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ORIGINAL ARTICLE

Bringing the History of the Earth to the Public by Using Storytelling and Fossils from Decorative Stones of the City of Poznań, Poland

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Abstract
The fossil content of building and decorative stones is used to communicate a wide range of geological knowledge, namely the history of the Earth, plate tectonics, evolutionary patterns and climate change, to nonexpert audiences. Storytelling and narratives are employed to improve the level of interpretation of palaeontological geoheritage. Seven rock types, five of which are highly fossiliferous, widely utilized in most recognizable monuments of the city of Poznań in Poland are employed to produce a complex narrative that guides the individual from the Ordovician to the Neogene period. The narrative is accompanied by rich visuals (graphic reconstructions of ancient ecosystems and now-extinct organisms, palaeogeographical maps) available in four printed and online leaflets and guides, supplemented by a museum exhibition where additional rocks and complete fossil specimens are shown and by workshops for more deeply interested participants. The narrative component of the project allows the detection of the most common misconceptions related to the Earth sciences and strengthens the engagement of individuals involved in the project. The project is developed further with self-guided walks around other Polish cities.

Keywords Urban geology · Palaeontological geoheritage · Storytelling · Geoscience education

Introduction

Storytelling and narratives support the communication of scientific phenomena to nonexperts (Dahlstrom 2014). Although stories can potentially result in distorted display of scientific data (Katz 2013), they are also found by nonexpert audiences to be more engaging than formal scientific communication (Green 2006). The persuasive influence of narrative is found to be greater than in the case of purely scientific arguments (Green and Brock 2000). The potential of storytelling can be particularly high in communicating scientific phenomena that lie beyond the human scale and cannot be directly experienced (Dahlstrom 2014), for example the geologic time scale or plate tectonics. Moreover, narratives describe cause-and-effect relations over a particular time span which closely relates to the natural order of geological processes, such as in the Wilson cycle or rock cycle. The scientific communication of Earth science facts can therefore significantly benefit from the concept of storytelling.

Narratives have been used in geological sciences from the times of Wolfgang Goethe and Charles Darwin (Lennox 1991). The role of scientific storytelling in Earth sciences has been analysed by Phillips (2012), who identified eight basic plots (i.e. storylines and schemes) that can be employed when reporting geological facts. Although no applications of narratives in geoheritage promotion have been cited by Phillips (2012), the concept of storytelling is well established in museum exhibitions (see example explanatory panels figured in Mariotto and Venturini 2017). The idea of improving the level of interpretation of geoheritage by means of storytelling has also been studied by Migoń and Pijet-Migoń (2017). Here, an example of the utilization of narratives in the promotion of urban geological and palaeontological heritage is discussed.

The importance of geological sites that are located in cities has been underlined by De Wever et al. (2017). Geological sciences are perceived by nonexpert audiences as disconnected from everyday life, and geologists' work is commonly associated with fieldwork in distant countries and on other continents. Thus, the promotion of geological objects that can be found in nearby surroundings and easily

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studied becomes an important mission of Earth science scholars and museums.

The present study concentrates on urban palaeontological geoheritage, that is, the fossil content of the building and decorative stones and its relation to the history of the Earth, changes of the climate, plate tectonics and evolution. Most of the geological processes involved form a clear cause-and-effect relationship, which makes storytelling and narratives a logical choice for communication of such phenomena.

The use of building and decorative stones from historic buildings and monuments in the promotion of geological concepts is common. The potential of building stones for geotouristic purposes has also been recognized in Poland, with an extensive guide for the city of Kraków published in Polish and summarized in English (Rajchel 2008) and smaller contributions for other cities. However, none of the Polish guides and few from other countries focus on the palaeontological content of decorative stones and their relation to the history of life and the history of the Earth. The Paleourbana website (http://paleourbana.com), which maps fossils preserved in building stones from localities all over the world, is a notable exception. The project also hosts a list of published guides and websites that list fossil occurrences in the architecture of Amsterdam, Barcelona, Montreal, Moscow, Washington, D.C. and other cities across Europe and North America. Those projects explore fossil content, but its stratigraphical context and palaeogeographical interpretations are rarely described. The fossils in the architecture of Washington, D.C. project (http://dcfossils.org) are an exception; fossils are grouped into separate galleries according to their ages. Discussion on the anatomy of the fossil groups and their palaeoenvironmental significance is also provided. However, broader palaeogeographical interpretations and implications for the study of the history of the Earth play a less important role in that project. In the present study, the level of interpretation is significantly higher and involves storytelling to improve the dissemination of crucial Earth science concepts, in particular the basic principles of the palaeontology, plate tectonics and history of the Earth and the geological history of Poland and central Europe. The main scheme of the project fits well within the genesis story plot of Phillips (2012).

Pulling out rocks from their stratigraphical context hinders understanding of the palaeontological record (Clary and Wandersee 2014). Thus, the project under study aims at

Fig. 1 Source areas of building and decorative stones used in the project under study (marked by diamonds) and cities/towns in Poland for which palaeontological guides have been developed (marked by circles)

retaining of stratigraphical order of rock types that have abundant fossil contents and at focusing on the broader view, that is, on palaeoecological and palaeogeographical facts that can be read from the rock by a professional geologist. Cause-and-effect sequences of geological events are used in the narratives included in the guide and in the explanatory panels displayed in the exhibition.

Structure of the Project

Carbonates, sandstones and conglomerates that were deposited in the Ordovician, Devonian, Jurassic, Cretaceous and Miocene seas and in the foreland basins of the Carboniferous and Permian mountain belts are among the best recognized Polish building and decorative stones. They are widely used in

Table 1 Fossiliferous decorative stones and other rock types that were employed in the project under study. For a map of localities, see Fig. 1

Building/decorative stone, commercial names, source	Lithological description	Geologic features suitable for geotouristic purposes
Fossiliferous limestones and conglomerates		
Middle Miocene Pińczów Limestone (Pińczów area of the Carpathian Foredeep, 50° 33′ N, 20° 38′ E)	Organodetritic limestones composed mostly of skeletal remains of a diverse fauna; formed on a carbonate platform of the Miocene Paratethys sea at depths estimated as 30–80 m (Studencki 1988)	Rich assemblage of red algae, bryozoans, brachiopods
Middle and Upper Jurassic limestones from Poland (Morawica, 50° 44′ N, 20° 35′ E; Raciszyn, 51° 05′ N, 18° 51′ E), Germany (Eichstätt, 48° 54′ N, 11° 8′ E) and Hungary (Tardos, 47° 39′ N, 18° 26′ E)	Morawica Limestone (Middle Oxfordian, Holy Cross Mountains, southern Poland): light-grey to dark-beige sparry and micritic limestones with rich organic remains, deposited on an carbonate platform (Matyja 1977); Raciszyn limestone (Oxfordian, Działoszyn area in central Poland): grey to beige, sponge-bearing carbonates, massive to bedded, with ammonite, belemnite, and brachiopod fossil fauna (Wierzbowski 2002); Plattenkalk (Tithonian, Solnhofen/Eichstätt area, Bavaria, Germany): thin-bedded, fine-grained, pure limestones (Munnecke et al. 2008); Ammonitico Rosso: red, nodular, pelagic limestones with pelagic microfossils, rich in ammonites (Jenkyns 1974), widespread in the Alpine-Mediterranean realm, nodular limestones that are used in Poznań are from Hungary (Tardos limestone, Gómez-Heras et al. 2006)	Numerous fossils of siliceous sponges, ammonites and belemnites
Zygmuntówka conglomerate (Czerwona Góra quarry and Bolechowice area near Kielce, Holy Cross Mountains, southern Poland, 50° 48′ N, 20° 30′ E)	Coarse-grained, clast-supported conglomerates, deposited on an alluvial fan (Zbroja et al. 1998).	Coarsely grained sedimentary rocks, with clasts of older, fossiliferous Devonian carbonates
Middle to Upper Devonian limestones from the Holy Cross Mountains (Bolechowice, 50° 48′ N, 20° 30′ E) and Kraków area (Dębnik, 50° 9′ N, 19° 40′ E) in southern Poland	Grey, brown and black limestones deposited at depths estimated as less than 30 m, on a shallow-marine carbonate platform, with numerous stromatoporoid sponge fossils, corals, bivalves, brachiopods and bivalves (Racki 1993)	Rich assemblage of massive and dendroid stromatoporoid sponges
Ordovician limestones from the island of Öland ("Orthoceratite Limestone", 56° 50′ N, 16° 40′ E)	Red to brown and light-grey, fine-grained, bedded limestone, deposited at middle palaeolatitudes, with abundant fossil content (Calner et al. 2014).	Rich and diverse nautiloid shells (Kröger 2004)
Other stones used in the project		
Coniacian (Cretaceous) sandstones of the North Sudetic Synclinorium ("Upper Quadersandstein", southwestern Poland; Żerkowice, 51° 9′ N, 15° 34′ E)	Quartz sandstones of upper shoreface to foreshore origin, with large-scale cross--stratification, bivalves, ammonites and numerous trace fossils (Leszczyński 2010).	Clastic sedimentary rocks, sedimentary structures (cross-stratification)
Carboniferous granitoids from Lower Silesia (Strzegom, 50° 57′ N, 16° 19′ E; Strzelin, 50° 46′ N, 17° 2′ E)	Variscan granitoid (granite, granodiorite, diorite, tonalite) plutons of Western Sudetes, emplaced approximately 330–300 Ma ago (Kennan et al. 1999; Oberc-Dziedzic et al. 2013).	Mineral composition of the plutonic rocks; xenoliths in granitoids, magmatism related to the Variscan orogeny and to the formation of the supercontinent Pangaea

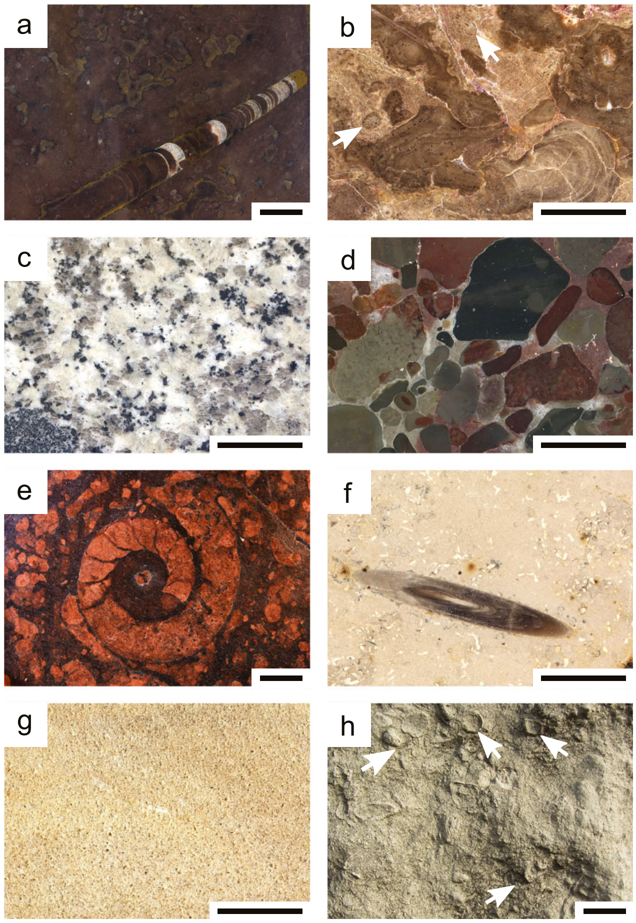

Fig. 2 Photographs of the building and decorative stones included in the project and examples of their fossil contents. **a** Ordovician "Orthoceratite limestone" with nautiloid shell. **b** Devonian limestone from the Holy Cross Mountains, with massive stromatoporoid-sponge skeletons and dendroid stromatoporoids (*Amphipora*, marked by arrows). **c** Carboniferous granitoid from Strzegom (Lower Silesia). **d** Permian Zygmuntówka conglomerate from the vicinity of Kielce, with rounded clasts of Devonian carbonates. **e** Jurassic ammonite limestone from Hungary. **f** Jurassic limestone from Bavaria, with cross-section of belemnite guard. **g** Cretaceous sandstones from the North Sudetic Synclinorium. **h** Miocene Pińczów limestone with shells of brachiopods and bivalves (marked by arrows). Scale bars 2 cm

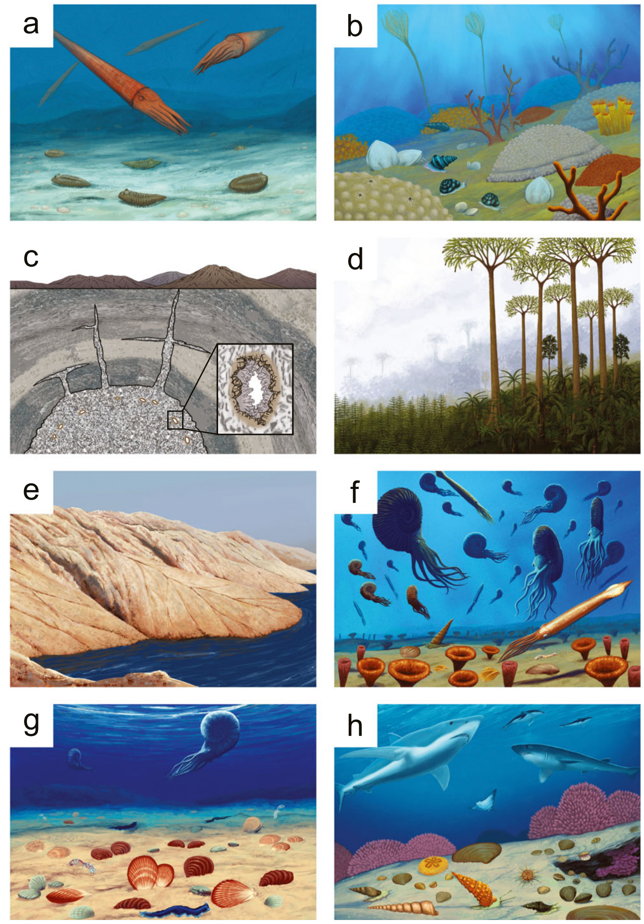

Fig. 3 Reconstructions of the sedimentary environments of decorative stones. Visuals are included in the printed guides/leaflets and featured on the explanatory panels at the exhibition. **a** Epicontinental sea of the Ordovician, located at the middle palaeolatitudes of the southern hemisphere, with free swimming orthoconic (i.e. straight) nautiloids and benthic trilobites *Asaphus* and *Megistaspis*. **b** Stromatoporoid-coral carbonate buildup of the warm Devonian sea of central Poland, with massive, dome-shaped stromatoporoid sponges *Actinostroma*, branching tabulate corals (*Thamnopora*), colonial *Hexagonaria*-type rugose corals, brachiopods (*Desquamatia* and *Spinatrypina*), gastropods (*Loxoplocus*, *Orecopia*), bivalves (*Megalodon*), and crinoids. **c** Simplified model of a granitoid pluton emplaced during the Variscan orogeny. **d** Carboniferous rainforest that occupied intramontane troughs and river valleys along the Variscan mountains during the times when granitoid plutons were emplaced. The dominant plants include scale trees (*Lepidodendron*), horsetails (*Calamites*), tree ferns (*Psaronius*) and gymnosperms (cordaites). **e** Deeply incised valleys stretching from the heavily eroded Variscan mountain ranges down to the coastline, dominated by gravity flows and fluvial processes in semi-arid to arid palaeoenvironment, in which Zygmuntówka conglomerates have been deposited. **f** Epicontinental sea of the Oxfordian (Jurassic) of Poland, with nektonic ammonites (*Perisphinctes*, *Cardioceras*, *Taramelliceras*) and belemnites (*Hibolites*) and benthic brachiopods (*Cheirothyris*, *Lacunosella*), sponges (*Cnemidiastrum*, *Craticularia*), and bivalves (*Pholadomya*). **g** Cretaceous sea of the North Sudetic Synclinorium in which sandstones have been deposited, with free swimming ammonites (*Lewesiceras*) and benthic bivalves (*Lima*, *Inoceramus*), brachiopods (*Rhynchonella*), flatworms and shrimps. **h** Middle Miocene Paratethys sea of the Pińczów area (Carpathian Foredeep), with sharks (*Hexanchus*, *Megalodon*), dolphins (*Lagenorhynchus*), echinoderms (*Cidaris*, *Clypeaster*), brachiopods (*Argyrotheca*, *Megathiris*), bivalves, gastropods, and red algae (*Lithothamnion*, *Mesophyllum*). All reconstructions drawn by Edyta Felcyn

pavements, facades and columns of historic monuments and public buildings of many of the cities and towns of Poland. These stones contain a diverse assemblage of fossils of sea animals, which can be relatively easy found and identified within polished slabs, even by nonpalaeontologists.

The building and decorative stones of the most emblematic monuments and the public buildings of the city of Poznań, Poland (Fig. 1) have been studied, and rock types that contain abundant fossils have been identified. The list of localities compiled during this part of the study contains over 60 buildings, most of them located in the city centre. Five types of decorative stones that were found to be fossiliferous are listed in Table 1. In addition, two other rock types that can potentially be used to popularize the knowledge related to the

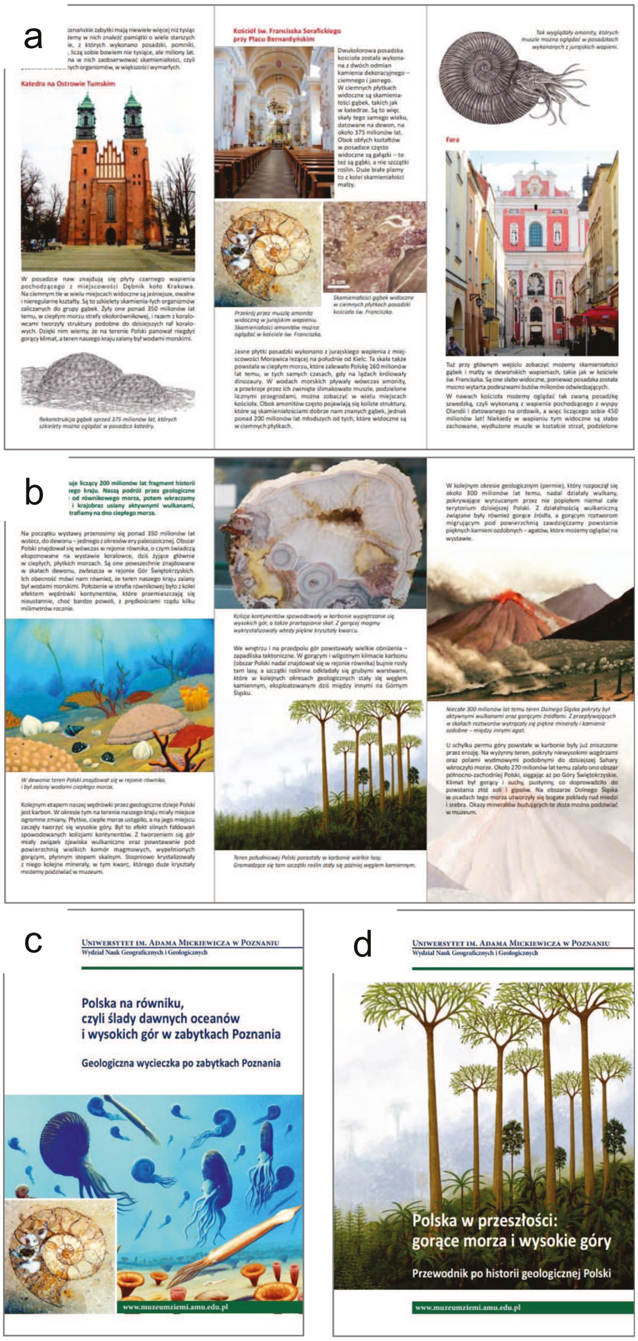

Fig. 4 Printed guides and leaflets published. All material is available in Polish. **a** A leaflet that introduce the tourist to decorative stones and fossils that can be spotted in the monuments of Poznań. **b** A leaflet that includes an introduction to the geological history of decorative stones. **c**, **d** Short geological guides that include more details on the decorative stones in the monuments of Poznań (**c**) and on the geological history of Poland (**d**)

history of the Earth and are present in most recognizable monuments of the city of Poznań have also been included in the database and in Table 1. Selected decorative stones allow the design of a complex storyline and can be easily spotted and recognized by nongeologists thanks to their unique features or fossil contents (Fig. 2).

Table 2 Four well-known historic churches of Poznań in which fossiliferous decorative stones are most prominent and fossils can be easily identified (these occurrences are included in all printed and online guides)

Archcathedral Basilica of St Peter and St Paul (The Cathedral) 52° 24′ 41″ N, 16° 56′ 54″ E The chessboard stone floor of the naves is made of the dark Devonian limestone from Dębnik near Kraków (southern Poland) and much lighter, yellow tiles of the Jurassic limestones from Morawica near Kielce (Holy Cross Mountains in Poland). The Devonian limestone contains easily visible, white and pale grey skeletons of sponges and corals. Cross sections of ammonite shells, belemnite guards and sponge mummies are common in tiles made of the Jurassic limestone.
St Francis Seraphic Church 52° 24′ 13″ N, 16° 56′ 14″ E The chessboard stone floor comprises yellow tiles of the Jurassic Morawica limestone and much darker, brownish tiles of the Devonian limestone from the vicinity of Bolechowice village near Kielce (Poland). The latter contain cross sections of massive and dendroid stromatoporoid sponges, bivalve shells and corals.
The Parish Church of St Stanislaus (The Collegiate Church) 52° 24′ 23″ N, 16° 56′ 03”E Most of the floor is comprised of two-coloured, chessboard-like, brown and grey tiles of the Ordovician limestone from the island of Öland (Sweden), in which light, arrow-shaped contours of large shells of extinct nautiloids are common. The stone floor of the porch is made of the Devonian limestone from Bolechowice near Kielce.
The Church of St Anthony of Padua 52° 24′ 30″ N, 16° 55′ 53″ E The stone steps of the altar are made of diversely coloured Zygmuntówka conglomerates from the vicinity of Kielce. Rounded clasts of the Devonian limestones are visible; many of them contain sponge fossils.

Earlier publications that involved the study of fossil content and the palaeoecological and palaeogeographical significance of each of the rock types employed in the project were used to prepare detailed geographical reconstructions of the sedimentary environments and fossil taxa which are best visible and common in decorative stones (Fig. 3). Palaeogeographical maps that show the position of Poland in past geological systems were also designed. The most remarkable fossils localized within the monuments were photographed. Polished slabs from source material were prepared and scanned using a flatbed scanner.

To make the geological history written in the decorative stones accessible to the public, the following printed and online material, accompanied by a museum exhibition, has been created:

(1). guides to decorative stones of Poznań: a short geological guide and a leaflet that introduce the tourist to decorative stones and fossils of the most impressive and widely recognized monuments of Poznań (Fig. 4), available for download at http://www.muzeumziemi.amu.edu.pl/poznan (in Polish)

(2). guides to the history of the Earth: a booklet and a leaflet that describe the geological history of decorative stones

Table 3 Distinct lithological types other than decorative or building stones included in the narrative and displayed in the exhibition at the Earth Sciences Museum in Poznań

Geological period (epoch)	Fossil, rock type, ore displayed on the exhibition	Geological events and palaeoenvironments
Neogene (Miocene)	Brown coal	Climate change during the Neogene in Europe; evergreen forests of the Miocene
Permian	Copper ore, salt and gypsum, fossil fuels	Warm sea of the Late Permian; its transgression and evaporation resulted in the formation of rich deposits of copper, salt and gypsum; carbonate rocks deposited in Late Permian sea later became a reservoir for fossil fuels
Carboniferous to Permian	Fossil wood, agates and other gemstones of Lower Silesia	Carboniferous rainforest collapse; Carboniferous to Permian volcanism of southern Poland
Carboniferous	Hard coal, fossils of scale trees, horsetails, and tree ferns	Carboniferous rainforests in intramontane troughs and river valleys along the Variscan mountain ridges
Ordovician	Fossils of the Ordovician to Silurian nautiloids and trilobites from Pleistocene erratic boulders of northern Poland	Pleistocene glaciations of Poland and erratic boulders of Ordovician to Silurian limestones of Sweden

and give geological background on the formation of the rocks under study (in Polish)

(3). an exhibition at the Earth Sciences Museum in Poznań, where fossils and samples of decorative stones are shown along with visuals (see details on the website of the museum: http://www.muzeumziemi.amu.edu.pl/poznan/en/, in English)

The guides and leaflets include descriptions of four to eleven occurrences of decorative stones, depending on the size of the publication, located in well-known historic churches and public buildings in which these stones can be spotted and fossils can be easily identified (Table 2). Initial attempts at studying the fossil contents of decorative stones with nonspecialists showed that printed and online materials are not sufficient when no fossil expert is available in place. Since it is not possible to provide a naturalist or trained mentor within the public buildings, a dedicated exhibition at the Earth Sciences Museum in Poznań has been set up. The exhibition is

Fig. 5 An example showcase displayed in the exhibition at the Earth Sciences Museum in Poznań. Its content enhances the visitor experience and enables a better visualization of the ancient ecosystem of the Jurassic sea

organized around a stratigraphic table which forms a logical outline for display units and reconstructions that introduce the visitor to the geological history of Poland and central Europe. Distinct lithological types that are not used as decorative or building stones but are related to events that are discussed in the exhibition or contain valuable mineral deposits (e.g. copper ore, salt and gypsum, hard and brown coal) are also displayed (Table 3). In the exhibition, most representative rock samples, polished slabs, fossil specimens and graphical reconstructions of fossil genera and ancient ecosystems are shown in 13 showcases that guide the visitor through the sequence of ancient ecosystems which documents over 300 million years of the Earth's history and facilitates better understanding of the underlying geological history, allowing each of the decorative stones within the monuments and public buildings of Poznań to be located much more easily (Fig. 5). Guides and leaflets present a narrative that involves the geological interpretation obtained both from decorative stones and from rock samples exhibited in the museum. For a short extract from the final story featured in the printed and online media, see Table 4. The successive scenes are connected to form a coherent narrative (Fig. 6), more deeply integrated than the content of a traditional exhibition.

Due to the enormous wealth of fossils in the Devonian limestones from southern Poland (Table 1) which formed on a carbonate platform of Laurussian shelf (Racki 1993), the printed and online material has been supplemented by workshops in which high school students and adults reconstruct the anatomy of the Middle to Late Devonian organic

Table 4 Summary of the narrative written for the project and included in printed/online material (in Polish) distributed among participants. The story is divided into scenes, and geological periods are provided here for a better understanding, but published guides and leaflets contain an uninterrupted narrative which better explains the concept of ongoing geological time. Note that the table should be read in stratigraphic order, that is, from bottom to top, while the printed material (read from the first to last page) is free of this limitation

Geological period (epoch)	Scenes from the narrative written for the present project	Geological terms and processes explained
Neogene (Miocene)	Shallow sea reached southern Poland for the last time. Thick salt and gypsum deposits originated from its warm waters. Farther north, evergreen forests overgrew the swamps of central Poland, giving birth to brown coal deposits.	Marine transgressions, evaporites, brown coal
Cretaceous	A large amount of sandstones were deposited in the shallow waters of the sea that flooded Poland in Cretaceous times. The climate was much warmer than today.	Formation of sandstones and cross-stratification
Jurassic	Marine waters returned to central Europe and Poland several times. The deep Jurassic sea was inhabited by large ammonites (some of them were active predators) and much smaller, squid-like belemnites. The sea floor was covered by living corals and sponges. Fossilized remains of these animals are abundant in the Jurassic rocks of Poland.	Fossil cephalopods, evolutionary processes, marine transgressions
Permian	Millions of years later, the inevitable geological processes of weathering and erosion brought the history of the mountains to an end. Large basins and deserts were flooded in Late Permian times by a warm, tropical sea. Under the conditions of hot and arid climate, huge masses of water evaporated, which led to the formation of layers of salt and gypsum. The Lower Silesian copper ores were also formed thanks to the transgression of the Permian sea. Along the mountainous coasts of the sea, sedimentary rocks such as Zygmuntówka conglomerates were deposited in deeply incised valleys. Their red to brown colour shows us that they were formed under conditions of semi-arid to arid climate, when Europe was located near the Northern Tropic.	Weathering and erosion, copper ore, evaporites, climate of the past, clastics, formation of conglomerates and salt deposits
Carboniferous	Much time passed by and immense mountain ridges emerged from the sea waters. In the Carboniferous Period, central Europe became a maze of mountains and valleys, marked by numerous active volcanoes and deep basins, in which vast swamp forests gave birth to huge coal deposits. The mountains formed when the collisions of continents gave birth to Pangaea, a giant supercontinent that assembled from other earlier continents.	Plate tectonics, continental collisions, magmatism, formation of Pangaea, plutonic rocks, hard coal
Devonian	The sea that flooded central Europe became warm and shallow. Its waters provided habitats for a diverse group of animals (corals and sponges) that formed organic buildups similar to contemporary barrier reefs. The presence of such organic buildups in mid and high latitudes shows that continents move over time and that Europe was once located near the equator.	Continental drift, fossil reefs
Ordovician	Millions of years ago, central Europe was flooded by a sea inhabited by extraordinary, now-extinct animals. Giant, predatory nautiloids ruled the waters, skimming across the sea in a hunt for prey. Their long, uncoiled shells can be easily spotted on the stone floors made of Ordovician limestone.	Evolution, extinct groups of animals

buildups. At least three distinct facies are easily spotted on the polished surfaces of the Devonian limestone: (1) amphiporid limestones with numerous dendroid skeletons of stromatoporoid sponges accompanied by brachiopods and bivalves; these limestones formed in a shallow lagoonal environment in central parts of the carbonate buildup

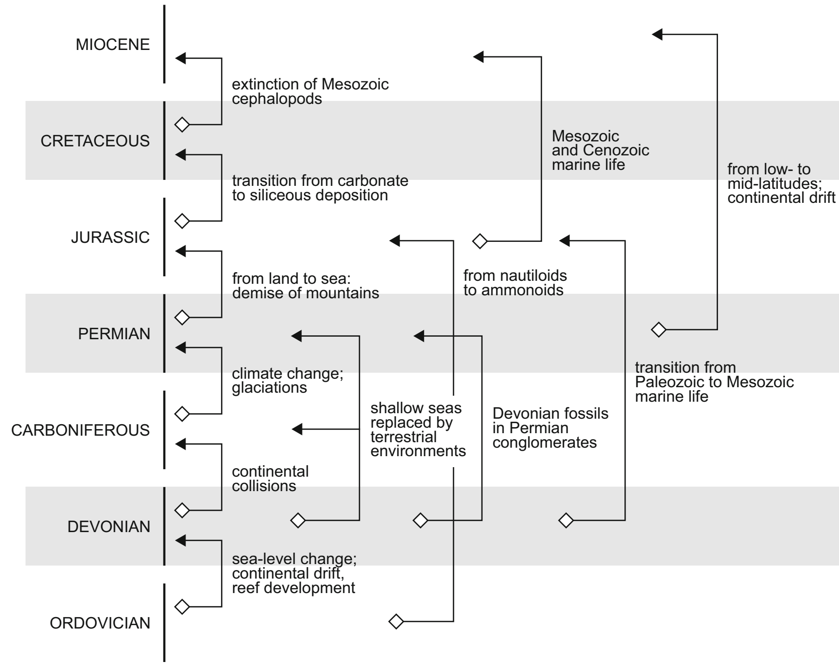

Fig. 6 Summary of the interconnections between successive scenes of the narrative written for the project and cause-and-effect relations between geological events and palaeoenvironments

(Fig. 7; Racki 1993); (2) massive stromatoporoid (sponge) limestones formed on the boundary of the organic buildup, in the wave-agitated zone; and (3) stromatoporoid-coral limestones deposited downslope, at depths of 10–20 m (Racki 1993). The participants learn to identify the most common fossils and discuss the relation of the Devonian carbonate buildups to modern reef barriers, acknowledging that the position of the European continent has changed dramatically from Devonian times.

Outcome of the Project

The project has been available to the public since September 2015. More than 2300 individuals have visited the Earth Sciences Museum in Poznań and 2500 copies of leaflets and printed guides have been distributed among them. Over 450 pupils and students from schools located in the vicinity of Poznań have participated in classes devoted to evolutionary processes and decorative stones and gained skills in the identification of basic minerals and rock types.

The further development of the project involves the preparation of geological guides and leaflets for other cities in Poland. A detailed description of a self-guided walk that comprises thirteen stops in the city centre of Gdańsk, Gdynia and Wejherowo in northern Poland and involves five types of decorative stones is available on the Internet (https://zywaplaneta.pl/trojmiasto/, in Polish). Similar guides are now being developed for Olsztyn and Warszawa (Fig. 1).

Discussion

The layers of rocks tell a story about their geological histories, which enable geoscientist to communicate the scientific facts by using a strong narrative. The fossil content and sedimentary structures accompanied by graphical reconstructions and a storyline broaden the palette of possible geological topics and themes that can be communicated by using decorative stones. However, the usage of visuals or multimedia is of equal importance to a clear narrative, because static and unexplained fossils or sedimentary structures are not sufficient for nonexpert audiences to understand the dynamic processes of the distant past (Dodick and Orion 2003).

Most spectacular geological phenomena (volcanic eruptions, earthquakes) occur abruptly, and therefore, long timescales that lie beyond human scale are not easily appreciated by the individual (Dahlstrom 2014). Thus, the storytelling component facilitates the communication of scientific findings that involve enormous time scales that are beyond the comprehension of a nonexpert audience. Moreover, a clear narrative restores the stratigraphic context of geological events that led to the formation of decorative stones.

Rocks that are used as decorative stones are easily available to the public without the need for fieldwork in remote areas. The presence of these stones in well-known historic monuments makes it easier to gain the interest of tourists and traditional media. Moreover, polished building and decorative stones offer a rich resource of geological features which are poorly visible within outcrops and can be used for educational purposes, for instance cross-sections of coral-sponge intergrowths and internal structures of nautiloid and ammonite shells. These features alone

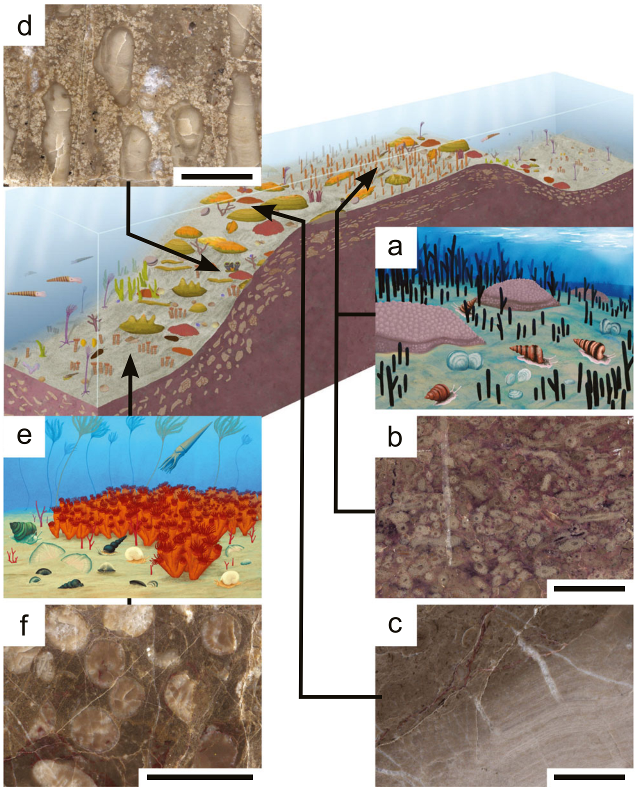

Fig. 7 The anatomy of the Devonian carbonate buildup and the corresponding variations of decorative stones from the vicinity of Bolechowice near Kielce: (**a**, **b**) shallow lagoons in central parts of the carbonate buildup populated by dendroid stromatoporoids (*Amphipora*), brachiopods (*Desquamatia*), and gastropods; (**c**) wave-agitated zones at the flanks of the carbonate buildup populated by massive stromatoporoids (*Actinostroma* in the bottom part of the photograph), tabulate/rugose corals, and bivalves (for a reconstruction of the sedimentary environment see Fig. 3b); (**d**) small *Stachyodes-Renalcis* (stromatoporoid sponge and blue-green algae) buildups located downslope; (**e**, **f**) slopes of the buildup with a diverse assemblage of rugose corals (*Disphyllum*), brachiopods (*Uchtospirifer*), crinoids, and gastropods (*Bellerophon*, *Pleurotomaria*, *Loxonema*). Block diagram of the Devonian carbonate buildup drawn by Szymon Górnicki; other visuals by Edyta Felcyn. Scale bars 2 cm

make up for the loss of the stratigraphical context, which can be retained owing to the narrative element of the project.

The story of rock and fossil formation through deep geological time increases the level of interpretation of palaeontological geoheritage. Fossils are used not only to demonstrate the diversity of the past life forms but also to disseminate the knowledge of geological processes, namely plate tectonics, the origin of mountains, weathering and erosion and climate change. The component of in-depth interpretation differentiates the project under study from many earlier urban geoheritage projects and enhances the engagement of visitors: a desire to go fossil hunting in other public buildings was noted among many individuals who visited historic monuments included in the printed material.

Although the project is a journey through a geological history that spans over 300 million years, the initial exposure of printed material to a small group of high school students revealed that most participants tend to consume small bites of geological knowledge, that is, selected scenes from the whole of the geological time that is involved in the current project. Moreover, within those little portions of the Earth science information, some misconceptions related to the history of the Earth are shared by many of the individuals. The most common false beliefs are listed in Table 5. These misconceptions arise from deeply rooted but unexamined beliefs named by Kusnick (2002) as conceptual prisms. Examples listed in Table 5 fall into two categories sensu Kusnick (2002): II (scales of space and time) and III (stable Earth). Interviewed participants of workshops described rocks as forming in short time scales, not surpassing human life spans (conceptual prism II), and assumed that seas, mountain ridges and rivers do not change significantly with time even if hundreds of millions of years are involved (prism III). To address these misconceptions and to ensure that participation in

Table 5 Most common misconceptions revealed in the workshops and shared by many participants

Misconception	Scientific explanation
Fossil guards of belemnites are interpreted as fulgurites	Belemnite guards (rostra) are common fossils of an extinct order of Mesozoic cephalopods
In Poland, dinosaur bones are scattered on the ground and can be easily collected	Most of the territory of Poland is covered with Pleistocene sediments; during the Middle and Late Jurassic and in the Late Cretaceous, the area of Poland was occupied by shallow seas, and dinosaur fossils are thus extremely rare discoveries
Warm climate of central Europe in the past has been caused by the rotation of the entire Earth relative to its axis (true polar wander); the continents were fixed in their present positions	True polar wander is accompanied by the motion of individual plates (continental drift)
The positions of seas and oceans are fixed; even the continental shelf seas such as the Baltic Sea last forever, and their coastlines migrate only with sea level rise/fall	Oceans form and disappear over geologic time due to continental drift

the project would lead to positive changes in deeply held beliefs about the history of the Earth, geological time scales and processes and the formation of fossils, the contents of the printed material and posters exhibited in the museum were significantly altered. However, the tendency to memorize the selected scenes from the whole story is a sign of some other deeply rooted, unexamined beliefs that hinder the ability to grasp the concept of geological processes that continue through time that is measured in thousands and millions of years (Johnson et al. 2014). The presence of a strong narrative that connects the successive scenes of the story more closely than in Fig. 6 could potentially address that problem better, but more intensive investigations of a larger population with a detailed assessment of learning outcomes are necessary.

Most of the students who participated in workshops declared that their interest in the Earth sciences and awareness of the importance of the geological processes that occurred during the millions years of the history of the planet rose significantly. This stands in accordance with previous suggestions that scientific communication should be done less for the purpose of delivering information and more to inculcate warm feelings (Stewart and Nield 2013).

Conclusions

Scientific information on geological phenomena and events in deep time can be communicated to the wider public in an engaging way by using the fossil content of building and decorative stones coupled with elements of narratives and storytelling. This method raises the level of interpretation of geological heritage and allows detection of the most common misconceptions related to Earth sciences. Rich visuals and graphical reconstructions included in printed and online material strengthen the engagement of individuals and gain the attention of the traditional media.

The list of geological phenomena that can be explained using the fossil content of decorative stones from urban geosites includes plate tectonics, the rock cycle, the formation of mountains, weathering and erosion and evolutionary patterns. The major events in the Earth's past are linked together to form a coherent story that is driven by these processes. A number of key ideas from geological, biological and physical sciences are brought together, emphasizing the multidisciplinary nature of the project.

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