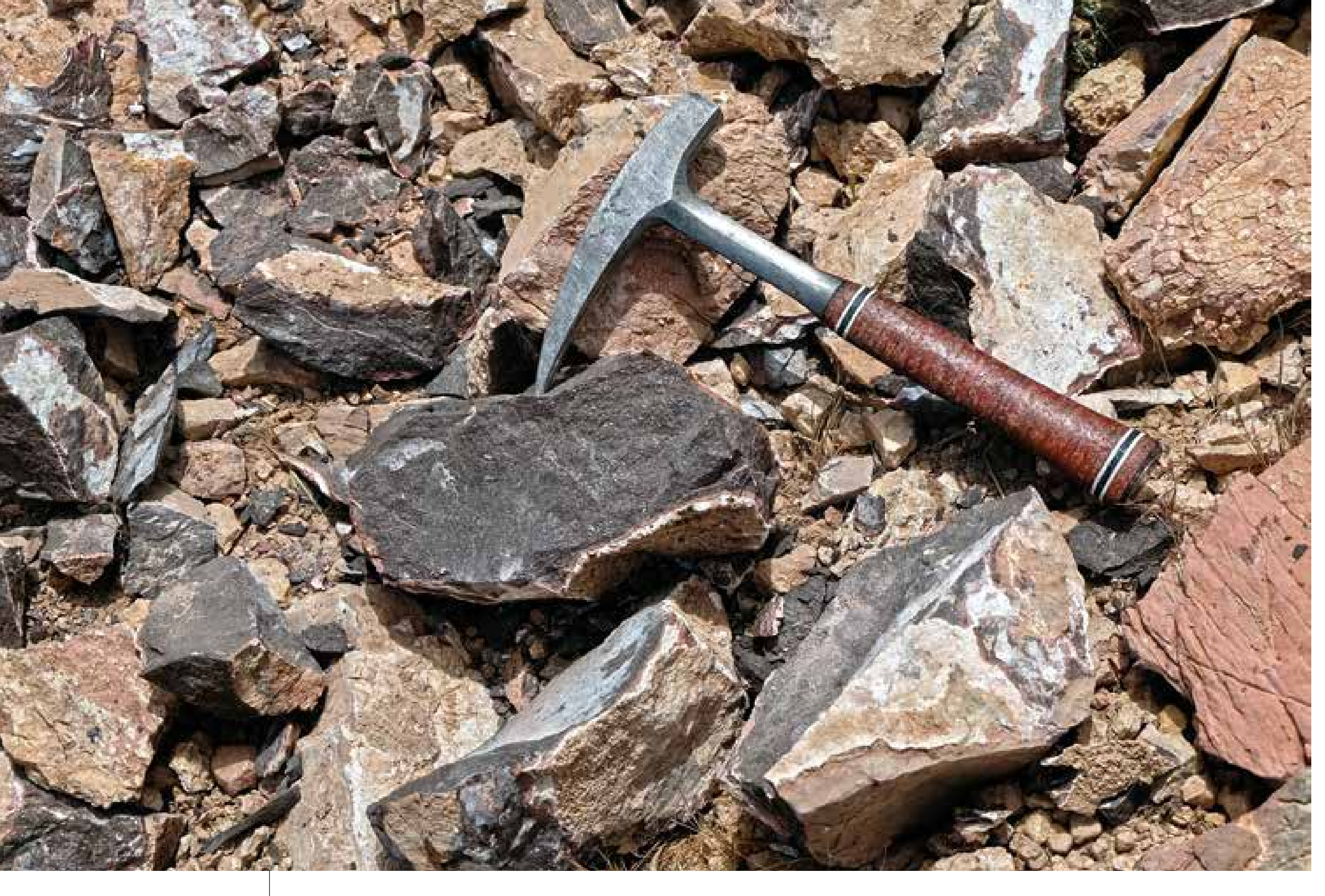
And the Rocks Shall Lead Us

Apart from the commonly known minerals, nature also provides certain very rare varieties discovered only relatively recently. Some, due to their unique physical characteristics, can be utilized in various industries, while others may be used as inspiration for developing new synthetic materials.

Photo taken while collecting samples of larnite rock in Israel.



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Nature has been an unending source of inspiration for painters, musicians and poets alike. Just think of Vivaldi's *Four Seasons*, Van Gogh's *Sunflowers* or *The Ackerman Steppe* by Mickiewicz. Undoubtedly, the world's first inventors and engineers were also inspired by the natural world surrounding them, such as Leonardo da Vinci, who designed wings based on his observations of birds and bats. But in today's times, with digitization evolving at a rapid pace, can nature still inspire? And more importantly from the point of view of an average person, can environmental research contribute to improving our quality of life in the world of computers and similar technologies?

The answer is simple: contemporary environmental research does indeed provide numerous benefits to the economy and industry – such as new technological materials.

Triply unique

Skarnoids are pyrometamorphic calcium-silicate rocks, which form under very distinctive conditions: at temperatures of 1000–1250°C, but at low pressures. Such conditions are not common in nature. Thus far, only two possible heat sources have been identified, for which high temperatures and relatively low pressure can cooccur – surface intrusions of magma and large-scale spontaneous combustions of fossil fuels. The samples we have come from extinct volcanoes, including Shadil-Khokh in South Ossetia and Bellerberg in western Germany. In both these cases the flowing magma carried these pieces of carbonate sedimentary rocks, giving rise to their unique mineralogical composition. The third known research site is the Hatrurim complex, located in Israel, Palestine and Jordan. The rocks found there were formed by high temperatures occurring most likely due to the spontaneous combustion of bitumen-rich layers. As far as their mineralogy is concerned, however, all these rocks are similar.

What makes them unique? First, their chemical composition. Silica was introduced into the primary limestone, followed by further geological processes, such as volcanic exhalations, which brought with them a whole spectrum of chemical elements. Thanks to this process these rocks contain almost all the elements in the periodic table. The second thing that makes these rocks special is their genesis. The unique pressure and temperatures may have helped create minerals never before found in any other geological formations. In the Hatrurium formation alone, as many as 25 previously unknown mineral species have been discovered since 2009. And the discovery of a new mineral is not only a valuable contribution to mineralogy, but also to other scientific fields, such as solid-state physics, chemistry, crystallography and materials science.

The many faces of mayenite

A newly discovered mineral, which has not yet been synthesized, may represent a new phase that may prove useful in various fields of technology. It is also sometimes the case that, despite the existence of a synthetic phase used in industry, studying materials of natural origin produces further quantifiable benefits.

A very interesting example of this can be found in the minerals of the mayenite supergroup, a phase rarely found in nature, commonly occurring in the types of rocks we have been discussing above. For many years, synthetic mayenite was known to be a common ingredient in Portland cement, but it wasn't until 1964 that it was discovered in natural conditions. Despite the fact that over 60 years have passed since this discovery in natural rocks, these phases are still relatively not well understood, as evidenced by the new developments within this group, such as the discovery of chlorkyuygenite, a mineral with the structure and composition of mayenite with additional water in structural voids, or the verification of the chemical formula of the first mayenite discovered and its being named chlormayenite. These minerals did not attract much interest until quite recently, but more thorough examination of their structure has shown them to have extraordinary physical characteristics, thus attracting much attention in terms of new technological applications. This is due to their unique crystalline structure, resembling that of other minerals, zeolites, which have also been known and used for a long time.

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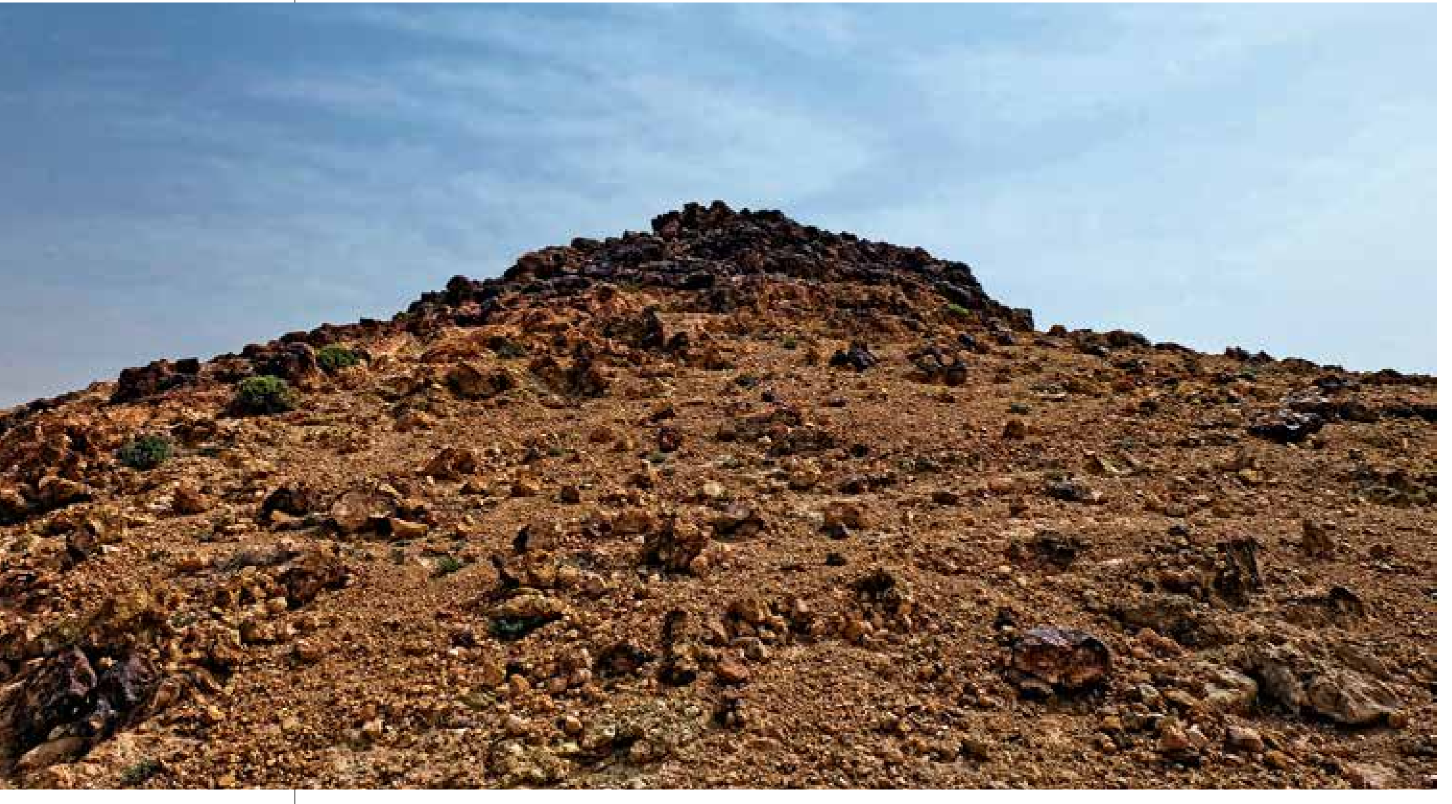

View of the top of hills in the Negev desert, formed by Hatrurim complex rocks.

Both these groups have a specific, nanoporous structure allowing them to capture elements from the surrounding environment. Because of this, mayenite is being considered as a future material for the production of a new "ecological" type of cement that can capture pollutants from sewage. Other possible uses for this mineral appeared with the discovery of oxygen mobility within it, and the fact that it is a transparent material. This allows it to be used as a conductor, more importantly a transparent one, which can be utilized in solar panels and electronics. The power cells used today are extremely expensive, as well as problematic when it comes to their disposal after use. Synthetic mayenite can be produced even from metallurgical waste and does not decompose, which solves both problems of the materials currently used in existing types of batteries.

And the possibilities offered by this mineral do not end there. This year there have been reports of another discovery within this group. Japanese scientists have published a study in which they showed that mayenites also have ferromagnetic properties, opening up new possibilities when it comes to using them as technological materials.

The minerals we are studying, however, are not only part of the mayenite group: in terms of their chemical composition and formation conditions, they are also the natural analogue of various cements. For example, the ye'elimite-larnite rocks of the Hatrurim Formation are the equivalent of belite cement clinkers. It suffices just to compare the minerals to their synthetic counterparts. Examples include the mineral hatrurite, which is referred to as alite in the cement nomenclature, whereas the mineral larnite, commonly found in these rocks, is known in the industry as type-II belite. This means that within their composition we can find many more phases that can be used in industry, and not just exclusively as cement components, but rather with much more practical applications. These include rondorfite and rusinovite, both potentially new luminescent materials (emitting light without heat), as well as ellestadite minerals, currently being tested for sulfur and chlorine immobilization capabilities (atom immobilization).

The need to search

Before such conclusions can be drawn, however, specialized studies first have to be carried out using modern research techniques. The process of discovering a new mineral starts with collecting rock samples in the field, where a lot depends on luck. The minerals we study rarely reach the size allowing them to be seen with the naked eye. This is why we collect many different types of samples, hoping to find more interesting phases within them. Next, we create thin sections from the collected rock samples and examine them mineralogically. Subsequent methods depend on what we happen to find in a given cross-section, although in most cases we study the chemical com-

Fragment of pyrometamorphic larnite rock from Jabel Harmun (Palestine Autonomy).

position and crystalline structure. Often this involves picking out mineral grains which are only about a few microns in size, which is quite difficult to imagine in practice! Before we can announce the discovery of a new mineral, however, we have to study a number of other physical characteristics, such as the mineral's hardness, density and even color. However, it should be stressed that finding and describing such a phase does not mean that we have discovered a new, useful material. The first step is to develop a method to synthesize a given mineral so that we can produce sufficient quantities of a given phase for further testing, and to determine its properties. Only then, after a number of tests, can we consider its possible applications. It is a long and very laborious process, with no guarantee of success.

At this point one might wonder whether such research is really necessary. After all, contemporary laboratories have the technology necessary to perform tests on synthetic materials. The pressure, temperature, and other parameters can be tailored to the needs of the experiment, providing detailed results and relationships. Despite this, researching natural rocks is important because it allows us to identify one important factor that we are unable to reliably reproduce in a laboratory – time. By exploring the properties of natural minerals that are counterparts to synthetic phases we are able to determine whether the material produced will biodegrade, or withstand weathering for one hundred, two hundred or even several thousand years. Also, testing natural phases sometimes enables us to utilize resources that have previously not been considered as potential materials for specific branches of industry. For example, researching the above materials has taught us that limestone sedimentary rocks with randomly distributed aluminum, gypsum and phosphate can be used as inexpensive natural materials for the production of belite clinker cement, as well as ecological replacements for ordinary Portland cement.

These examples demonstrate that the rare kinds of rocks described here are not only significant to mineralogical sciences, but also important to industry. This shows that Nature, despite rapid development and industrialization, can still provide technological solutions that can significantly contribute to facilitating everyday life. In 2009 Professor Wulf Depmeier from Kiel University wrote: "It is shown that Nature has many advantages over technology which can be profitably exploited for finding new materials with useful properties. [...] Nature can and should be used as a guide and source of inspiration for the preparation of new synthetic compounds with the goal of finding advanced materials."

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Further reading:

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