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# Combined mineral and geoheritage resources related to kaolin, phosphate, and cement production in Egypt: Conceptualization, assessment, and policy implications

Dmitry A. Ruban <sup>a, b, \*</sup>, Günter Tiess <sup>b, c</sup>, Emad S. Sallam <sup>d</sup>, Alena A. Ponedelnik <sup>a</sup>, Natalia N. Yashalova <sup>e</sup>

<sup>a</sup> Higher School of Business, Southern Federal University, Rostov-na-Donu 344019, Russia

<sup>b</sup> International Agency for Minerals Policy, Dreistetten A2753, Austria

<sup>c</sup> Faculty of Mining and Geology, Technical University of Ostrava, Ostrava 70032, Czech Republic

<sup>d</sup> Department of Geology, Benha University, Benha 13518, Egypt

<sup>e</sup> Department of Economics and Management, Cherepovets State University, Cherepovets 162600, Russia



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## ABSTRACT

Societal and environmental importance of geological resources has to be fully considered, as well as their relevance to national heritage conservation, tourism development, etc. Geological resources are usually understood in the context of mineral extraction, energy production, and waste storage, but their significance to the society is also linked to their heritage value. As geological resources constitute a part of the natural heritage, they need conservation and sustainable exploitation. Evidently, mineral and geological heritage (geoheritage) resources often co-occur. Production of raw material *via* extraction from the interiors and subsequent processing determine certain heritage value. As a result, the combined mining and geoheritage resource should be recognized. Such a resource can be exploited for the purposes of mining and tourism. For instance, huge reserves and globally-important production of kaolin, phosphate, and cement in Egypt determine the existence of the combined mineral and geoheritage resources that can be doubly exploited (for mining and tourism) and conserved. Some sites relevant to mining and processing of the noted raw materials are potential geoheritage sites (in Egypt, these include the Kalabsha and El-Sebaiya quarries and the Medcom-Aswan cement factory). Management of mining-related geoheritage is challenging, and disputes between different stakeholders are possible. Special policy related to simultaneous exploitation and conservation of the combined mineral and geoheritage resource has to be developed. In order to better evaluate the combined mineral and geoheritage resource, it is recommended to link its potential to provisioning and recreational geosystem services analogous to the similar ecosystem services.

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## 1. Introduction

Geological resources are essential for the human well-being because they provide raw materials for different industries, energy, space for waste storage, etc. These resources are chiefly

limited, a fact which makes their rational extraction from the interiors urgent. Anyway, mining, quarrying, well drilling, and related activities disturb environment, and, as a result, the latter needs protection from the anthropogenic negative influences; some material resulting from the noted activities needs recycling, and many areas hosting these activities need restoration. These issues are well-known and the current mineral policy attempts to solve the relevant problems (e.g., [1,2]). However, the understanding of the geological environment has experienced significant change during the two past decades. It has been realized that the geological resources are not limited to the only mineral resources, but include

\* Corresponding author. Higher School of Business, Southern Federal University, Rostov-na-Donu 344019, Russia.

E-mail address: [ruban-d@mail.ru](mailto:ruban-d@mail.ru) (D.A. Ruban).

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also the vast category known as the geological heritage (geoheritage). The relevant ideas have been conceptualized, particularly, by Wimbledon [3], Henriques et al. [4], Thomas [5], and Ruban [6].

Evidently, mineral resources and geoheritage resources intersect at several points. For instance, quarrying for gravel and sand for the need of the building industry may lead to the better exposure of rocks and fossils at the quarrying site. Moreover, an operated quarry itself may be a kind of geoheritage because of its huge size or global importance of this site for the given raw material extraction. In such a case, quarrying contributes to the heritage value of the local geological environment. With regard to the above-said issues, it appears to be irrational to separate mineral and geoheritage resources, but the relevant ideas are scarce in the professional literature. The main objective of the present paper is, therefore, to provide the first characteristics of the combined mineral and geoheritage resources of Egypt (a still developing, but fast-growing country) where the co-occurrence of the two types of resources has been recognized very recently [7]. Production of kaolin, phosphates, and cement in this country provides representative examples for the understanding of this new resource, which is necessary for subsequent development of the relevant policy. Undoubtedly, full-scale exploitation of each natural resource requires first its recognition as something *potentially* important and general description. This is why the present paper offers tentative framework for further discussion.

## 2. Conceptual framework

First of all, some principal terms should be defined. *Geoheritage* is the entity of unique (either very typical or, in contrast, very peculiar) geological features on a given area. *Uniqueness* determines the heritage value of the features, i.e., the societal importance of their existence “as is”. Depending on the spatial occurrence of the features of the same kind, the uniqueness may be local, regional, national, and global, and, thus, four relevant ranks of the geoheritage exist [8]. *Geoheritage resource* means the potential of geoheritage to be used for scientific, educational, and tourism (recreational) purposes. All geoheritage objects (first of all, *in situ* objects, i.e., *geosites*, but also *ex situ* objects stored in museum collections) can be assigned to geoheritage resource if their utility is established and well-argued. The utility of such objects should be professionally realized, i.e., evaluated, documented, and communicated to the circle of specialists, policy-makers, and the broad public. Different objects have different utility, which is also determined by the degree of geoheritage uniqueness.

Mineral resources manifested as mineral (ore or non-ore) deposits are to be exploited (if economically reasonable), which means extraction and subsequent processing of the precious components. This activity requires regulation for sustainable resource exploitation, minimization of negative environmental impacts, and restoration. Geoheritage resources are both similar and different. Their similarity to the mineral resources is linked to balancing between the exploitation versus conservation concerns (Fig. 1). Three main differences are as follows. First, geoheritage has been recognized for the purposes of conservation (*geoconservation*) [4,9]: unique geological features should be identified and conserved properly as a specific kind of natural heritage for future generations who should have chance to see them in the natural state as sources of essential information about permanently changing geological environment. Exploitation of geoheritage is an important, but only second-order goal (if even this goal has become more and more important recently). Second, exploitation of geoheritage resources may have different negative consequences for these resources themselves and for the environment. This is linked

to outcrop oversampling, occasional damage by tourists, changes of the aesthetic properties of geosites, tourism wasting, and environmental disturbance because of surface cleaning, among others. Various examples of geoheritage damage have been given (e.g., [10]). However, minimization of environmental impact of geoheritage resource exploitation should be differentiated from the geoconservation, and the latter does not have evident analogues in the mineral resource treatment. Third, the main form of geoheritage resource exploitation is not extraction (as in the case of the mineral resource), but non-extractive use chiefly for tourism purposes. Geotourism based on geosites, geoparks, and geological landscapes taken alone or integrated with natural environment has risen quickly since the mid-2000s [11,12]. This form of geoheritage exploitation becomes more and more comparable in its intensity to raw material extraction for industrial purposes.

The relationships between the mineral and geoheritage resources are documented and discussed by some specialists [13–15]. However, the problem is two-folded. On the one hand, the mineral and geoheritage resources may only co-occur at one place. For instance, coal mining may result in better exposure of layers carrying fossil plants of unique preservation. On the other hand, mining and quarrying themselves may contribute to geoheritage. This occurs in four cases (at least), namely when 1) mine or quarry are of interest because of their size or peculiar technologies, 2) mine or quarry are important for the production of a given type of raw material, 3) mine or quarry are of historical importance and represent individual stage in geological exploration, and 4) mined or quarried material is unique itself (rare ore, unusual deposit genesis, outstanding deposit size, etc.). In all these cases, mining resources do not simply co-occur with geoheritage resources, but the former produces the latter. In other words, the unique features and their value are determined by extraction and processing activities. This is proposed to be called as *combined mineral and geoheritage resource* (Fig. 1).

The combined mineral and geoheritage resource is a subject of highly-complex activities (Fig. 1). These include exploitation for the purposes of mining industry, science, education, and tourism. Mining permanently contributes to the better functioning of the resource for three other purposes. Geoconservation has to occur together with minimization of negative environmental impacts of the both mining and tourism. It appears geoconservation is able to contribute to sustainable (rational) use of mineral resources *via* establishment of additional regulative mechanisms for raw material production. Generally, the balanced use of these resources is the highest goal. In regard to tourism exploitation, this activity appears to be also very complex. First, the combined mineral and geoheritage resource is interesting potentially to geotourists and some other occasional visitors (e.g., eco-tourists). Second, the same resource can be used efficiently for the purpose of industrial tourism, which develops actively in the world [16,17]. The combination of the two forms of tourism contributes to diversification of local tourism services, which is always favourable for attraction of the great number of visitors. However, efficient regulation of the combined mineral and geoheritage resource is necessary, and the modern legal basis of such a regulation remains questionable [18] and requires normalization.

Generally, combined mineral and geoheritage resources are worth recognizing to judge about premises for simultaneous exploitation and conservation of geological environment. Mining and geotourism taken alone are profitable, but geotourism enhanced by mining appears to be even more efficient. Similarly, minimization of negative environmental impact of extractive activity can be coupled successfully with additional geoconservation practices for more sustainable exploitation. Tourism development at mining sites can facilitate creation and promotion of brands of

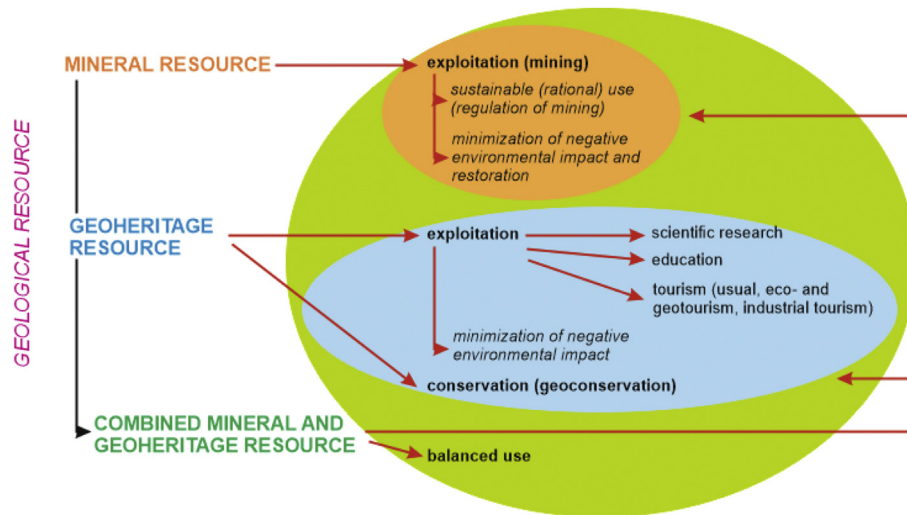


Fig. 1. Conceptual idea of combined mineral and geoheritage resources.

mining companies, as well as better public awareness of a particular resource as a kind of national treasure. Moreover, geoconservation and geotourism can be developed jointly since the stage of mineral deposit exploitation permit to solve problems links to subsequent closure of a given mine or quarry and following restoration of local environment. The already enabled conservation mechanisms would permit to achieve these tasks in a more sustainable form, and the use of a site for the purposes of tourism (with already realized promotion among possible visitors and already built infrastructure) would also permit to avoid site abandonment, environmental degradation and pollution, and uncontrolled evolution. Moreover, the already developed geotourism would reduce costs linked to closure of a mining site because of earlier investments.

The most difficult issue linked to the combined mineral and geoheritage resource is expected scepticism of representatives of mining companies and, particularly, mining engineers. However, geoheritage always remains at the centre of intersection of interests and multiple stakeholders. Standard approaches of environmental dispute resolution can help in this case. The intervention of municipal, regional, and national governmental authorities and specialized environmental agencies can also help. It should be realized and broadly explained that mineral resources exploitation is a dynamic process that becomes less economically profitable or even stops together with extraction of more and more raw material. Tourism initiatives based on exploitation of co-existing geoheritage resources can cover (at least partly) such losses, i.e., these provide sustainable economical activity. Moreover, these may reduce losses linked to necessity of restoration of closed quarries and mines because this mining infrastructure remains valuable to geotourists. In the other way, exploitation of the discussed combined resource permits diversification of economic activities and relevant incomes of mining companies that permits to reduce risks (even if only slightly) on the enterprise level.

### 3. Methodology

Several representative examples of combined mineral and geoheritage resources can be found in Egypt. This country is characterized by rich mineral and, particularly, non-ore resources [19,20]. The diverse geological setting of this country reflecting its evolution during four billion of years determines outstanding richness of the national geoheritage.

The examples considered in this paper are linked to kaolin, phosphate, and cement production in Egypt (these directions are important in the mining economy of this country). The basic information on kaolin production in Egypt is taken from USGS [20], BGS [21], and Baioumy [22]. The data on phosphate production are taken from BGS [19], USGS [20], and Pestitschek et al. [23]. Finally, the information on cement production is taken from USGS [20] and CemNet [24]. In all cases, geographical distribution of the main production areas, production dynamics for the period of 1970–2017, and the global ranking of the national industry are considered. Moreover, the authors refer to some operated quarries and factories that have been visited in the course of field geoheritage studies.

This study is aimed at first assessment of combined mineral and geoheritage resources related to kaolin, phosphate, and cement production in Egypt. This means that the presence of these resources should be documented, its importance demonstrated, and the sites at which this resource is available indicated. The methodology employed refers to the conceptual considerations given above. The available statistical information is used to describe kaolin, phosphate, and cement production in Egypt and to prove its uniqueness. The latter is possible *via* argumentation of that the production of the noted raw materials and extraction sites is valuable in the terms of geoheritage. Then, exploitation potential of the combined mineral and geoheritage resources related to kaolin, phosphate, and cement production is interpreted. In this case, both utility for tourism development and conservation issues are considered. Mining/processing sites used as examples of the established geoheritage are selected with two criteria. First, this should be really representative sites, i.e., localities demonstrating a given resource with geoheritage value. Second, these sites should be restricted in space, i.e., these should correspond to any given quarry, mine, or factory.

## 4. Results

### 4.1. Resource assessment

#### 4.1.1. General statistics of raw material production

Kaolin is a white clay mineral that is used for production of paper, ceramic, plastic, as well as in pharmacology and nanotechnology industries. Egypt has very significant reserves of kaolin in three main areas [22,25], and it is one of the main world producers

of this raw material (Fig. 2). Despite certain fluctuations, production of this raw material in Egypt has risen during 45 years. The Kalabsha quarry is a representative kaolin extraction site of Egypt.

Phosphate rocks (phosphorites) are used for production of fertilizers and some food (stabilizers, preservatives, or taste intensifiers in meat bread and farinaceous food). These rocks are mined in the central and eastern parts of Egypt [23]. The phosphate production has increased substantially in Egypt during past two decades to make this country one of the world leading phosphate producers (Fig. 3). The El-Sebaiya quarry is one of the most important and, thus, representative phosphate extraction sites in Egypt.

Cement is a vital material for the construction industry and the production of which requires extensive exploitation of specific limestone formations with the content of CaCO<sub>3</sub> of no less than 75% and low content of Mg compounds. Such formations crop out widely in Egypt, which facilitates growth of the cement production industry. Cement companies are located in large cities, along the Nile Valley, and in some other places of the country (Fig. 4). The relevant limestone quarrying is very active. At present, Egypt is one of significant contributors to the world cement production (Fig. 4). The amount of cement produced in Egypt has increased instantly during the past 45 years; acceleration in its production took place twice, namely in the late 1980s and the late 2000s. The Medcom-Aswan cement factory is a typical example of cement production sites in Egypt.

4.1.2. Geoheritage recognition

Kaolin, phosphorites, and limestones used for cement production are interesting from the purely geological point of view, although their uniqueness differs depending on their appearance on a given area. Kaolin and phosphate rocks are relatively rare in the world geological environment, a fact of which increases geoheritage value of their occurrence in Egypt. Additionally, aesthetic properties of kaolin (white colour – Fig. 2) make it attractive to possible visitors, which also contribute to geoheritage value.

Mining/processing sites of the noted raw materials constitute the geoheritage of Egypt. Two main lines of evidence are as follows.

First, these sites provide representative examples of the national scale of the relevant geological phenomena. Second, the large reserves of kaolin, phosphorites, and cement limestones and their global importance (Figs. 2–4; see also above) indicate their uniqueness [7]. For instance, the strikingly growing phosphate production in Egypt (Fig. 3) implies the outstanding geoheritage value of the El-Sebaiya phosphorite quarry because of exceptional contribution of the relevant resource exploitation to the noted growth and the global phosphate production. Therefore, the very importance of the mineral resources and their excessive exploitation increases the value of the relevant geological features as geoheritage resources. If so, it is sensible to conclude about the existence of the combined mining and geoheritage resources in Egypt. These resources are accessible, particularly, at the Kalabsha kaolin quarry (Fig. 2), the El-Sebaiya phosphate mining site (Fig. 3), and the Medcom-Aswan cement factory (Fig. 4).

4.2. Exploitation issues

4.2.1. Heritage and tourism issues

The kaolin, phosphate, and cement limestone resources of Egypt can be exploited simultaneously for the purposes of raw material production (the latter takes place already) and tourism, and the development of the former facilitates the potential of the latter. The joint development of geological and industrial tourism may increase income from the exploitation of the resource. Similarly important is its contribution to the sustainable development. Guidance of excursions, maintenance of tourism infrastructure, and some other relevant activities require human resources, which mean creation of new jobs and better nature-oriented education of the local communities. Indeed, the only specialists and geotourists with certain professional knowledge may realize the importance of kaolin or phosphate rocks exposed outside of mining sites. In contrast, mining/processing sites seem to be considerably more valuable because of four main reasons. First, societal importance of kaolin, phosphate rocks, and cement limestones is the most evident there (operation of a quarry or mine highlights the existing demand for the resource in the public perception). Second, these geological

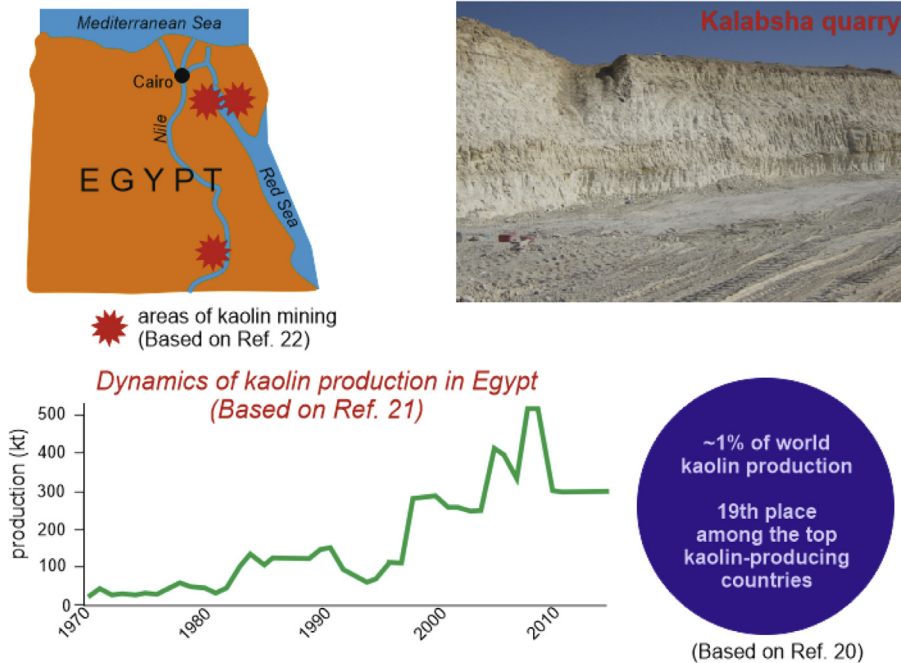


Fig. 2. Summary factsheet of the kaolin production in Egypt.



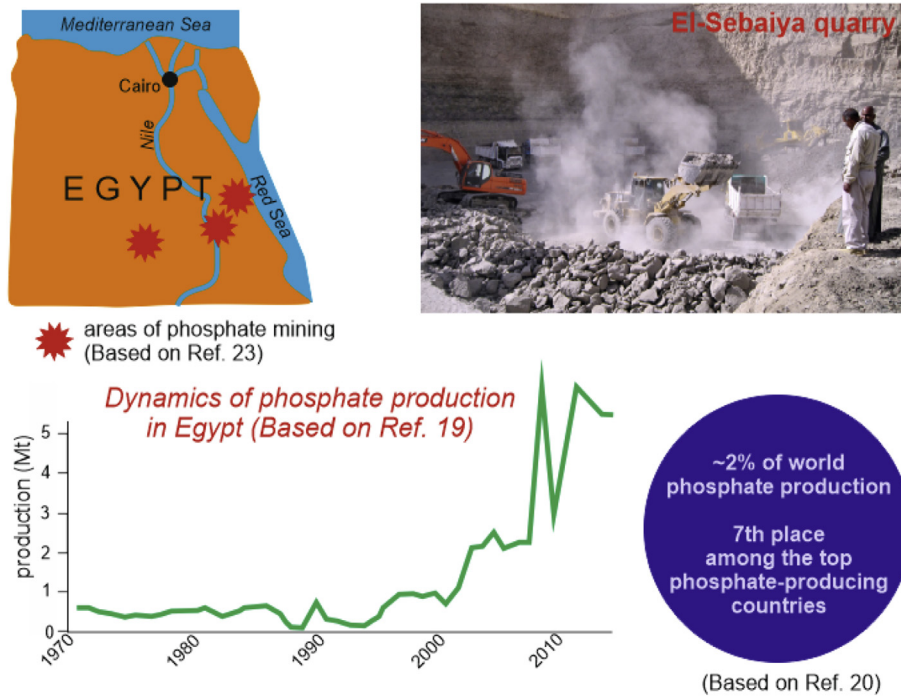


Fig. 3. Summary factsheet of the phosphate production in Egypt.

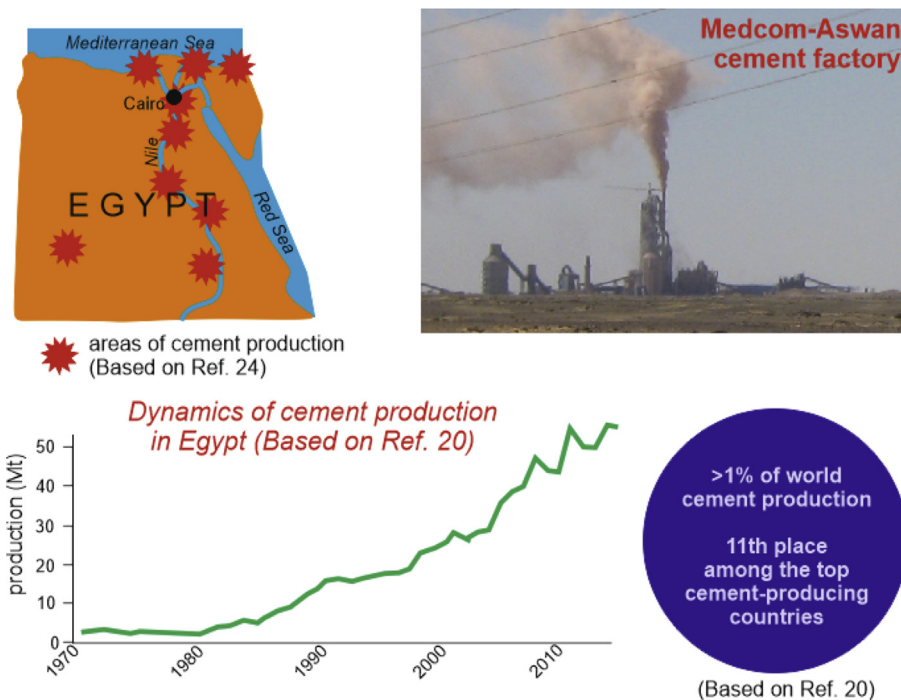


Fig. 4. Summary factsheet of the cement production in Egypt.

features are available at mining/processing sites in the “concentrated” form and can be understood comprehensively. Third, mining makes these features well visible and perfectly accessible. Fourth, professionals may be interested in specific features of the mineral or rock genesis that made possible this deposit to appear. For instance, a visit to the El-Sebaiya phosphorite quarry in Upper Egypt (Fig. 3) permits to realize the necessity of this resource to the national economy of Egypt and the export to the other countries.

Moreover, the characteristic properties of this rock can be understood in the field. The Kalabsha kaolin quarry in southern Egypt exhibits a representative sequence of kaolin deposits, where visitors can learn about the character of this important resource and scientists can investigate the origin of this unusual deposit (Fig. 2).

The geoheritage value and tourism potential of selected cement factories located in Egypt (e.g., the Medcom-Aswan factory – Fig. 4) become evident after comparison with some experience in other

countries. At least, four examples are known worldwide (Table 1). All represent the combined mineral and geoheritage resource because of three reasons. First, these are sites at which the specific carbonate raw material was exploited for cement production. Second, these sites played a significant role in the development of the cement industry (on local, regional, or national levels). Third, unique geological features can be visited at some of these sites or in their vicinities. At present, this resource is exploited actively and successfully for the purposes of tourism. The modern cement factories in Egypt are definitely of the same importance with regard to the rise of the cement industry in this country (Fig. 4). These are relevant not only to the natural resources for cement production, but also to the geoheritage.

#### 4.2.2. Conservation and environmental issues

Recognition of the combined mineral and geoheritage resources in Egypt should contribute to the better conservation of the geological environment. Quarrying for kaolin, phosphorites, and cement limestones aims at their maximum extraction. This is especially urgent because of the evident growth of the relevant raw materials production in Egypt (Figs. 2–4). Such an extensive extraction leads to significant anthropogenic pressure on the environment near mining/processing sites. However, the recognition of the heritage value of the same resource means that it needs conservation, i.e., some “pieces” of the kaolin, phosphorite, and cement limestone deposits represented at the mining sites should remain to serve as sources of information about these deposits and the relevant geological features. Importantly, this occurs not because quarrying results in discovery of some unique geological features, but because operation of quarries itself increases the uniqueness of the sites. Therefore, the exploitation of the mining sites in Egypt has to be more balanced to allow the above-mentioned geoconservation without any serious interruption of the extraction activities. Moreover, the employment of mining sites for the purposes of tourism (particularly, geotourism and industrial tourism) requires adequate conservation practices to provide the comfortable and safe environment for visitors.

The establishment of the combined mineral and geoheritage resources linked to the kaolin, phosphate, and cement production in Egypt creates important premises for more efficient exploitation and conservation of these resources. Indeed, further actions based on these premises requires development and implementation some legal mechanisms of regulation similarly to how this is done in some European countries [18,26]. However, the first stage in this direction is designation of geosites for the doubly exploitation and geoconservation. Among these are two geosites in southern Egypt proposed by Sallam et al. [7], namely the Kalabsha kaolin quarry (Fig. 2) and the site of the Medcom-Aswan cement factory (Fig. 4)

where geotourism coupled with industrial tourism may develop together with mining or processing of the raw material, as well as some geoconservation activities. The other potential geosite is the El-Sebaiya phosphorite quarry in central Egypt (Fig. 3), which is very representative with regard to phosphate rocks and their industrial importance.

## 5. Discussion

### 5.1. Policy implications

Recognition of the combined mineral and geoheritage resources linked to the kaolin, phosphate, and cement production in Egypt and realization of possibilities for their exploitation and conservation require development of the relevant policy on the national level. Various problems linked such a policy in different countries were discussed by several investigators [18,26,27]. Two fundamental issues are as follows. First, a legal basis for geoheritage management is necessary. Second, mechanisms for this management should be established.

The Egyptian legislation permits establishment of nature protectorates and some other protected areas. This possibility can be used principally for the purposes of geoheritage management like in the cases of the Wadi El-Hitan in the Faiyum Oasis [28] and the Abu Roash area [29]. However, the status of natural protectorate does not help to realize the essence of geoheritage and its difference from the other natural heritage. Moreover, this status prescribes strict protection, but not balanced management that is necessary at operating extraction/production sites. Most probably, preparation and subsequent approval of special legal acts focussing on geoheritage and its specific features are necessary. The experience of Russia where such an act was approved about two decades ago shows this task can be realized easily (see also in Ref. [18]).

The mechanisms of geoheritage management can be preoccupied from the practice of conservation of natural and archaeological sites in Egypt, but only partly. It should be underlined that combined mineral and geoheritage resources have counterparts matching interests of different stakeholders, i.e., industry, geoconservation, and geotourism. These interests evidently intersect and may be often conflicting. For instance, as the production of kaolin, phosphorites, and cement rises and leads Egypt to the world leading positions (Figs. 2–4), the owners and engineers of mining enterprises, as well as the government may be disinterested in involvement of extraction/production sites into geoconservation and geotourism programs. However, the same reason determines high geoheritage importance of these sites and stimulates interest of potential administrators of these programs. This is why new mechanisms (both political and economical) for efficient

**Table 1**  
Examples of heritage-related tourism activities at cement factories.

Site	Location	Essence	URL
Qixin cement industrial museum	Tangshan, China	First cement industry museum in China on the basis of the closed factory, creative park.	<a href="http://news.xinhuanet.com/english/2017-09/13/c_136606942.htm">http://news.xinhuanet.com/english/2017-09/13/c_136606942.htm</a>
Maceira-Liz plant Cement Museum	Maceira, Portugal	History of the local cement production and the Leiria Cement Company; the relevant industrial, archaeological, and geological features are explained.	<a href="http://www.secil-group.com/museu/en/">http://www.secil-group.com/museu/en/</a>
Atlas Cement Company Museum	Northampton, USA	History of the cement industry, including cement supply to the major projects like the Panama Canal and the Empire State Building.	<a href="https://www.roadsideamerica.com/tip/23212">https://www.roadsideamerica.com/tip/23212</a>
Asland Cement Museum	Castellar de n'Hug, Spain	History of the first cement factory in Catalonia (now closed) and its modernist building; local geological features can be visited.	<a href="http://www.berguedareserves.cat/activities/cultural-tourism/asland-cement-museum-of-castellar-de-n-hug-reduced-rate/357">http://www.berguedareserves.cat/activities/cultural-tourism/asland-cement-museum-of-castellar-de-n-hug-reduced-rate/357</a> ; <a href="http://museuciment.cat/ca/home/">http://museuciment.cat/ca/home/</a>

negotiation between stakeholders should be invented and enabled. Moreover, exploitation of operating quarries and mines, as well as factories raises safety issue. The latter should be addressed adequately to provide safe excursions and to avoid occasional interruptions in the work of mining industry.

Generally, the establishment of the combined mineral and geoheritage resources in Egypt is the only first step toward their simultaneous and mutually benefiting conservation and double exploitation (Fig. 1). Broad consultation of experts representing governmental (national, provincial, and local) authorities, geo-tourism and geoconservation community, and mining industry is necessary for the development of optimal strategy and further adoption of legal acts and practices. However, the very establishment of the discussed resources should facilitate this movement. And, thus, a minimal policy requirement for now is establishment of a national-scale framework (e.g., governmentally-supported research projects) for assessment of the combined mineral and geoheritage resources. At least, these are new resources that can contribute *potentially* to the sustainable development in Egypt, and, thus, the knowledge of them matches the national interests.

5.2. Perspectives from geosystem services approach

The combined mineral and geoheritage resource needs to be valued for a better understanding of its true socio-economic importance. In doing this, it is sensible to implement the approach analogous to ecosystem services used widely in the ecological economics and environmental policy-making. The idea of ecosystem services was developed by others [30–36]. It is applied broadly in case studies and for practical solutions. The well-known summary of this idea was published in Millennium Ecosystem Assessment [37]. Generally, the ecosystem services indicate the ways by which the natural capital contributes to the human well-being through the interaction with the built, human, and social capitals [33]. Recognition of these services and their economic valuation offer understanding of the full value of the particular ecosystems and the income from their functioning.

Ecosystems (*sensu stricto*) occur near (on, above, and below) the Earth's surface and these are related to the living nature. In such a case, it is difficult (if possible) to relate their services to the combined mineral and geoheritage resource, which is linked chiefly to the abiotic world of the planetary interiors. However, the geological environment can be imagined as the entity of geosystems; the functioning of which can be analyzed through the services approach. The given combined mineral and geoheritage resource can be considered as a particular geosystem (Fig. 5). Evidently, *geosystem services* (this term was discussed in-depth by Van Ree and van Beukering [38]) can be classified similarly to ecosystem services [37] to include the supporting, provisioning, regulating, and cultural categories. The mineral resource offers the only provisioning service of raw materials production. In contrast, the geoheritage resource offers the cultural services, namely the scientific, educational, and recreational services (see also conceptual developments by Gray [39]). In such a case, the combined resource offers two categories of services (Fig. 5). This means that this resource is not only more valuable, but also offers more diverse and more complex interactions between the natural, built, human, and social capitals on the local, regional, and national levels. Different views of the ecosystem services discussed recently by Hermelingmeier and Nicholas [35] seem to be also plausible to the geosystem services of the combined mineral and geoheritage resource (Table 2).

The idea of geosystem services applied to the combined mineral and geoheritage resources permits detection of some complex relationships and feedbacks. For instance, the exploitation of the Egyptian phosphate resources (and, first of all, the El-Sebaiya mining site) facilitates the phosphate export and the domestic production of fertilizers. The subsequent use of these fertilizers in the national agriculture increases productivity, i.e., enhances the provisioning service of Egyptian ecosystems. The geoconservation activities that should follow establishment of the heritage value of the discussed resource will contribute to minimization of the negative anthropogenic impact of phosphorite mining that is necessary to support the sustainable functioning of the local ecosystems.

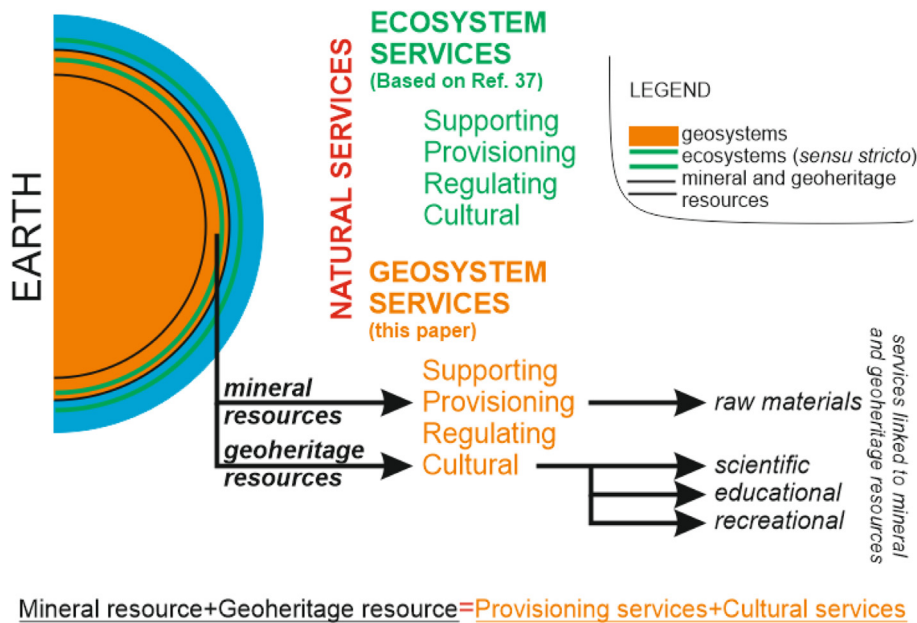


Fig. 5. Combined mineral and geoheritage resources in the context of natural services.

**Table 2**  
Combined mineral and geoheritage resources in the light of geosystem services.

Perspectives on ecosystem services [35] adapted to geosystem services	Geosystem services provided by combined mineral and geoheritage resources	
	Provisioning	Cultural
Non-economic utilitarian	Environmental impact of raw material extraction and processing	Environmental importance of mining balanced with conservation, post-mining restoration, nature-based education
Critical idealist	Value of mineral resource	Additional values from tourism development
Anti-utilitarian	Heritage context of mining	Social importance of joint resource exploitation and cultural activities
Methodologist	Algorithms for resource evaluation	Algorithms for description and evaluation of scientific, educational, and recreational activities at mining sites
Moderate economist	Rational resource exploitation	Complexity of resource exploitation

## 6. Conclusions

The analysis of the co-occurrence of mining and geoheritage permits making four general conclusions:

- 1) the establishment of the combined mineral and geoheritage resource creates strong premises for its simultaneously efficient exploitation for the purposes of mining industry on one side and tourism and geoconservation on the other side;
- 2) the combined mineral and geoheritage resources of Egypt are linked, particularly, to the kaolin, phosphate, and cement production in this country;
- 3) a special policy related to this specific resource management (first of all, for resolution of disputes between different stakeholders) has to be developed;
- 4) it is possible to implement the geosystem services approach (by analogy to ecosystem services) to examination of the combined mineral and geoheritage resource.

The authors understand that their considerations are tentative and provocative in somewhat. And, thus, they welcome critical comments of the other specialists that can initiate broad discussion on the combined mineral and geoheritage resources.

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