a Mediterranean moist climate prevailed in areas that are desert at present. Hence, something in the rock properties should have been linked with the survival of mesophytes in the desert. The runoff contribution properties were searched, and the conclusion was that biogenic weathering of rocks has a direct impact on this parameter. A study carried out later that dealt with water penetration into the soil in deep rock crevices (Yair & Danin, 1980) approved the earlier assumptions. Additional researches dealing with rock surface weathering (Danin et al., 1982; Danin & Garty, 1983) took place. It was concluded that epilithic lichens encrusting the rocks in north-facing slopes protect the rock from local accelerated weathering, thus leading to the formation of smooth-faced outcrops. This kind of surface contributes high quantities of runoff water.

In preparation for the steppe-forest investigations, plants of the entire country were classified according to the rarity of their occurrence in the desert. The sources of information used were my vegetation records and personal experience. A value of rare-species-supporting index was calculated for each plot according to the findings in the field. We tried to evaluate the runoff contribution of each type of terrain to the first *P. atlantica* tree closest to the local water divide. However, smooth-faced large outcrops support seedlings of *P. atlantica* and

relatively small areas of this terrain are needed to sustain trees on slopes. Danin and Orshan (1970) give an average of 1500 m² (n = 7) for the first *P. atlantica* tree. On the other hand, a much larger area of fissured rocks is found to sustain the first tree on a slope—it is 250,000 m² (n = 9). A by-product of the steppe-forest investigations is the discovery of a rare tree species new to science, *Amygdalus ramonensis* Danin (Figure 2; Danin, 1980).

The attempts to produce a mathematical equation failed, but the models directed me to conclude the main 2 thumb-rules: 1. The smoother and larger smooth-faced rock outcrops may harbour larger numbers of specimens of rare species. Such rocks may be detected by trees growing on slopes of steppe-forests. 2. There is always a high chance to find some unexpected findings in rock outcrops that were not visited before.

Plants confined to chalk, marl, and clay outcrops

Chalk, marl, and clay outcrops function as a soil with high water holding capacity. Rain water becomes retained in these substrata close to their surface and is thus highly influenced by direct evaporation. Rain water in Israel contains some 8 ppm of sea-derived salts (Yaalon, 1963). Most areas of these rocks in the desert are covered by plant communities dominated by halophytes (Danin, 1978; Danin & Solomeshch, 1999). Several species new to science have been discovered on such outcrops, probably because earlier researchers were not aware of the peculiar edaphic conditions of these strata. Recording the chalk and marl vegetation and treating separately the land units with soft rocks of different eras yielded in Israel the discovery of *Reaumuria negevensis* Zohary &



Figure 2. *Amygdalus ramonensis* at a wadi enjoying a catchment area with smooth-faced rock outcrops.

Danin, which is confined mainly to Eocene and Cretaceous chalk and marl, and *R. hirtella* Jaub. & Spach varieties, which abound on Senonian chalk and marl (Zohary & Danin, 1970). *Ferula daninii* Zohary was collected first on Senonian marl outcrops near Sede Boqer (Zohary, 1972). *Satureja thymbrifolia* Hedge & Feinbrun is a narrow endemic plant of an endemic rock sequence derived from Senonian marl (Danin, 1968). *Brassica deserti* Danin & Hedge was collected from soft-rock terrain at the margins of Gebel el Igma in Sinai (Danin & Hedge, 1973).

In conclusion, soft rocks with their salinity should be regarded as a peculiar habitat and should be investigated in detail due to the possibility of their supporting poorly known taxa.

Sinai research

From 1967 through the 1980s I was part of the research team of the Hebrew University, which had a mandate to study the flora and vegetation of Sinai. We tried to implement the knowledge and experience gathered through research in Israeli deserts to Sinai. The mountains of the Isthmic Desert (N Sinai) are similar geomorphological structures to those of the Negev. Their rock sequence is similar as well; the climate is a bit drier, but the general picture is the same. When preparing our excursion to the anticline of Gebel Halal, we used a light airplane for a reconnaissance flight. We discovered a large smooth-faced limestone outcrop at Wadi Abu Sayala area (Figure 3), supporting dozens of *Juniperus phoenicea* L. trees. A few days later, when walking there we discovered among others a new *Origanum* L., which after

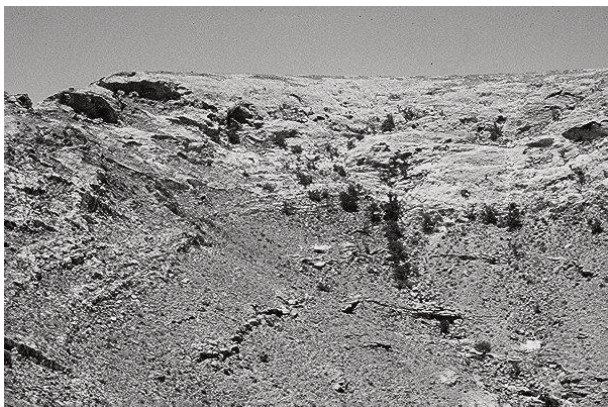


Figure 3. A large outcrop of smooth-faced limestone at the catchment area of Wadi Abu Sayala, N. Sinai, supporting *Juniperus phoenicea* trees.

additional investigation became *O. isthmicum* Danin (Danin, 1969).

Large areas of exposed sandstone occur in the sandstone belt of S Sinai (Danin, 1983). However, the shortage of time prevented us from conducting a thorough investigation of the sandstone. In addition, the elevation of the sandstone belt in Sinai seems to be below the threshold altitude enabling the development of certain lichens that have an important role in the weathering of sandstones in Jordan. The elevation of the magmatic-metamorphic massive of S Sinai is much higher and there are granite rocks there that constitute huge outcrops of smooth rocks. Such are Gebel Serbal, G. Musa, and G. Bab. Several taxa new to science were discovered by our team. Earlier explorers of S Sinai, and specifically the collector Bové in 1834, seem to have known the “secret” of the smooth-faced granite outcrops.

S Jordan research

The peace treaty between Israel and Jordan opened new horizons for Israeli botanists. Our theories developed in the Negev, tested and expanded in Sinai research, served us during excursions to the areas unknown to us. The theory of smooth-faced rock outcrops supporting taxa new to science was tested again. Of the 11 new species discovered in Jordan 10 are confined to smooth-faced rocks. Of these 8 are growing only on sandstone, 2 on limestone and sandstone, and 1 only on limestone outcrops (Danin, 1990, 1991; Danin & Kuenne, 1996; Danin & Hedge, 1997; Danin et al., 2000). One of the southern-most *Quercus calliprinos* Webb. specimens in Jordan is seen in Figure 4, and a typical landscape supporting a *Juniperus phoenicea* population north of Petra, Jordan, in Figure 5.

Conclusions

The edaphic factor has a high impact on the distribution of plants in desert areas. Two groups of rocks should be marked in the chores list of any botanic investigation in an unknown area: 1. Smooth-faced hard rocks of limestone and dolomite, sandstone, and granite. This edaphic type may enable the growth of mesophytic plants, which continue to survive in these local refugia from times when the climate was moister (Table 1). 2. Soft rocks, mainly of chalk, marl, and clay, which display moisture regime of fine-grained soils, become saline under desert conditions and tend to support highly adapted plants (Table 2).

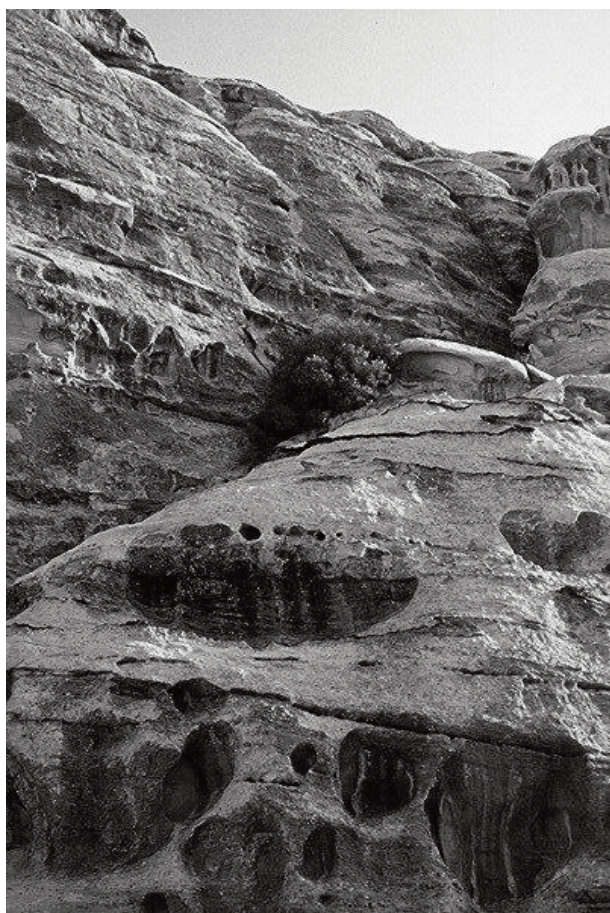


Figure 4. A hard sandstone outcrop near "small Petra", SW Jordan, supporting an oak specimen. The entire surface of the rock is populated by crustose lichens.



Figure 5. A *Juniperus phoenicea* population in hard sandstone outcrop terrain near Petra, Jordan.

Table 1. A list of species and subspecies, confined to smooth-faced rock outcrops in desert, described by A. Danin.

Taxon	Year Published
<i>Origanum ramonense</i> Danin	1967
<i>Origanum isthmicum</i> Danin	1969
<i>Kickxia macilenta</i> (Decne.) Danin	1973
<i>Micromeria serbaliana</i> Danin & Hedge	1973
<i>Kickxia judaica</i> Danin	1977
<i>Amygdalus ramonensis</i> Danin	1980
<i>Polygala negevensis</i> Danin	1987
<i>Origanum petraeum</i> Danin	1990
<i>Origanum punonense</i> Danin	1990
<i>Kickxia petrana</i> Danin	1991
<i>Origanum jordanicum</i> Danin et Kuenne	1996
<i>Micromeria danaensis</i> Danin	1997
<i>Rubia danaensis</i> Danin	1997
<i>Silene danaensis</i> Danin	1997
<i>Teucrium leucocladum</i> Boiss. subsp. <i>jordanicum</i> Danin	1997
<i>Teucrium leucocladum</i> Boiss. subsp. <i>sinaicum</i> Danin	1997
<i>Pycnocycla saxatilis</i> Danin, Hedge & Lamond	2000
<i>Bufonia ramonensis</i> Danin	2001

Table 2. A list of species, confined to chalk and marl outcrops in desert, described by A. Danin.

Taxon	Year Published
<i>Reaumuria negevensis</i> Zohary & Danin	1970
<i>Ferula daninii</i> Zohary	1972
<i>Brassica deserti</i> Danin & Hedge	1973
<i>Satureja thymbrifolia</i> Hedge & Feinbrun	1968
<i>Minuartia sinaica</i> (Boiss.) Danin	1987

References

- Bourvine A (1963). Mapping and ecology of the plant communities of Sodom salt marsh. – *MSc Thesis, The Hebrew University, Jerusalem* (in Hebrew).
- Braun-Blanquet J (1951). *Pflanzensoziologie*. 2nd ed. Wien: Springer.
- Danin A (1967). A new *Origanum* from Israel, *Origanum ramonense* Danin sp.n. *Isr J Bot* 16: 101-103.
- Danin A (1968). On the ecology of *Satureia thymbrifolia* in the Judean Desert. *Isr J Bot* 17: 216.
- Danin A (1969). A new *Origanum* from the Isthmic Desert (Sinai), *Origanum isthmicum* sp.n. *Isr J Bot* 18: 191-193.
- Danin A (1972). Mediterranean elements in rocks of the Negev and Sinai Deserts. *Notes Roy Bot Gard Edinburgh* 31: 437-440.
- Danin A (1978). Species diversity of semishrub xerohalophyte communities in the Judean Desert of Israel. *Isr J Bot* 27: 66-76.
- Danin A (1980). A new *Amygdalus* from Israel, *Amygdalus ramonensis* sp. n. *Notes Roy Bot Gard Edinburgh* 38: 283-285.
- Danin A (1983). Desert Vegetation of Israel and Sinai. Jerusalem: Cana.
- Danin A (1990). Two new species of *Origanum* (Labiatae) from Jordan. *Willdenowia* 19: 401-404.
- Danin A (1991). A new species of *Kickxia* (Scrophulariaceae) from Jordan: *K. petrana* sp.n. *Willdenowia* 21: 181-184.
- Danin A (1999a). Desert rocks as plant refugia in the Near East. *Bot Rev* 65(2): 93-170.
- Danin A (1999b). Sandstone outcrops - a major refugium of Mediterranean flora in the xeric part of Jordan. *Isr J Plant Sci* 47: 179-187.
- Danin A (2001). Near East ecosystems, plant diversity. In: Levin S (ed.) *Encyclopedia of Biodiversity*, 4: 353-364. Academic Press.
- Danin A & Garty J (1983). Distribution of cyanobacteria and lichens on hillsides of the Negev Highlands and their impact on biogenic weathering. *Z Geomorph* 27: 423-444.
- Danin A, Gerson R, Marton K & Garty J (1982). Patterns of limestone and dolomite weathering by lichens and blue-green algae and their palaeoclimatic significance. *Palaeogeogr Palaeoclimatol Palaeoecol* 37: 221-233.
- Danin A & Hedge IC (1973) Contributions to the flora of Sinai. I. New and confused taxa. *Notes Roy Bot. Gard. Edinburgh* 32: 259-271.
- Danin A & Hedge IC (1997). Contributions to the flora of Jordan: a new species of *Satureja* and some new records. *Willdenowia* 28: 135-142.
- Danin A, Hedge IC & Lamond JM (2000). Contributions to the flora of Jordan 4: A new species of *Pycnocycla*. *Willdenowia* 30: 77-81.
- Danin A & Kuenne I (1996). A new species of *Origanum* (Labiatae) from Jordan: *O. jordanicum* Danin et Kuenne sp.n., and notes on the species of section *Campanulatalyx*. *Willdenowia* 25(2): 601-611.
- Danin A & Orshan G (1970). Distribution of indigenous trees in the northern and central Negev Highlands. *La-Yaaran* 20: 115-120.
- Danin A, Orshan G & Zohary M (1964). Vegetation of the Neogene sandy areas of the Northern Negev. *Isr J Bot* 13: 208-233.
- Danin A, Orshan G & Zohary M (1975). The vegetation of the Northern Negev and the Judean Desert of Israel. *Isr J Bot* 24: 118-172.
- Danin A & Solomeshch AI (1999). Synopsis of the vegetation and enumeration of the associations. In: Danin A & Orshan G (editors) *Vegetation of Israel. I. Desert and coastal vegetation*. Leiden: Buckhuys.
- Lipkin Y (1971). *Vegetation of the Southern Negev*. PhD thesis, The Hebrew University, Jerusalem (in Hebrew with an English abstract).
- Monod Th (1954). Modés "contracté" et "diffus" de la vegetation Saharienne. Pp. 35-44 In: Cloudsley-Thompson JL (ed.), *Biology of Deserts*. New York: Stechert-Hafner.
- Rudich D & Danin A (1978). The vegetation of the Hazeva area, Israel. *Isr J Bot* 27: 160-176.
- Whittaker RH (1962). Classification of natural communities. *Bot Rev* 28: 1-239.
- Yaalon DH (1963). On the origin and accumulation of salts in groundwater and soils of Israel. *Bull Res Council Isr* 11c: 105-131.
- Yair A & Danin A (1980). Spatial variations in vegetation as related to the soil moisture regime over an arid limestone hillside, Northern Negev. *Oecologia (Berl.)* 47: 83-88.
- Zohary M & Danin A (1970). The genus *Reaumuria* in the Near East. *Isr J Bot* 19: 305-313.
- Zohary M (1972). Flora Palaestina. part II. Israel Acad. Sci. Human. Jerusalem. 486 pp.