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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 (вештачке пећине, терасаст рељеф, итд.), што је изгледа довољно за генералну дискусију о концепту антропоцена.

Међутим, иако дистрибуција анализираних ЛСБ по старости иде у прилог "раном" (пре 1800. год.) почетку антропоцена, добијени подаци нису довољни за комплетнију дискусију о доњој граници овог одељка. Примери наведени у овом раду показују да неки од разматраних ЛСБ пружају изузетно значајна сазнања везана 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 (CRUTZEN & SOTERMER 2000; CRUTZEN 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 (HOOKE 2000; CRUTZEN 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; WAGREICH 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 coexist. 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 MIGON (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-

Table 1. Signs of the geological activity of humans from the UNESCO WHSs.

Evidence	Signs (selected examples)
Direct	• artificial caves • construction of new landforms • engineering geological solutions • mines and quarries • rock art • rock carving • terrace building
Indirect	• constructions => extraction of building materials • creating cultural landscapes => modification of natural topography • remains/ruins of past civilizations => agricultural influences on geological environment and palaeoclimate

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.

Fig. 1. Geographical location of the WHSs considered as examples in the present paper. Abbreviations: **AI.** Aeolian Islands; **CVD.** Cilento and Vallo di Diano National Park with the Archaeological Sites of Paestum and Velia, and the Certosa di Padula; **EC.** Ellora Caves; **KK.** Historic and Architectural Complex of the Kazan Kremlin; **SI.** Cultural and Historic Ensemble of the Solovetsky Islands.

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.

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, Konârak	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)
Champaner-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.

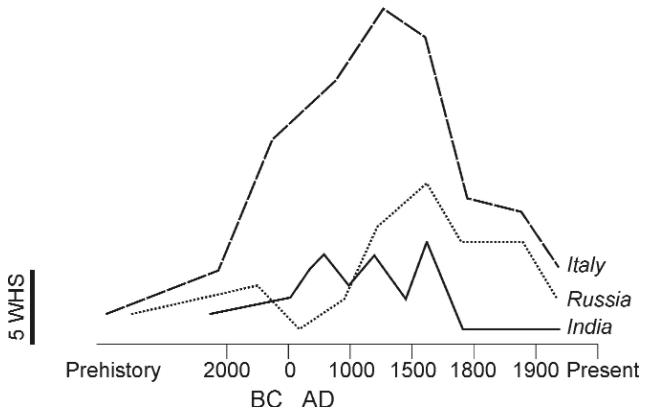

Fig. 2. Approximate distribution by age of the Indian, Italian, and Russian WHSs with direct and indirect evidence of geological activity of humans.

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 Annunziata	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 engineerin geological solutions) and indirect

Table 3. continued.

Syracuse and the Rocky Necropolis of Pantalica	Direct and indirect (rock cutting)
Genoa: Le Strade Nuove and the system of the Palazzi dei Rolli	Indirect
Mantua and Sabbioneta Rhaetian Railway in the Albula / Bernina Landscapes	Indirect Direct (engineering geological solutions)
The Dolomites Longobards in Italy. Places of the Power (568-774 A.D.) Prehistoric Pile dwellings around the Alps	No Indirect Indirect
Medici Villas and Gardens in Tuscany	Indirect
Mount Etna	No
Vineyard Landscape of Piedmont: Langhe-Roero and Monferrato	Direct (landscape modification) and indirect

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Russia

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 statigraphical 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.

Table 4. The geological activity of humans represented in the UNESCO WHSs of Russia.

WHS	Evidence of geological activity of humans
Historic Centre of Saint Petersburg and Related Groups of Monuments	Direct (modification of geological environment) and indirect
Kizhi Pogost	No
Kremlin and Red Square, Moscow	Indirect
Cultural and Historic Ensemble of the Solovetsky Islands	Direct (artificial landforms, including stone labyrinths and fishery constructions) and indirect
Historic Monuments of Novgorod and Surroundings	Indirect
White Monuments of Vladimir and Suzdal	Indirect
Architectural Ensemble of the Trinity Sergius Lavra in Sergiev Posad	Indirect
Church of the Ascension, Kolomenskoye	Indirect
Virgin Komi Forests	No
Lake Baikal	No
Volcanoes of Kamchatka	No
Golden Mountains of Altai	No
Western Caucasus	Direct (megalithic constructions)
Curonian Spit	Direct (efforts to mitigate natural wind and tide erosion and to sustain landform)
Ensemble of the Ferapontov Monastery	Indirect
Historic and Architectural Complex of the Kazan Kremlin	Indirect
Central Sikhote-Alin	No
Citadel, Ancient City and Fortress Buildings of Derbent	Indirect
Uvs Nuur Basin	Direct (mounds)
Ensemble of the Novodevichy Convent	Indirect
Natural System of Wrangel Island Reserve	No
Historical Centre of the City of Yaroslavl	Indirect
Struve Geodetic Arc	Direct (ability of humans to measure the Earth)
Putorana Plateau	No
Lena Pillars Nature Park	No
Bolgar Historical and Archaeological Complex	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.

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

Fig. 3. The Ellora Caves WHS: **A.** panoramic view; **B.** internal view.

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; GAM-

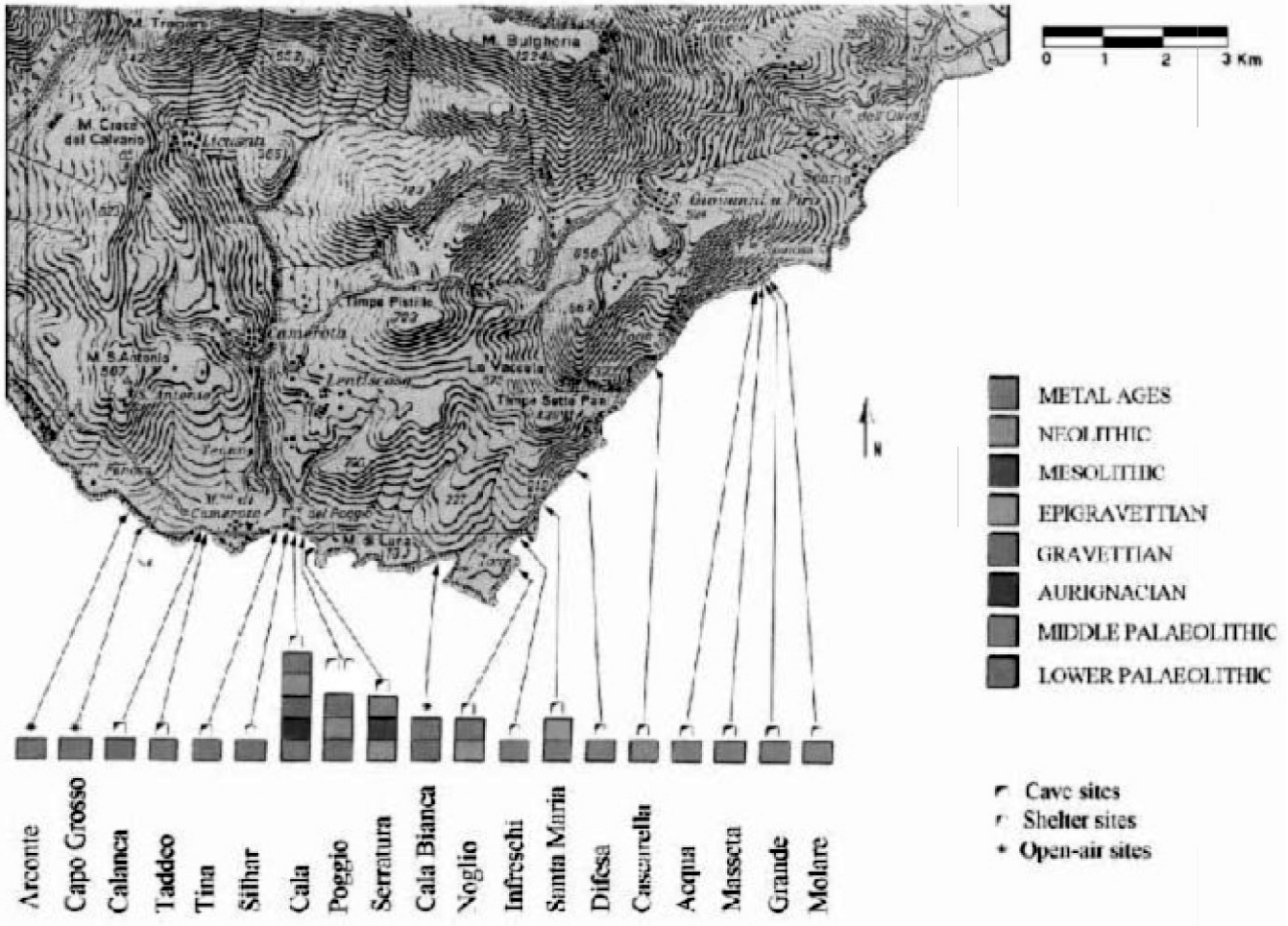

Fig. 4. Prehistoric sites located along the coast between Camerota and Scario in the Cilento and Vallo di Diano National Park (WHS) (modified from GAMBASSINI *et al*. 1995).

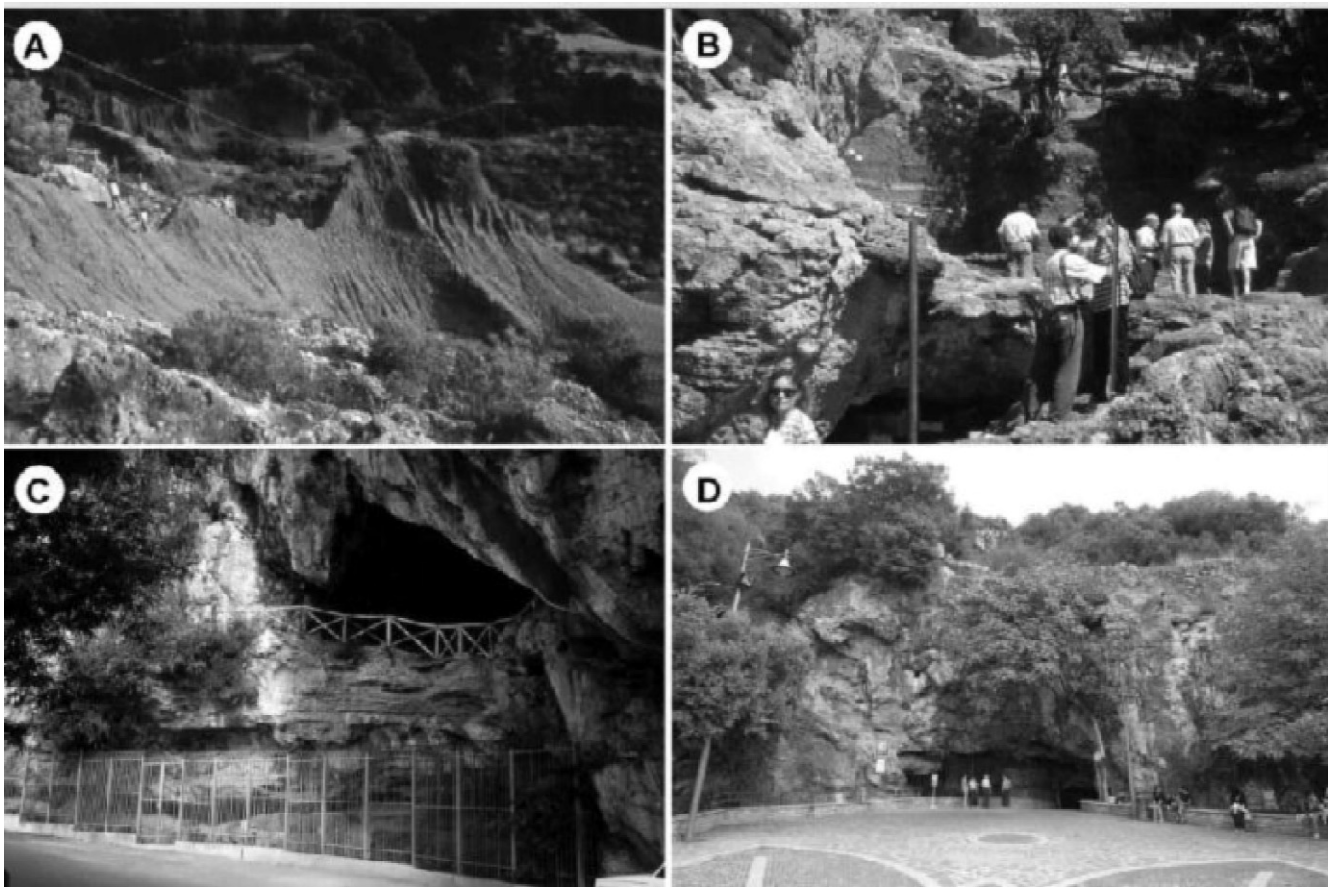

Fig. 5. The Cilento and Vallo di Diano National Park with the Archeological Sites of Paestum and Velia, and the Certosa di Padula WHS: **A.** Arconte; **B.** Riparo del Molare; **C.** Grotta della Cala; **D.** Grotta di Castecivita (photos from the archives of the University of Siena).

BASSINI 1995a, 2003; CARAMIA & GAMBASSINI 2006) for the Middle Palaeolithic, Grotta della Serratura (MARTINI 1993, 1995) for the Upper Palaeolithic and the Holocene, Grotta della Cala, (PALMA DI CESNOLA 1971; GAMBASSINI 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 chronology 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 Arkhangel'sk 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 km^2 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

Fig. 6. The Historic and Architectural Complex of the Kazan Kremlin WHS: **A, B.** general views; **C.** masonry of the Khan's period (15th–mid-16th centuries); **D.** masonry used by Pskov architects (1556–1562).

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 conclusionsabout 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).

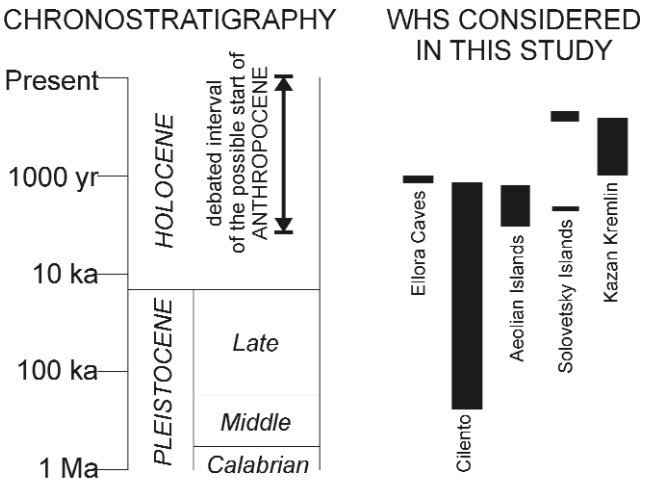

Fig. 7. The WHSs considered in the present study along the geological timeline.

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 WHSs 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
maharashtratourism.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).

Cala Bianca (oper-air site): Lower Palaeolithic (Acheulean) (Palma di Cesnola 1969a, 1976, 2001; Gambassini & 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 (Sarti 1995).

Grotta Grande (cave site): Middle Palaeolithic (Ronchitelli 1995b).

Riparo del Molare (shelter site): Middle Palaeolithic (Mallegni & Ronchitelli 1987, 1989; Ronchitelli 1993, 1995a).

Grotta Tina (cave site): Middle Palaeolithic (MARTINI *et al*. 1972-74; GAMBASSINI *et al*. 1995).
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).
Grotte di Castelcivita (cave site): Middle Palaeolithic, Upper Palaeolithic (Uluzzian, Proaurignacian) (GAMBASSINI 1995c, 2000).
Grotta della Serratura (cave site): Middle Palaeolithic, Upper Palaeolithic (Gravettian, Epigravettian), Mesolithic (Sauveterrian), Neolithic (MARTINI 1993, 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; BENINI *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 Santa Maria (cave site): Upper Palaeolithic (Epigravettian) (BACHECHI 1989-90; GAMBASSINI *et al*. 1995).
Grotta del Noglio (cave site): Bronze Age (VIGLIARDI 1975; GAMBASSINI *et al*. 1995).
Grotta di Cascarella (cave site): Bronze Age (GAMBASSINI *et al*., 1995).

Appendix 4. On-line information sources on the labyrinths and the fishery constructions of the Cultural and Historic Ensemble of the Solovetsky Islands.

dic.academic.ru
karelia-lines.ru
my-solovki.ru
redigo.ru
sciteclibrary.ru
solovki-monastyr.ru
turizm.ru
whc.unesco.org

Резиме

Геолошка активност човека представљена на локалитетима светске баштине у Италији, Индији и Русији: докази антропоцена

Антропоцен представља релативно нови концепт али је већ привукао пажњу великог броја истраживача. У првом реду, антропоцен одражава геолошку (укључујући и геоморфолошку) активност човека. Осим тога, термин антропоцен има и стратиграфско значење: појављује се на геолошкој скали као нова епоха или као формална/неформална јединица другог реда. Најупечатљивији докази о постојању антропоцена долазе са простора који истовремено пружају геолошке и културолошке податке, при чему су локалитети на листи светске баштине УНЕСКА од највећег значаја. Главни циљ овог рада је да пружи преглед доступних података са локалитета под заштитом УНЕСКА који се налазе у три земље са богатом културном и природном баштином тј. Индији, Италији и Русији који се односе на геолошку активност човека, у циљу дефинисања њиховог значаја за боље разумевање антропоцена. Истраживања за потребе овог рада спроведена су током четири фазе. Прво је установљено присуство различитих трагова геолошке активности човека везане за локалитете светске баштине (ЛСБ) у свакој од три наведене земље како би се утврдили директни или индиректни докази ове активности. Затим је утврђено време геолошког деловања човека везано за сваки од истраживаних локалитета. У трећој фази истраживања коришћене су две аналитичке методе. Израчунат је процентуални однос директних и индиректних доказа о геолошкој активности човека добијених на одређеном броју локалитете светске баштине у свакој од земаља. Утврђено је и оквирна старост геолошке активности човека значајне за сваки од истраживаних локалитета. На основу тога изведени су закључци о значају ових доказа и њиховој релевантности за концепт антропоцена. У четвртој фази су детаљно анализирани репрезентативни примери ЛСБ који су потенцијално значајни за даљи развој концепта антропоцена. Од укупно 32 ЛСБ рагистрована у Индији, 75% пружа директне и/или индиректне а 22% директне доказе доказе геолошке активности човека. Од 50 ЛСБ у Италији, 90% носи директне и/или индиректне доказе геолошке активнсти човека, а 28% локалитета пружа директне доказе. На 26 ЛСБ у Русији, директни и/или индиректни докази геолошке активнсти човека пронађени су на 65% локалитета, а 23% локалитета пружа директне доказе. Анализа локалитета светске баштине на тлу Индије, Италије и Русије показује да ове земље генерално имају велики значај за разматрање проблема везаних за антропоцен, као и за даљи развој овог концепта. Локалитети светске баштине у наведеним земљама могу бити коришћени као аргумент за „рани" почетак антропоцена (на основу значајне геолошке активности човека пре 1800. г.н.е.) али, нажалост, ови објекти дефинитивно не пружају довољно аргумената за дискусију о почетку антропоцена у 19. веку или касније. Елора пећине, ЛСБ у за-

падној Индији, указује на то да је човек био значајан геолошки фактор далеко пре 19. века или, боље речено, већ у првом миленијуму нове ере. Иако је реч о једном локалитету, ово представља важан аргумент за дискусију о „раном“ почетку антропоцена. Национални парк Ћиленто и Вало ди Дано, 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 Казањски Кремљ у Русији представља типичан пример ЛСБ са индиректним доказима геолошке активности човека: вишефазна изградња Казањски 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 периду праисторије тако и током историје. Ипак, на основу поменутих локалитета може се дискутовати само о „раном“ почетку антропоцена. Даља истраживања би требало 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 разумео њихов прави значај у стицању нових сазнања везаних за антропоцен.