Geological activity of humans represented in the World Heritage Sites of India, Italy, and Russia: Evidence of the Anthropocene

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Abstract. The idea of the Anthropocene attracts attention of scientists, policy-makers, and broad public to the geological activity of humans and poses new important questions for the modern stratigraphy. The growth of the Anthropocene-related knowledge and its promotion can be based potentially on the UNESCO World Heritage Sites (WHS). On the one hand, many of these sites provide spectacular evidence of the human activity. On the other hand, these are remarkable tourist attractions. The WHSs of three heritage-rich countries, namely India, Italy, and Russia, have been assessed with regard to how these reflect the geological activity of humans. It is established that 65–90% of all WHSs in each country provide direct and indirect evidence of such an activity (artificial caves, terrace building, etc.), which appears to be enough for the general discussion of the idea of the Anthropocene. However, the distribution of the WHSs by their age allows focusing only on the “early” (before 1800 AD) start of the Anthropocene, which is not enough for full discussion of the lower limit of this unit. The examples considered in the present study imply that some WHSs alone provide very important pieces of the Anthropocene-related knowledge.

Key words: Geoarchaeology, World Heritage Site, human activity, Anthropocene, India, Italy, Russia.

Апстракт. Концепт антропоцена усмерава пажњу истраживача, креатора јавне политике и шире јавности на геолошку активност човека и отвара нове значајне проблеме у оквиру модерне стратиграфије. Локалитети светске баштине под заштитом УНЕСКА (ЛСБ) могу потенцијално бити значајни за ширење сазнања о антропоцену и промовисање овог концепта. Многи од ових локалитета пружају изузетно важне доказе људске активности. С друге стране, ради се о значајним туристичким локалитетима. Истраживани су ЛСБ на територијама три земље богате светском баштином, Индије, Италије и Русије, у циљу процене видљивих трагова геолошке активности човека на овим локалитетима. Утврђено је да 65–90% укупног броја ЛСБ у свакој од земаља пружа директне и индиректне доказе о оваквој активности, што је изгледа добро за генералну дискусију о концепту антропоцена. Међутим, нако дистрибуција анализираних ЛСБ по старости иде у прилог “раном” (пре 1800. год.) почетку антропоцена, добијени подаци нису довољни за комплетну дискусију о доним граница овог одељка. Примери наведени у овом раду показују да неки од разматраних ЛСБ пружају изузетно важне доказе за концепт антропоцена.

Кључне речи: Геоархеологија, светска баштина, људска активност, антропоцен, Индија, Италија, Русија.

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Introduction

The Anthropocene is a relatively new idea, but it has already attracted a lot of attention of researchers (Cruzen & Soterner 2000; Cruzen 2002; Ruban 2008; Zalasiewicz et al. 2008, 2014, 2015; Ruddiman 2013; Brown 2014; Jordan & Prosser 2014; Waters et al. 2014a, 2016; Beach et al. 2015; Lewis & Maslin 2015; Brondizio et al. 2016). Generally, this idea consists of two closely related propositions. Firstly, the Anthropocene reflects the geological (including geomorphological) activity of humans. This does not only indicate their ability to influence a geological environment, but also stresses that such an influence is of geological scale, i.e., it is more or less comparable in strength to the other geological forces (e.g., mass wasting, volcanism, wind erosion, etc.).

The evidences are reported by many specialists (Howe 2000; Cruzen 2002; Ruddiman 2005, 2013; Wilkinson 2005; Brown 2014; Goudie 2013; Dirzo et al. 2014; Zalasiewicz et al. 2015). Secondly, the Anthropocene is treated in terms of stratigraphy (for general review of this subject see Waters et al. 2014a, 2016; Head & Gibbard 2015; Lewis & Maslin 2015). It appears on the geological time scale as a new epoch or formal/informal unit of any other rank. It should be emphasized that there are different views on the duration of the Anthropocene. Some advocate its beginning since the 1800s or even later (Cohen 2014; Waters et al. 2014b, 2016; Zalasiewicz et al. 2008, 2014, 2015; Head & Gibbard 2015), while other suggest much earlier start, somewhere in the middle of the Holocene (cf. Ruddiman 2013; Wargleich 2014). The noted difference in views only increases the curiosity of specialists and broad public in the Anthropocene-related knowledge.

Evidently, there is an urgent requirement to find out appropriate geological objects for 1) research on the Anthropocene issues and arguing particular points of view (e.g., on its lower boundary - see Jordan & Prosser 2014; Waters 2014a,b; Zalasiewicz et al. 2014; Lewis & Maslin 2015) and 2) promotion of the relevant knowledge to increase public awareness and to justify policy-making (e.g., Lövbrand et al. 2009, 2015; Dalby 2013; Houston 2013; Brondizio et al. 2016). The best evidence of the Anthropocene comes from places where geological and cultural records co-exist. In fact, many cultural (archaeological and historical) sites are important for understanding the geological-scale activity of the man (e.g., Moroni et al. 2015). However, the UNESCO World Heritage Sites (WHS) are potentially of utmost importance. These are exceptional by definition, and if these are man-made features linked to the disturbance of the geological environment, they are almost ideal to study the geological-scale activity of humans and, therefore, to provide material for discussion on what is the Anthropocene and when has it started. Moreover, almost all WHSs are important tourist attractions that are already in use (Yang et al. 2010; Poria et al. 2013; Su & Lin 2014; Wang et al. 2015), thus these can be used efficiently to promote the Anthropocene-related knowledge. Similar ideas have been developed by Mignon (2009) on the basis of the famous site of Petra in Jordan and later by Gontareva et al. (2015) on the basis of the not less famous Ajanta Caves in India. Moreover, the recent suggestions of Jordan & Prosser (2014), Beach et al. (2015) and Del Lama et al. (2015) echo these ideas as well.

The main objective of the present work is to summarize the available information on the geological activity of humans represented in the WHSs of three large countries boasting by rich heritage, namely India, Italy and Russia, in order to understand their potential to provide the Anthropocene-related knowledge. In this paper, the authors do not tend to advocate the formal or informal, short-term or long-term understanding of the Anthropocene. They emphasize the evidence of geological activity of humans in the past, available from the WHSs and valuable for further debates on the essence and the time limits of the Anthropocene.

Material

The short and long descriptions of all Indian, Italian, and Russian WHSs presented on the official webpage of the UNESCO World Heritage Centre (http://whc.unesco.org/en/list/) serve as a main material for the present study. The authors also consider their own field observations (particularly, they visited the Ajanta Caves and the Ellora Caves in India, the Cilento and Vallo di Diano National Park with the Archeological Sites of Paestum and Velia, and the Certosa di Padula in Italy, the Cultural and Historic Ensemble of the Solovetsky Islands and the Historic and Architectural Complex of the Kazan Kremlin in Russia).

Method

The present study is realized in four steps. First, the presence of various signs of the geological activity of humans is checked for each WHS in all three countries to establish direct or indirect evidence of such activity. Direct evidence means the presence of signs that permit to visualize the kind and the strength of the anthropogenic influence on the geological environment at a particular site (Table 1). It is enough to turn attention to these signs in order to realize this influence. Indirect evidence means the presence of signs that do not indicate any geological activity of humans at a given site, but permit to judge about such an anthropogenic influence (Table 1). Adequate expla-
nations of these signs are necessary in order to judge about this influence. For instance, some WHSs represent constructions (or ruins) made by past civilizations. It is well-known that the agricultural activity affected the global climate (e.g., via methane emission from rice paddies and perturbation of the carbon cycle as a result of forest clearance), thus humans became a geological force (Ruddiman 2001, 2005, 2013; Li et al. 2009; Fuller et al. 2011; Zhou 2012). Similarly, colossal constructions built with natural stones indicate geological activity of humans because of the relevant voluminous extraction (e.g., quarrying) of building material somewhere.

Second, the time of the geological activity of humans (age) relevant to each given WHS is established on the basis of various information and, first of all, the above-mentioned official UNESCO descriptions.

Third, two analytical procedures are used. The proportion of the WHSs with direct and indirect evidence of geological activity of humans is measured for each country. The approximate distribution of these sites by their age is considered. All this led to conclusions on how significant is this evidence and how relevant is it to the idea of the Anthropocene.

Fourth, particular attention is paid to certain representative examples of the WHSs that can potentially contribute to the Anthropocene-related knowledge (Fig. 1).

Evidence of the geological activity of humans from heritage sites

India

Among 32 WHSs established in India, 75% bear direct and/or indirect evidence of geological activity of humans and 22% bear direct evidence (Table 2). The majority of them represent the 0–1800 AD time interval (Fig. 2). The most impressive are the WHSs with artificial caves (e.g., the Ajanta Caves), construction of which required significant intervention of humans in the geological environment (Gontareva et al. 2015). The rise of the past empires (e.g., the Great Mughals) in the history of India resulted in monumental construction that required extraction of the huge volume of building material.

| Evidence    | Signs (selected examples)                                                                 |
|-------------|------------------------------------------------------------------------------------------|
| Direct      | • artificial caves<br>• construction of new landforms<br>• engineering geological solutions<br>• mines and quarries<br>• rock art<br>• rock carving<br>• terrace building |
| Indirect    | • constructions => extraction of building materials<br>• creating cultural landscapes => modification of natural topography<br>• remains/ruins of past civilizations => agricultural influences on geological environment and palaeoclimate |
Table 2. The geological activity of humans represented in the UNESCO WHSs of India.

| WHS                                           | Evidence of geological activity of humans |
|------------------------------------------------|------------------------------------------|
| Agra Fort                                      | Indirect                                 |
| Ajanta Caves                                   | Direct (artificial caves)                |
| Ellora Caves                                   | Direct (artificial caves)                |
| Taj Mahal                                      | Indirect                                 |
| Group of Monuments at Mahabalipuram             | Direct (rock art, rock carving) and indirect |
| Sun Temple, Konârâk                             | Indirect                                 |
| Kaziranga National Park                        | No                                       |
| Keoladeo National Park                         | No                                       |
| Manas Wildlife Sanctuary                       | No                                       |
| Churches and Convents of Goa                   | Indirect                                 |
| Fatehpur Sikri                                 | Indirect                                 |
| Group of Monuments at Hampi                     | Indirect                                 |
| Khajuraho Group of Monuments                    | Indirect                                 |
| Elephanta Caves                                | Direct (artificial caves and rock art)    |
| Great Living Chola Temples 12                   | Indirect                                 |
| Group of Monuments at Pattadakal                | Indirect                                 |
| Sundarbans National Park                       | No                                       |
| Nanda Devi and Valley of Flowers National Parks | No                                       |
| Buddhist Monuments at Sanchi                   | Indirect                                 |
| Humayun’s Tomb, Delhi                          | Indirect                                 |
| Qutb Minar and its Monuments, Delhi             | Indirect                                 |
| Mountain Railways of India                     | Direct (engineering geological solutions) |
| Mahabodhi Temple Complex at Bodh Gaya           | Indirect                                 |
| Rock Shelters of Bhimbetka                     | Direct (rock shelters, rock art)          |
| Champaran-Pavagadh Archaeological Park          | Indirect                                 |
| Chhatrapati Shivaji Terminus (formerly Victoria Terminus) | Indirect                             |
| Red Fort Complex                               | Indirect                                 |
| The Jantar Mantar, Jaipur                      | No                                       |
| Western Ghats                                  | No                                       |
| Hill Forts of Rajasthan                        | Indirect                                 |
| Great Himalayan National Park Conservation Area | No                                       |
| Rani-ki-Vav (the Queen’s Stepwell) at Patan, Gujarat | Direct (stepwell and water tank construction) and indirect |

The list follows the web-page of the UNESCO World Heritage Centre (http://whc.unesco.org/en/list/); accessed on March 22, 2015. Evaluation is based on the official UNESCO site descriptions (the both short and long descriptions are considered) on the noted web-page. The authors’ own observations in some of the listed WHS are also taken into account.

Italy

Among 50 WHSs established in Italia, 90% bear direct and/or indirect evidence of geological activity of humans and 28% bear direct evidence (Table 3). Their age varies significantly, and the prehistorical, historical, and modern time spans are represented adequately (Fig. 2). The WHSs representing ancient catacomb construction (in Historic Centre of Naples) and rock cutting, ancient mining and quarrying, workshops and stone tool production, terrace building, etc. provide bold examples of the geological activity of humans. Building large constructions and landscape modification since the Prehistoric times and, particularly, during the period of the Roman Empire and the Renaissance epoch, have affected significantly the geological environment on the territory of this country.
Table 3. The geological activity of humans represented in the UNESCO WHSs of Italy.

| WHS                                                                 | Evidence of geological activity of humans                                                                 |
|---------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|
| Rock Drawings in Valcamonica                                      | Direct (rock art, ancient mining)                                                                       |
| Church and Dominican Convent of Santa Maria delle Grazie with “The Last Supper” by Leonardo da Vinci  | Indirect                                                                                               |
| Historic Centre of Rome, the Properties of the Holy See in that City Enjoying Extraterritorial Rights and San Paolo Fuori le Mura | Indirect                                                                                               |
| Historic Centre of Florence                                       | Indirect                                                                                               |
| Piazza del Duomo, Pisa                                            | Indirect                                                                                               |
| Venice and its Lagoon                                              | Direct (modification of geological environment) and indirect                                            |
| Historic Centre of San Gimignano                                   | Indirect                                                                                               |
| The Sassi and the Park of the Rupestrian Churches of Matera        | Direct (prehistoric rock-cut settlement) and indirect                                                   |
| City of Vicenza and the Palladian Villas of the Veneto             | Indirect                                                                                               |
| Crespi d’Adda                                                      | No                                                                                                      |
| Ferrara, City of the Renaissance, and its Po Delta 14              | Indirect                                                                                               |
| Historic Centre of Naples                                         | Direct (catacombs) and indirect                                                                        |
| Historic Centre of Siena                                          | Indirect                                                                                               |
| Castel del Monte                                                   | Indirect                                                                                               |
| Early Christian Monuments of Ravenna                               | Indirect                                                                                               |
| Historic Centre of the City of Pienza                             | Indirect                                                                                               |
| Trulli of Alberobello                                              | Direct (limestone dwellings) and indirect                                                               |
| 18th-Century Royal Palace at Caserta with the Park, the Aqueduct of Vanvitelli, and the San Leucio Complex | Indirect                                                                                               |
| Archaeological Area of Agrigento                                  | Indirect                                                                                               |
| Archaeological Areas of Pompei, Herculaneum and Torre Anunziata    | Indirect                                                                                               |
| Botanical Garden (Orto Botanico), Padua                           | No                                                                                                      |
| Cathedral, Torre Civica and Piazza Grande, Modena                  | Indirect                                                                                               |
| Costiera Amalfitana                                                | Direct (terrace building) and indirect                                                                  |
| Portovenere, Cinque Terre, and the Islands (Palmaria, Tino and Tinetto) | Direct (terrace building) and indirect                                                                  |
| Residences of the Royal House of Savoy                             | Indirect                                                                                               |
| Su Nuraxi di Barumini                                              | Indirect                                                                                               |
| Villa Romana del Casale                                           | Indirect                                                                                               |
| Archaeological Area and the Patriarchal Basilica of Aquileia       | Indirect                                                                                               |
| Cilento and Vallo di Diano National Park with the Archeological Sites of Paestum and Velia, and the Certosa di Padula | Direct (stone tools production, landscape modification, creation of recognizable stratigraphical record) and indirect |
| Historic Centre of Urbino                                         | Indirect                                                                                               |
| Villa Adriana (Tivoli)                                             | Indirect                                                                                               |
| Assisi, the Basilica of San Francesco and Other Franciscan Sites   | Indirect                                                                                               |
| City of Verona                                                     | Indirect                                                                                               |
| Isole Eolie (Aeolian Islands)                                      | Direct (collecting obsidian for stone tools production)                                                 |
| Villa d’Este, Tivoli                                               | Indirect                                                                                               |
| Late Baroque Towns of the Val di Noto (South-Eastern Sicily)       | Indirect                                                                                               |
| Sacri Monti of Piedmont and Lombardy                               | Indirect                                                                                               |
| Monte San Giorgio                                                  | No                                                                                                      |
| Etruscan Necropolises of Cerveteri and Tarquinia                   | Direct (rock cutting) and indirect                                                                       |
| Val d'Orcia                                                        | Direct (landscape modification and engineering: geological solutions) and indirect                     |
Among 26 WHSs established in Russia, 65% bear direct and/or indirect evidence of geological activity of humans and 23% bear direct evidence (Table 4). The majority of them represent the time interval after 1000 AD (Fig. 2). The most impressive are the artificial landforms (e.g., mounds in the Uvs Nuur Basin). Flourishing of the Russian society since the beginning of the 2nd millennium AD led to the rise of very spectacular architecture (e.g., White Monuments of Vladimir and Suzdal) and building these churches and architectural ensembles (world-famous historical monuments nowadays) required extraction of the really huge volume of material from the geological environment.

**Summary: relevance to the Anthropocene**

Evidently, the world heritage differs significantly in India, Italy, and Russia. Among these three countries, Italy has the biggest number of WHSs (Table 3) and Russia has the smallest (Table 4); India is somewhere in between (Table 2). However, all these countries boast really rich world heritage. The number of WHSs with direct and/or indirect evidence of geological activity of humans is high in India and Italy, while it is moderate in Russia. This difference can be explained by a higher proportion of natural WHSs and a lower proportion of cultural WHSs in Russia. Anyway, all countries considered in this study possess numerous WHSs informing about anthropogenic influence on the geological environment. Moreover, these sites are essentially diverse, which means they represent different kinds of this influence (Table 2–4). If so, India, Italy, and Russia have significant potential for discussion and promotion of the Anthropocene-related issues on the basis of their world heritage.

It is important that the idea of the Anthropocene is not something too general, too qualitative, and, thus, too vague. In addition to its almost philosophical essence (CRUTZEN & SOTERMER 2000; CRUTZEN 2002; LÖVBRAND et al. 2009, 2015; BROWN 2014; DIRZO et al. 2014), it is of practical importance in modern geology because of the stratigraphical value of the Anthropocene (RUBAN 2008; ZALASIEWICZ et al. 2008, 2014, 2015; WATERS et al. 2014a, 2016; see also BEACH et al. 2015). In order to use WHSs of any given country for the purposes of discussion of the rank and the boundaries of this stratigraphical unit, it is necessary to have a range of WHSs representing the time span from the very Prehistory to the Present, including WHSs dated by the 18th–20th centuries. From the three countries considered in this study, only Italy has more or less suitable WHSs with regard to their distribution by age (Fig. 2). Although Prehistorical and post-1800 AD world heritage is available in all countries, its amount is not so large. Moreover, many cultural WHSs are older than the 19th century. If so, it is possible to use WHSs of India, Italy, and Russia to argue the “early” start of the Anthropocene (via emphasis on the very strong geological activity of humans before 1800 AD) but, unfortunately, these objects are evidently not enough to discuss the start of the Anthropocene in the 19th century or later. This can be also interpreted so that the underrepresentation of the post-1800 record in the WHSs makes the relevant judgements of the Anthropocene incomplete.

An intriguing addition is possible. LEWIS & MASLIN (2015) proposed that 1610 can be a very appropriate year for the beginning of the Anthropocene (the alternative option is 1964). If so, all three countries considered in the present study provide a lot of evidence for discussion of this idea because India, Italy, and Russia have many WHSs representing the 17th century (Fig. 2). Stratigraphers dealing with the lower limit of the Anthropocene should not miss this option.
Case examples

India

The Ellora Caves WHS is located in the state of Maharashtra (western India) (Fig. 1). Its historical and geological contexts are discussed by SHARMA & DHAWAN (1994) and ANSARI et al. (2014) and also in a number of on-line sources (Appendix 1). Generally, this WHS is an example of rock-cut architecture of the 1st millennium AD. Thirty four caves were carved for religious (Buddhist, Hindu, and Jain) purposes in the Deccan basalt flows, where ‘aa’ and ‘pahoehoe’ lavas alternate. The Chitya Hall measures 26×14×10 m (SHARMA & DHAWAN 1994). The colossal size of these artificial landforms (Fig. 3), the ‘physical’ efforts that were necessary to cut large caves in solid volcanic rock forming the 2 km-long cliff, as well as the depth and the complexity of the knowledge of the ancient architects (SHARMA & DHAWAN 1994) are signs of geological-scale activity of humans. Interestingly, the Ellora Caves are promoted on-line (Appendix 1) also as a tourist destination without environmental pollution, i.e., the lowest degree of anthropogenic influence is stressed in this case.

This WHS implies that humans have been significant geological agents well before the 19th century or, better to say, already in the 1st millennium AD. This is a local, but important argument for the discussion of the “early” start of the Anthropocene.

Italy

The Cilento and Vallo di Diano National Park with the Archeological Sites of Paestum and Velia, and the Certosa di Padula WHS is located in the province of
Salerno (Campania, Italy) (Fig. 1). This area is very important for our knowledge of the Prehistory as it is characterized by the occurrence of cave, shelter and open-air sites, mainly situated along the rocky coast (Fig. 4, 5) (see also Appendices 2, 3). The results of the half-century-long research allowed scholars to reconstruct in detail the pre-protohistoric peopling of the region from the Lower Palaeolithic (Cala Bianca, Arconte, and Capo Grosso) (PALMA DI CESNOLA 1969a, 1976, 2001; GAMBASSINI & PALMA DI CESNOLA 1972; GAMBASSINI 1984; GAMBASSINI et al. 1995) to the Bronze Age (Grotta del Noglio) (VIGLIARDI 1975) in the both palaeoenvironmental and cultural perspectives. The coastal area between Scario and Camerota is of special interest. With their very thick stratigraphical sequences, several sites provided a detailed framework of the human occupation during the Middle and Upper Palaeolithic: Grotta Grande, Riparo del Molare di Scario, and Grotta/Riparo del Poggio (PALMA DI CESNOLA 1969b; BARTOLOMEI et al. 1975; GAMBASSINI et al. 1995).
for the Middle Palaeolithic, Grotta della Serratura (MARTINI 1993, 1995) for the Upper Palaeolithic and the Holocene, Grotta della Cala, (PALMA DI CESNOLA 1971; GAMBAZZINI 1995b; BENINI et al. 1997; BOSCATO et al. 1997; BORGIA & WIERER 2005; BORGIA 2008; MORONI et al. in press) for the Middle-Upper Palaeolithic and the Holocene. Additionally, interesting human remains like the Neandertal juvenile mandible are available from Riparo del Molare (MALLEGNI & RONCHITELLI 1987, 1989; RONCHITELLI 1993, 1995a,b).

Grotta della Cala was occupied, with few interruptions, from the final Middle Palaeolithic to the Copper Age. During the Palaeo-Mesolithic human occupation, the sea level was lower than nowadays (LAMBECK et al. 2011) and a flat land-belt was present in front of the cavity. The stratigraphical sequence of Grotta della Cala starts with a marine strongly cemented conglomerate (MIS 5). This is followed by a set of intercalating stalagmite and gravel layers belonging to the final Mousterian sealed by a thick “concretion” layer constituting the base of the Upper Palaeolithic sequence (Uluzzian, Aurignacian, Early Gavettian, Evolved Gravettian with few Noailles-type Burins, Evolved and Final Epigravettian), which is overlain by the Holocene sequence (Mesolithic, Neolithic and Eneolithic). One of the more interesting aspects of Grotta della Cala is the presence of layers, which document the earliest phases of the Upper Palaeolithic, namely the Uluzzian and the Aurignacian techno-complexes. This particular period, known as the Middle to Upper Palaeolithic transition, is currently the object of an international debate as it involves the demise of last Neandertal populations and their gradual replacement by the Modern Humans (Homo sapiens) between 45 and 40 ka (BENINI et al. 1997; MORONI et al. 2013). This intriguing aspect of the Italian Palaeolithic occurs also on another site, namely the Grotte di Castelcivita. This is a karst cavity, develops more than 4 km horizontally and about half of which can be visited by the public. The Palaeolithic site occupies the mouth of the cave. The stratigraphical sequence starts with a thick layer of blocks collapsed during a rather cold phase at ~ 60–50 ka. In the overlying layers, there is evidence of the occupation by last Neandertals (~ 45 ka), divided by a stratigraphic hiatus from the overlying Uluzzian (~ 41 ka) and Protoaurignacian (~ 40 ka) techno-complexes.
The cave was later invaded at ~39 ka by the dusts of a violent volcanic eruption (Campanian ignimbrite) (Gambassini 1995c, 2000).

Generally, this Italian WHS is important for the Anthropocene-related knowledge because it provides the precious technological information on the exploitation of lithic resources for stone tool production and landscape modification (creation of cultural landscapes and cultural exploration of such notable geomorphological objects as caves) by Neandertals and especially Modern Humans in the Prehistory, as well as on the creation of outstanding stratigraphical record of the past human activity (in other words, the anthropogenic deposits of geological scale appeared) (Appendices 2, 3). Moreover, the interaction between the geological forces (karst, volcanism, etc.) and the past human activity is visible there.

Another example of the Italian WHSs of the Anthropocene-related importance is the Aeolian (Lipari) Islands, which are located in the Tyrrhenian Sea to the north of Sicily (Fig. 1). From the Neolithic (but not during the Palaeolithic) these were permanently occupied by human communities. The economic and cultural growth of this archipelago during the Neolithic was partly due to the exploitation of obsidian. This natural material is very suitable for knapping, and it was especially used for making sharp edged blades. Because of its characteristic and its fine bright appearance, it was largely exported in the Prehistory, and small quantities of obsidian often travelled (as a kind of “exotic” goods) over large distances. Since obsidian occurs on only four islands (Sardinia, Palmarola, Lipari, and Pantelleria) in the Central-Western Mediterranean, this material is of broad interest for provenance studies: its physical and chemical properties can be used to discriminate the raw material natural sources and, as a consequence, to correlate artefacts retrieved in prehistoric sites to the supplying outcrops. At Lipari, the largest of the seven islands of the Aeolian Archipelago, there are several obsidian outcrops (including Forgia Vecchia, Pomiciazzo or Gabellotto, Canneto Dentro, and Rocche Rosse), the formation of which is due to a number of volcanic events that took place between 11.4 ka and 1.4 ka (Bigazzi et al. 2005). Pomiciazzo and Canneto Dentro are the only outcrops showing a chrono-stratigraphic consistent with their potential exploitation in Prehistory. Obsidian from Lipari started circulating systematically in Southern Italy from the Early Neolithic. During the Middle Neolithic (phase of the Tricromic and Serra d’Alto painted pottery), there was an increase in circulation and the widest distribution network of obsidian from Lipari. This moved up peninsular Italy and reached the Northern regions where it can be often found in association with obsidian from Palmarola and Monte Arci. Many V millennium BC artefacts (usually finished products – see Vaquer 2006) obtained from Lipari obsidian are found in Malta, Southern France (Vaquer 2003), and Istria (Tykot et al. 2013).

The Aeolian Islands WHS is important for the Anthropocene-related knowledge because it provides direct evidence of geological activity of Prehistoric humans linked to obsidian collecting. This was a primitive form of mining. However, a very significant amount of collected obsidian that can be deduced from its wide distribution in the Mediterranean and, particularly, on the Italian territory implies that this mining was massive and that those Prehistoric humans acted as true geological agents.

Russia

The Cultural and Historic Ensemble of the Solovetsky Islands WHS is located on the Solovetsky Archipelago in the White Sea in the Arkhangelsk Region (northwestern Russia) (Fig. 1). It was known mainly because of the famous monastery founded in the 15th century and flourished in the 16th century, as well as by the tragic events of the 20th century. However, this WHS includes also some cultural elements that are of geoarchaeological and geomorphological importance (Appendix 4). Firstly, these are dozens of the stone labyrinths, cairns, and other megalithic constructions on the Big Zayatsky and Anzer islands. Labyrinths (locally called “Babylons”) were built with local boulders in the 3rd millennium BC; on the Big Zayatsky Island, these concentrate on the area of only 0.4 km² in size, and their purpose is far from being fully understood. Secondly, fishery constructions (so-called “Philip’s ponds”) of the 16th century are of interest. These are shallow ponds (not longer in use) divided by dams on the seashore of the Solovetsky Island. The dams were constructed from large granitic boulders with smaller boulders in between. Generally, these fishery constructions changed the natural seashore landscape completely, and they represent the highly specific artificial landform. Their building required extraction and transportation of a huge amount of natural stones, as well as engineering geological solutions for seashore modification. Both kinds of cultural elements of this WHS stress the geological scale activity of humans in the prehistorical and historical times. With regard to the idea of the Anthropocene, this conclusion does not support the idea that the geological power (with regard to the ability of landscape modification) of the prehistorical societies was lesser than that in the historical times. Locally, the Anthropocene started well before the 19th century.

The Historic and Architectural Complex of the Kazan Kremlin is located in the city of Kazan in the Republic of Tatarstan (European part of Russia) (Fig. 1). It combines elements belonging to the culture of the Volgian Bulgars, the Golden Horde, the Medieval Kazan Tatars, the Russians, and the modern Tatars (Fig. 6). Generally, the Kazan Kremlin is preserved substantially since its last major reconstruction after
the conquest of the Kazan Khanate by Ivan IV in 1552. During 1556–1562, the fortress walls and towers were built by Pskov architects from “white stone”. The latter is the Late Kazanian (Roadian, Middle Permian; see MENNING et al. 2006) light-gray dolostones and limestones. These rocks are exposed in the coastal cliffs on the right bank of the Volga River, from where they had been extracted and transported to the Kazan Kremlin together with the stones from the pre-Mongolian destroyed buildings dating back to the 12th century (SITDIKOV 2009). The masonry of the Khan’s period (15th–mid–16th centuries) is characterized by almost complete absence of mortar (Fig. 6). Later, the Pskov masters used a solid fill with mortar from the outer to the inner edge of the wall (KHUZIN 2001). The space between the outer blocks was filled with relatively large rough stones. Some towers of the second half of the 16th century were built on the ruins of the towers of the Khan’s period (KHUZIN 2001). They were built as monoliths by pouring of large limestone and dolostone hewn blocks and fragments of brick with mortar. Blocks were obtained by dismantling of the masonry of the earlier square tower.

The site described above is a typical example of WHS with indirect evidence of the geological activity of humans: the multi-stage building of the Kazan Kremlin required extraction of a huge amount of geological material (carbonate rocks) from the nearby outcrops. Besides this, one should expect significant modification of local landforms, because this extraction led to the destruction of the natural cliffs, where these rocks are exposed. The evidence is indirect because one needs special interpretation (and “deep thinking”) of signs available at the site itself. In other words, geological activity of man can be only imagined, not viewed directly there. With regard to the Anthropocene, this WHS provides an additional argument for its “early” start in the Volga region of Russia.

**Summary of case examples**

The five representative examples of the WHSs from India, Italy, and Russia discussed above allow conclusions about the geological activity of humans in both prehistorical and historical times (Fig. 7). The most impressive among them is the Ellora Caves WHS in India because it permits to judge about the outstanding potential of past civilizations to affect the geological environment. However, the only “early” start of the Anthropocene can be discussed consider-
ing all these sites, because they represent the time before the 19th century (Fig. 7).

**Conclusions**

The present study of the WHS importance for accumulation and promotion of the Anthropocene-related knowledge in three heritage-rich countries, namely India, Italy, and Russia, permits to make three general conclusions:

1) the studied countries have many WHSs with the direct and indirect evidence of the geological activity of humans and, thus, these are appropriate for general discussion and promotion of the idea of the Anthropocene;

2) the world heritage available in India, Italy, and Russia permits discussion about an “early” (pre-1800 AD) start of the Anthropocene, but it is much less suitable for the analysis of anthropogenic influence on the geological environment in the 19th century and later;

3) some WHSs taken alone (e.g., the Ellora Caves in India) are of utmost importance to realize the geological scale of the human activity.

Future studies should consider more countries in order to extend the conclusions made on the basis of information from India, Italy, and Russia. Special attention should be paid to tourism programs offered at WHSSs in order to understand their true importance for effective promotion of the Anthropocene-related knowledge.

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Appendix 1. On-line information sources on the Ellora Caves.

asi.nic.in
buddhist-pilgrimage.com
elloracaves.org
maharashtrastratotourism.gov.in
sacred-destinations.com
whc.unesco.org

Appendix 2. On-line information sources on the Cilento and Vallo di Diano National Park.

lonelyplanet.com/italy/campania/parco-nazionale-del-cilento-e-vallo-di-diano
europeangeoparks.org/?page_id=561
italia.it/en/travel-ideas/unesco-world-heritage-sites/cilento.htm
whc.unesco.org

Appendix 3. Geoarchaeological sites of the Cilento and Vallo di Diano National Park (listed in chronological order).

Calà Bianca (open-air site): Lower Palaeolithic (Acheulean) (Palma di Cesnola 1969a, 1976, 2001; Gambassi-Ni & Palma di Cesnola 1972; Gambassini 1984; Gambassini et al. 1995).

Arconte and Capo Grosso (open-air sites): Lower Palaeolithic (Acheulean) (Palma di Cesnola 1969a, 1976, 2001; Gambassini & Palma di Cesnola 1972; Gambassini 1984; Gambassini et al. 1995).

Grotta and Riparo del Poggio (cave and shelter sites): Middle Palaeolithic (Palma di Cesnola 1967, 1969b, 2001; Gambassini 1995a; Caramia & Gambassini 2006).

Grotta di Porto Infreschi (collapsed cave): Middle Palaeolithic (Ronchitelli 1995b).

Riparo del Molare (shelter site): Middle Palaeolithic (Mallegni & Ronchitelli 1987, 1989; Ronchitelli 1993, 1995a).
Grotta Taddeo (cave site): Middle Palaeolithic (VIGLIARDI 1968; GAMBASSINI et al. 1995).
Nicchia Silhar (shelter site): Middle Palaeolithic (GAMBASSINI et al. 1995).
Riparo della Difesa (shelter site): Middle Palaeolithic (GAMBASSINI et al. 1995).
Grotta dell’Acqua (cave site): Middle Palaeolithic (GAMBASSINI et al. 1995).
Grotta della Masseta (cave site): Middle Palaeolithic (GAMBASSINI et al. 1995).
Grotta di Castelcivita (cave site): Middle Palaeolithic, Upper Palaeolithic (BACHECHI & REVEDIN 1993; GAMBASSINI et al. 1995).
Grotta Calanca (cave site): Upper Palaeolithic (Uluzzian, Proaurignacian) (GAMBASSINI 1995, 2003; BEVINI et al. 1997; BOSCATO et al. 1997; GAMBASSINI & RONCHITELLI 1997; BORGIA & WIERER 2005; BORGIA 2008; MORONI et al. in press).
Grotta Calanca (cave site): Upper Palaeolithic (Gravettian) (VIGLIARDI 1968b; BACHECHI & REVEDIN 1993; GAMBASSINI et al. 1995).
Grotta della Cala (cave site): Middle Palaeolithic, Upper Palaeolithic (Uluzzian, Aurignacian, Gravettian, Epigravettian), Mesolithic (Sauveterrian), Neolithic, Eneolithic (PALMA DI CESNOLA 1967, 1971; BARTOLOMEI et al. 1975; MARTINI 1978, 1981; GAMBASSINI 1995, 2003; BEVINI et al. 1997; BOSCATO et al. 1997; GAMBASSINI & RONCHITELLI 1997; BORGIA & WIERER 2005; BORGIA 2008; MORONI et al. in press).
Grotta Tina (cave site): Middle Palaeolithic (MARTINI et al. 1972-74; GAMBASSINI et al. 1995).
Grotta di Cascarrella (cave site): Bronze Age (GAMBASSINI et al., 1995).
Grotta della Serratura (cave site): Middle Palaeolithic, Upper Palaeolithic (Uluzzian, Proaurignacian) (GAMBASSINI 1995, 2000).
Grotta dell’Acqua (cave site): Middle Palaeolithic, Upper Palaeolithic (BACHECHI & REVEDIN 1993; GAMBASSINI et al. 1995).
Grotta di Castelcivita (cave site): Middle Palaeolithic, Upper Palaeolithic (BACHECHI & REVEDIN 1993; GAMBASSINI et al. 1995).
Grotta di Cascarrella (cave site): Bronze Age (GAMBASSINI et al., 1995).
Grotta della Cala (cave site): Middle Palaeolithic, Upper Palaeolithic (BACHECHI 1989-90; GAMBASSINI et al. 1995).
падној Индији, указује на то да је човек био значајан геолошки фактор далеко пре 19. века или, боље речено, већ у првом милијуму нове ере. Иако је реч о једном локалитету, ово представља важан аргумент за дискусију о „раном” почетку антропоцена. Национални парк Тиленто и Вало ди Дино, ЛСБ у Италији са локалитетима Пестум, Велиа и Кертоса ди Падула, пружа драгоцене информације о технологији експлоатације стенских материјала за потребе израде камених оруђа, о морфолошким изменама предела од стране неандерталаца а нарочито модерног човека у праисторији, као и изузетно важне стратиграфске податке о некадашњој активности човека. Историјски и архитектонски комплекс Казњски Кремљ у Русији представља типичан пример ЛСБ са индиректним доказима геолошке активности човека: вишефазна изградња Казњски Кремља захтевала је екстракцију огромне количине геолошког материјала (карбонатних стена) са оближњих локалитета. На основу пет репрезентативних примера ЛСБ на територијама Индије, Италије и Русије могуће је донети закључке о геолошкој активности човека, како у периоду праисторије тако и током историје. Ипак, на основу поменутих локалитета може се дискутовати само о „раном” почетку антропоцена. Даља истраживања би трјбало да укључе више земаља како би се допунили закључци добијени на основу информација из Индије, Италије и Русије. Нарочиту пажњу би требало посветити туристичким програмима који се нуде на ЛСБ како би се боље разумело њихов прави значај у стицању нових сазнања везаних за антропоцен.