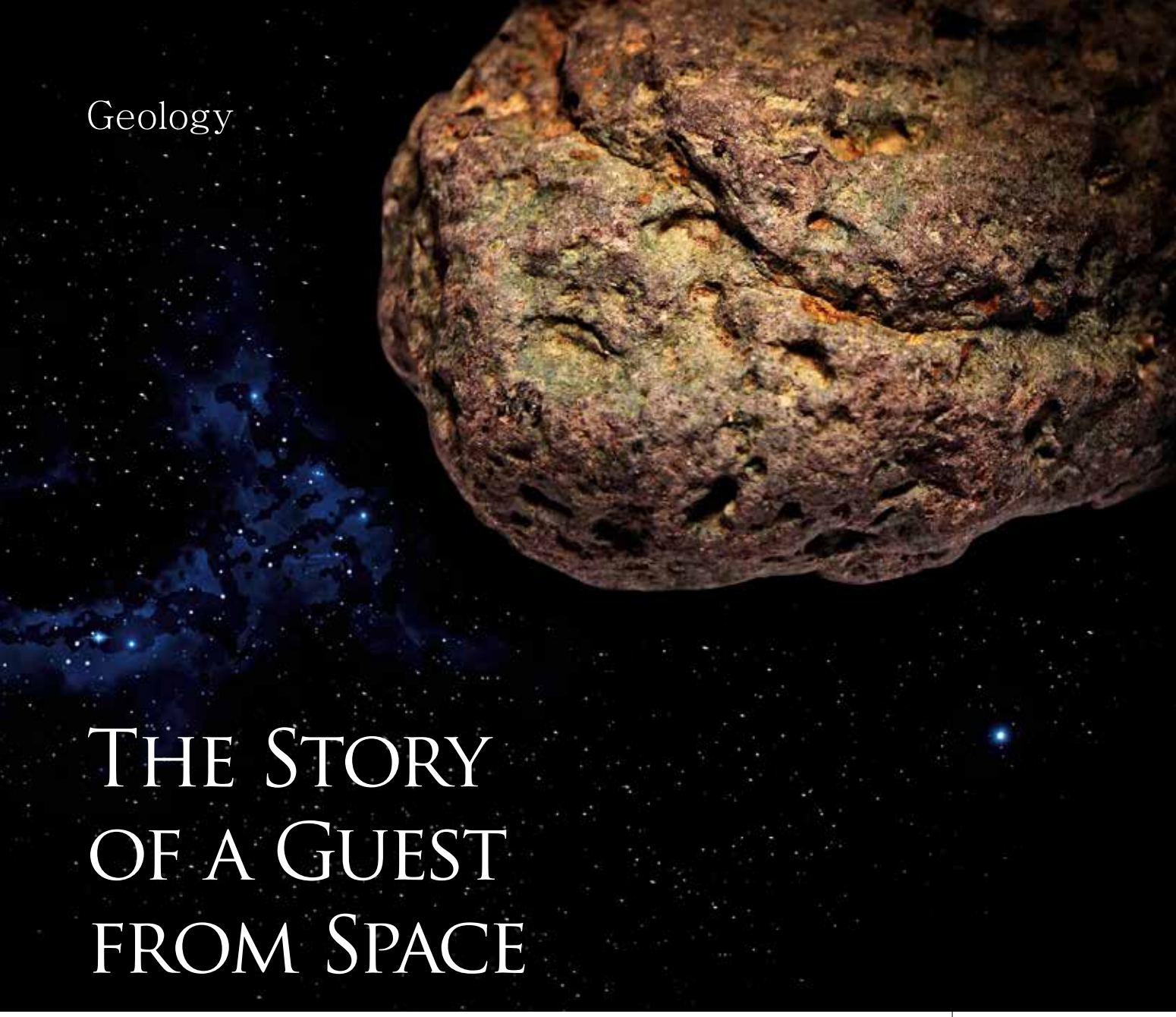

The Story of a Guest from Space

We have evidence of a meteorite impact near the village of Morasko in Poland around 5,500 years ago. What can it tell us about the past and the future?

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A planetoid hurtling towards Earth, threatening to destroy humankind, is a common theme in contemporary cinema. Such catastrophic visions may seem exaggerated, especially since our planet has experienced similar events many times in the past. The surfaces of Mercury, Mars or our own Moon are scarred by numerous impact craters, suggesting that collisions with planetoids and meteoroids are one of the most common geological processes in our solar system. Our own planet is no exception: we were reminded of this only recently, on 15 February 2013, when a meteorite struck near Chelyabinsk, injuring around 1,500 people and damaging 7,200 buildings.

Although there are many impact craters on Earth, they can be difficult to identify. This is mainly due to extensive erosion, sedimentation, and tectonic deformations taking place over long periods, all of which

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damage and destroy impact structures. The Earth Impact Database (www.passc.net/EarthImpactDatabase/) lists 190 confirmed events. One complex of impact craters can be found in Poland near the village of Morasko, which falls within the administrative boundaries of the city of Poznań. Since we have no historical documents describing their formation, one may ask: how do we know that a certain few shallow depressions amidst a mixed forest on the slope of Morasko Hill are actually impact craters?

The meteorite

The history of the Morasko meteorite dates back to the discovery of the first fragment in 1914, when Prussian soldiers, carrying out military exercises and digging trenches, came across an unusually

heavy stone which aroused the interest of their sergeant, Dr. Cobliner. The find was identified as an iron meteorite. Hundreds more fragments were found over the course of the following century, the heaviest of which weighs 261.2 kg. Their consistent chemical and mineral composition and spatial distribution indicate that they originated from the disintegration of a single meteoroid (note the terminological distinction: a "meteoroid" is a cosmic body, whereas a "meteorite" is the rock material left behind after meteoroid strikes the Earth). In fact the Morasko region is the site of the largest known iron meteorite shower in Central Europe.

Meteorites are an invaluable source of information on the development of our Solar System, the internal structure of planets and processes occurring in space. The extensive studies of the Morasko meteorite have resulted in many fascinating discoveries, the most important of which concern its composition. It is a coarse-grain octahedrite meteorite containing 7% nickel (Ni) and 93% iron (Fe) on average. Their mineral compositions is dominated by kamacite and taenite (alloy of Fe and Ni) with sporadic occurrence of cohenite and schreibersite (Fe and Ni calcites and phosphates). It also contains nodules with a diameter between 1 and 2.5 cm, comprising graphite and troilite with trace silicates, sulfates, oxides and phosphoranes. Recently, two new minerals known as moraskoite and czochralskiite – neither of which are found on Earth – have been discovered in the Morasko meteorite.

Craters

Not all meteorites cause the formation of impact craters. Many strike the Earth's surface without causing significant damage, and even the very fact that they are responsible for impact craters had been questioned until relatively recently. The American geologist and industrialist Daniel Barringer identified a vast impact crater in Arizona in 1903, which now bears his name,


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yet his view that it was actually formed by a meteoroid remained rejected by many scientists until after his death.

Dr. Jerzy Pokrzywnicki, one of the first scholars of the Morasko meteorite in the mid-20th century, suggested that a few round depressions with a diameter of up to 100 meters, found on the slopes of the moraine hills here, are indeed impact craters. However, the identification of such relatively small structures was fraught with difficulty. Major impacts are responsible for extremely high temperatures and pressures which cause visible changes in the rocks, in a process known as shock metamorphism. In more minor events, the conditions favoring the formation of craters may not be significantly different from other processes shaping the Earth's surface. This was just one of the problems facing researchers studying the Morasko craters.

The Morasko Hill was formed by successive ice sheets, which shaped the surface and deposited sand, gravel and glacial till. The pressure of a glacier with a thickness of hundreds of meters on sediments of local clay and silt, which is highly plastic, caused its deformation. Additionally, round hollows are not unusual in post-glacial landscapes and they can be found in many locations in northern Poland as so called kettle holes. The Morasko Hill has a highly complex structure whose formation culminated with the disappearance of the final ice sheet from the region around 18,500 years ago.

In the case of Morasko, it was the time of the ice sheet's retreat that proved key to solving the problem of the origin of the round depressions. The largest crater is filled with water and its bottom is covered with sediment including plant remains which have been radiocarbon dated to being no older than 5,500 years. This suggests that their formation is significantly younger than the surrounding post-glacial landscape. The impact origin of the depressions is indicated by their morphology, spatial distribution, age of sediment, findings of meteorites and micrometeorites,

Fig. 1.
The largest fragment of the Morasko meteorite, weighing in at a hefty 261.2 kg

Fig. 2.
The largest impact crater on the slopes of the Morasko Hill

and the recently documented sediment displaced from the craters and found in the surrounding area, called ejecta. Initially it was interpreted as glacial sediment; however, it has since been found that it covered soil whose age matches that of the oldest sediments filling the craters – around 5,500 years. Geophysical, sedimentological and mineralogical research continues to provide data which makes it possible to interpret crater formation processes with increasing precision.

Effects

Meteoroid strikes are rare and rapid, and they cannot be observed and measured in real time. The only way of gaining insight into the processes and the forces behind them is studying indirect evidence, such as crater size or shock metamorphism of rocks, as well as applying numerical modelling. Numerical experiments based on available data conducted by the research team from the Institute of Geology at the Adam Mickiewicz University in Poznań and experts from the Museum für Naturkunde, Leibniz Institute for Research on Evolution and Biodiversity in Berlin show that the meteoroid had an original mass between 600 and 1100 metric tons and moved at a speed between 16 and 18 km/s. It is likely to have disintegrated in the atmosphere; the largest crater was made by a fragment approximately 3 m in diameter and moving at a speed of around 6 km/s.

Did the event have any effect other than forming craters? Other well-known major impacts caused fires, powerful impact waves, earthquakes, tsunamis, and even climate change. The period of 5,000–5,500 years ago marks the beginning of the Neolithic in the Wielkopolska region, so naturally there are no historical descriptions of any effects. This means we need to rely on geological archives, such as sediments found in lakes. There are several post-glacial lakes near the craters which have accumulated sediments and plant and animal remains over thousands of years, making it possible to interpret environmental changes in the area, climate changes, results of human activity and local catastrophic events. Preliminary results indicate that the effects of the impact were far less significant than intuition suggests. Extensive fires were unlikely, and the range of the disaster was likely limited to the nearest surroundings of the actual impact sites.

The Morasko meteorite and the slowly emerging story of how it crashed into Earth is more than a fascinating piece of local history. It is also a terrific site for comprehensive research into the outcomes of one of the most common geological processes. The Near-Earth Objects (NEO) program monitors outer space and aims to identify objects which may strike Earth. Studying evidence of past events will help us learn about our planet's history and help make predictions of what could happen in the future.

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