



Dimension stone industry should meet the fundamental values of geoethics

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ABSTRACT

The term “Dimension Stone” refers to natural stone that has been quarried, selected and processed into specific sizes or shapes, with or without one or more mechanically dressed or finished surfaces, for use as building facing, curbing, paving stone, monuments and memorials, and various industrial products. The dimension stone industry is currently increasing the volume of its activities: based on a prudent medium-term development forecast, the net product could reach one hundred million tons in 2020. For this reason, geoscientists and stakeholders need to reason about methods and technologies in the dimension stone sector and how to operate responsibly and sustainably in accordance with the following geoethical values. After a definition of geoethics and an overview of the dimension stone industry, the paper focuses on fundamental values of geoethics as stated in the Cape Town Statement on Geoethics. More precisely, geoethical values have been referred to real and practical cases of dimension stone subsectors, by presenting some examples recorded in Sardinia (Italy). This region has a long history of production of ornamental stones. Finally, tips and suggestions on how geoscientists (in particular geologists and mining engineers) can help the dimension stone sector in a geoethical way, i.e., responsibly and sustainably are herein offered.

1. Introduction

Geoethics is an emerging field in geosciences (Bobrowsky et al., 2017; Peppoloni and Di Capua, 2017a; Peppoloni et al., 2019). Its main purpose is to identify values and practices as a base to solve the most critical environmental issues of modern times, and to develop a more responsible and, whenever possible, sustainable interaction between humans and the Earth system. Geoethics encourages a critical analysis of the use of geo-resources and the development of socio- and environmentally-friendly technologies; it aims at finding solutions that are compatible with natural dynamics and the conservation of landscape; it enhances the social role of geoscientists and promotes the geological heritage as a scientific, cultural, educational and social value; it supports the adoption of ethical guidelines within the geoscience community and the industrial sector to encourage good behaviours when dealing with issues impacting the environment and human life (Peppoloni and Di Capua, 2012).

The term “Geoethics” is the union of the prefix “geo” and the word “ethics.” (Peppoloni and Di Capua, 2015). “Geo” means “Earth”. “Ethics”, in a broad sense, is a branch of philosophy that deals with human behaviours (Peppoloni and Di Capua, 2017b).

Geoethics is defined as the “... research and reflection on the values

which underpin appropriate behaviours and practices, wherever human activities interact with the Earth system. Geoethics deals with the ethical, social and cultural implications of geoscience education, research and practice, and with the social role and responsibility of geoscientists in conducting their activities.” (Peppoloni and Di Capua, 2017a).

The concepts, values and views on individual responsibilities of geoscientists have been expressed in the “Cape Town Statement on Geoethics”. The statement aims to capture the attention of geoscientists and organizations, and to encourage better shared policies, guidelines, strategies and tools ensuring the conscious adoption of ethical and professional conduct in their work. Embracing geoethics is essential, in order to improve both the quality of professional work and the credibility of geoscientists, to foster excellence in geosciences, to assure sustainable benefits for communities, as well as to protect local and global environments; all with the aim of creating and maintaining the conditions for the healthy and prosperous development of future generations (Di Capua et al., 2017).

“Dimension stone” is the term historically used to distinguish stone for building purposes from stone unsuitable to be sawed, cut and sectioned (Primavori, 2004). The term “decorative stone” (sometimes “ornamental stone”) is also generically used in the industrial sector to refer to all natural stones that can be used as decorative material, first

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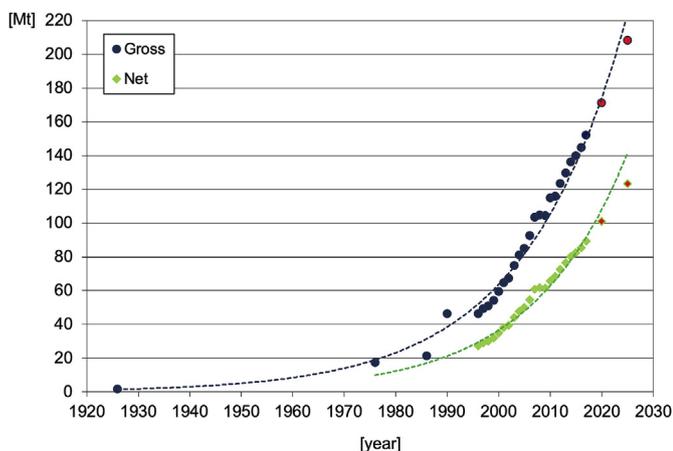


Fig. 1. Forecast of world development in dimension stone gross and net production (Elaborated from data in Montani, 2019).

of all for cladding and covering, as well as with a structural purpose. The dimension stone sector is strongly developing: China, India, Turkey and Iran lead the world quarry production while China and Italy lead the processed stone export. The world quarry net product is expected to reach one hundred-twenty million tons in 2025 (Montani, 2019), which, in any case, represents a prudent medium-term forecast. The current overview takes into consideration the last available data of the sector consisting of about three hundred million tons of gross quarrying production (Fig. 1), with a little more than 50% to be considered as quarrying waste.

This estimate includes also stone-waste materials which will be used to make aggregates as granules, powders and similar uses. The raw production is assessed to be about one hundred-fifty million tons.

Turning the attention towards the stone-processing stage, the world production has reached a little less than ninety-hundred million tons, and consequently, an amount of about sixty-hundred million tons of stone-processing waste is produced; all these data are summarized in Table 1. For this reason, both geoscientists and stakeholders should all be focusing on technical challenges in the dimension stone sector and widening the discussion on how this sector can contribute effectively to economic development with a more responsible and sustainable approach, by following best practices towards a circular economy (Careddu, 2019) and improving its ethical profile by applying guidelines such those proposed in the White Paper on Responsible Mining by the International Association for Promoting Geoethics (Arvanitidis et al., 2017).

Following the key question stated in Limaye (2015), the aim of this paper is to focus on some aspects in order to push the dimension stone industry to open a discussion to find an answer on how environment and economy could be integrated. It is widely acknowledged that a geoethical approach does not aim at recreating the original landscape and environment at the end of the quarrying activity. Its aim is to see that the mining-affected local community lives comfortably in an environment that has better financial and socio-cultural standards than before quarrying, an environment where the quality of life has

Table 1
Dimension stone industry world production and waste in 2017 (data from Montani, 2019, elaborated by authors).

World stone productions	000 tons
World quarry gross production	310,000 kt
World quarry net production (raw blocks)	152,000 kt
World processed production (finished products)	90,000 kt
Quarrying waste/scraps	158,000 kt
Stone-processing waste/scraps	62,000 kt

improved, the use of renewable resources has been maximized with minimized non-renewable resources, by reducing progressively the pressure on the local ecosystems. In that case, a sustainable development assumes also a more distinctive political significance (Vallega, 1994).

Regarding the cultural significance of the dimension stones, the Global Heritage Stone Resource (GHSR) designation has been proposed to recognize dimension stone types that have achieved important utilization in human culture (Cooper et al., 2013). According to internationally recognized rules, a GHSR is determined on the basis of the significant use in human history, wide geographic range of utilization, and the benefits that would accrue from designation. GHSR designation has a significant value for all professional groups that work with stone and helps to facilitate the safeguarding of resources for future use. Since GHSR is a scientific recognition only, enterprises which are involved in the production of a “GHSR recognized stone” could have some potential commercial benefits arising from GHSR designation. This may result in another set of ethical issues, such as to boost quarrying of those stones that, in virtue of the GHSR recognition, are universally considered of particular value for their scientific features and cultural significance. This means that through a formal and international recognition of their value, commercial advertising related to those stones could be strongly and unintentionally favoured, feeding a dangerous negative feedback that could lead to an over-exploitation of the resource, rather than favouring a restriction or much more controlled quarrying activities aiming to preserve and valorize those stones also for their geoheritage value.

2. Considerations on the application of ethical values in the dimension stone industry: the need for more responsible operators

Many would agree that geoscientists should adopt scientific and transparent methods in their research and studies to produce excellent scientific work and to assure reproducibility, as much as possible, of results. In particular, the possibility or ability to re-produce a previous study is a principle at the base of modern science. In most of cases geoscientists act with integrity and with a responsible conduct during their research activities, but malpractice, misconduct and unethical behaviour even in the geoscience community should not be underestimated (Mayer, 2015).

Geologists and mining engineers (herein referred to as “geoscientists”) are asked to follow best-practice procedures when they are planning/carrying out their work (i.e. the design of a quarry). To this aim, Matteucci et al. (2014) suggested that a “Geoethical Promise” should foster higher level of professionalism and integrity in geoscience research and practice and encouraging the sense of serving society in geoscience activities.

Professionals acting in the dimension stone industry are expected to be fully competent in this field. They should assure to follow regular training activities and a life-long learning. A degree in geology or mining engineering is a strategic option, which may be further enhanced by a PhD; however, a degree might not be enough if the person has not worked continuously in the field or, at least, in some of its subsectors (listed in Table 2) and doesn't know well the legal framework regulating those activities.

Technical and scientific knowledge and theoretical and practical experience achieved through various studies must be shared at all levels, while respecting industrial know-how and patents. Sharing knowledge should be carried out by publishing studies in journals which are subject to a peer-review process. An objective and unbiased peer-review process should always be applied to technical and scientific publications on dimension stone. Nonetheless, people working in the dimension stone sector often have published excellent studies and articles in commercial journals (especially in the years 1970–2010), that unfortunately lacked of any kind of peers' check (some valuable examples are: Capuzzi, 1989; Ritter, 1992; Freire and Motta, 1995;

Table 2
Dimension Stone main subsectors.

DS Subsectors
Exploration
Exploitation, Quarrying methods and Technologies
Manufacturing and processing
Characterization and quality control
Natural stone in architecture, buildings and street furniture
Deterioration and conservation
Environmental issues
Relevant legislation
New markets, market trends, economic aspects
Prospecting, new materials and products

Amaral et al., 2001; Careddu et al., 2007), also because in the past scientific peer-reviewed journals generally didn't accept publications on the topic.

The public presentation of research results at congresses or conferences should be highly encouraged, as well as the use of social networks that have nowadays become a very important sharing platform. Facebook is the most commonly used social networks, which allows the set-up of a private group to discuss a specific subject, i.e. the "Mining engineering" group (www.facebook.com/groups/346411622080346/) which has more than 15,000 members; it may also be very useful to use researchgate.com platform and LinkedIn, with the aim of sharing knowledge and results with a more competent audience.

Researches focusing on the dimension stone field should always verify the source of information and data, exactly in the same way as it is done for any other type of research activities. In other terms, the principle of integrity and rigor should be applied to the dimension stone sector in order to guarantee the achievement of excellent working results and the adoption of best practices (Mayer, 2015; Peppoloni et al., 2015). Unethical practices are still present, e.g. the habit of re-publishing research papers that have already been published, with slightly changes in the editing or with very few amendments, or with fake data. This malpractice should be reported and strongly contrasted by editors. Over the last few years, reviewers have sometimes questioned data which did not seem to have been obtained through scientific observations.

Surely, the dimension stone sector needs to increase the number of more responsible geoscientists capable to work together as a team, even if this is not unusual: in this respect, researchers and professionals in this sector like to consider themselves as a "big family", despite this field is often considered as a "little brother" of all mineral siblings. In this perspective, the goal of international congresses should focus on strengthening the function to create opportunities for networking, as clearly indicated in the motto of the last international Global Stone Congress, held in Brazil in 2018: "Connecting minds in the world of stone" (www.globalstonecongress2018.com.br).

3. Environmental implications in the dimension stone sector: the sardinia (Italy) case

Whenever possible, professionals in the dimension stone sector have to consider that their work has an important impact on the Earth system. This is clear during the set-up of a quarry for ornamental stone purposes. Virtually, worldwide mining laws must take into consideration environmental and social issues. The European Union has promulgated various directives especially on safety and health protection of workers in mineral extracting industries (European Communities, 1992), mining waste management (European Union, 2006) and raw material initiative (Commission of the European Communities, 2008). European countries have all different mining laws, although each one has to follow the EU directives. Italy, for instance, follows mainly the Royal Decree 1443/1927 and subsequent amendments (Regio Decreto 29 luglio, 1927); however, since 1998, the Italian government conferred to its Regions several functions in the mining field, including those relating to research permits and authorization to mining (Decreto Legislativo, 1998).

The island of Sardinia is an Italian region that lies in the Mediterranean Sea; due to its mining history of more than seven thousand years (Lilliu, 1986), Sardinia is a great example on which to base geoethical considerations related to mining and quarrying activities. The current regulatory framework requires that Sardinia's quarries, with more than 500,000 m³/year of extracted material, and/or occupying an area greater than 20 ha, will have to undergo a mandatory Environmental Impact Assessment (EIA) (R.A.S., 2012). When EIA is required, the entrepreneur applicant or, otherwise, the quarry designer must submit an Environmental Impact Study (EIS) which must be drawn by certified technicians. EIS is organized as follows: 1) general introduction, 2) programme, planning and environmental frameworks, 3) final impact assessment of those actions which cannot be fully avoided and the solution proposed for their mitigation; 4) summary for non-technical audience (to assure transparency in information). A report on landscape modifications is often required.

The Sardinian landscape offers a remarkable geological diversity, that has to be preserved as an essential aspect sustaining local biodiversity, favouring cultural and social diversity, since this is the key to a possible sustainable development of local communities. The law n.31/1989 by the Sardinian Regional Government recognizes 22 "geological monuments" (R.A.S., 1989) which constitute a tangible and intangible "resource", capable to comply with the idea of the sustainable development; some examples are shown in Fig. 2a, b, and 2c. The geological monuments of Sardinia are defined by the above cited law as "individual items or small areas of particular scientific value, which must be preserved in their integrity"; however, some of those areas have been impacted by mining and quarrying activities in the past. For example, the "Pan di Zuccherò" sea stack (Fig. 2a) was mined for galena, while in the areas near "Roccia dell'orso" (Fig. 2c) granite has been extracted since the Roman age.

The geological history of Sardinia covers a wide geological time of the Earth history (from the beginning of the Paleozoic Era – 541 Ma):



Fig. 2. Three Sardinian geological monuments: a) "Pan di Zuccherò" (Masua, West Sardinia); b) "Punta Goloritzè" (Baunei, Orosei Gulf, East Sardinia); c) "Roccia dell'Orso" (Palau, Costa Smeralda, North Sardinia). a) and b) courtesy of Max Maddanu, www.maxmad.it.

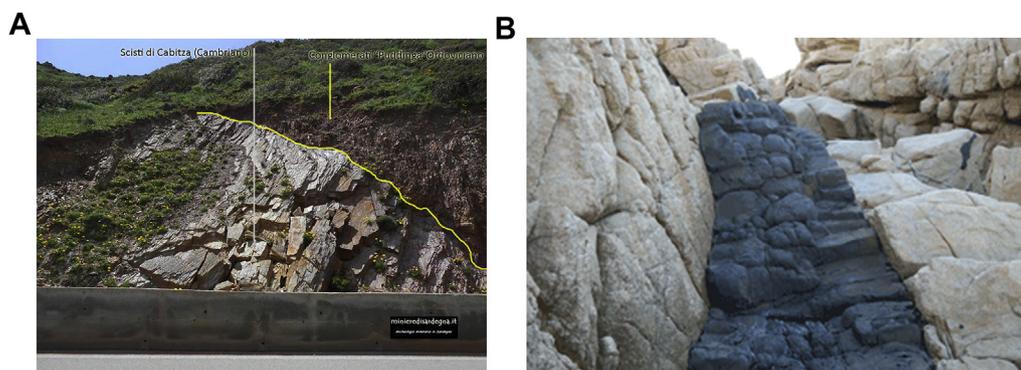


Fig. 3. Two Sardinian geosites which are of geological and teaching interest: a) Ordovician unconformity on Cambrian (Nebida); b) Lamprophiric vein (La Maddalena). Courtesy of M. Scanu, www.minieredisardegna.it.

there are many outcrops showing lithological and paleontological peculiarities (geosites) that are important teaching subjects. These particular geological outcrops (some of which shown in Fig. 3a and 3b) should be preserved, and any uncontrolled sampling should be prevented to preserve its geoheritage. In addition, inadequately managed and unregulated mass tourism could harm outcrops and natural habitats, due to the recent growing trend of picking up rocks, fossils, minerals, plants for as personal souvenirs.

Since ancient times, the life of Sardinian people has been strongly related to local rocks, to their strength and toughness, which turned out useful once men found a way to transform it and use it to organize their life. Those rocks were used as stone for building tombs, “nuraghi” (typical Sardinian huge megalithic towers with a round ground perimeter which tapers towards the top, built during the Bronze Age), places of worship, roads and cathedrals. Sardinian stones are now undergoing a new phase in their industrial use, for the production of street furniture and decorative parts used for public and private buildings (e.g. in the restoration of several villages and historic centres) (Careddu and Grillo, 2019).

Moreover, it should be noted that many Sardinian historical quarries for ornamental purposes (which have now discontinued their operations), ranging from Roman to modern times, are located especially in the coastal areas. All these quarries, whose locations are shown in Fig. 4, should be preserved and perhaps recovered as tourist sites, such as an industrial archaeology heritage structure, similar to the “Parco Geominerario della Sardegna” (Geomineral Park of Sardinia), developed in 1997, which is now part of the UNESCO Global Geoparks network (UNESCO, 1999).

The promotion of positive examples in operating quarries, like in the case of limestone quarries in Orosei (East Sardinia, Fig. 5), should be undertaken more effectively, in order to make local communities aware of the necessity of complying with sustainable development criteria and practices which are respectful of the environment: the effective market strategies promoted by local companies in Orosei have supported the economic development of the territory (Careddu et al., 2017) and the preservation of fossils found during the excavation process, without stopping industrial activities. Moreover, vintage equipment and machinery will be displayed in special outdoor areas: an historical route is to be offered to visitors, showing the outstanding advancement in the technological development of quarrying and stone processing from the late 60s till today. The above example is representative of synergies of industrial-oriented drivers and of tourist activities, with great potential to further develop into geotouristic hiking itineraries, that would respect geoethical values like sustainability and build a strong connection between local communities and the land they inhabit (Allan, 2015; Peppoloni and Di Capua, 2016).

4. Roles and responsibilities of different actors in the decision-making process

Geoscientists are left with no options but to take care of the economic and social development of our time without causing any further loss to our future generations. For this reason, they have to operate reasonably and make a responsible use of natural stone resources in relation to the real needs of society; at the same time, they have to always take into consideration sustainable practices and adopt a robust scientific approach in their studies and decisions.

Production-chain details should be planned carefully in order to ensure adequate supply of geo-resources to current and future generations, to preserve as much as possible the existing landscape, and to recover any used-up mine site (Arvanitidis et al., 2017). Unfortunately, negative past experiences in Sardinia have shown how avid and unethical exploitation of stone deposits can spoil and permanently damage the environment. Such quarrying methods, which are known also as “robbery mining” (already cited in Sella, 1871!), took place when many quarryers/entrepreneurs quarried the best portions of stone deposit and then they immediately closed their activity down. Such quarrying methods prevented every further work including any further discovery of other parts of deposits which may have been of economic interest.

A good example comes from the marble quarries of Orosei: if the quarry workers were to prevent the excavation of both the benches affected by crevasse and with not suitable material for further processing, and focus on quarrying only the areas which seemed to offer better resources, this would result in a substantial saving of the quarrying total cost; however, at the same time, this may also result in higher safety risks for workers, as well as for the environment and the landscape.

Landfills should be designed in the perspective of both low-waste and circular economy development, favouring the reuse of waste/scrap materials as secondary raw materials (Careddu et al., 2013, 2014). Finally, the opening of a quarry and/or a processing plant have to be carefully evaluated and assessed in comparison with other alternative activities which could be more interesting from an economic and social point of view. In fact, environmental resources are valuable mainly for the importance they have in general for social, cultural and economic development of local residents (Careddu and Siotto, 2011). The new idea is to move ahead in agreement with a “Restorative sustainability” approach, which requires that business be conducted in such a fashion that both social and environmental conditions are improved upon what they are now (Wessel, 2016). The concept of “responsible mining” is progressively asserting itself as a new way of developing socio-environmental oriented mining activities (Arvanitidis et al., 2017).

But responsibility should be a principle followed by all actors involved in mining projects.

Universities should create geoscience and engineering curricula in which ethical problems and dilemmas related to mining activities are

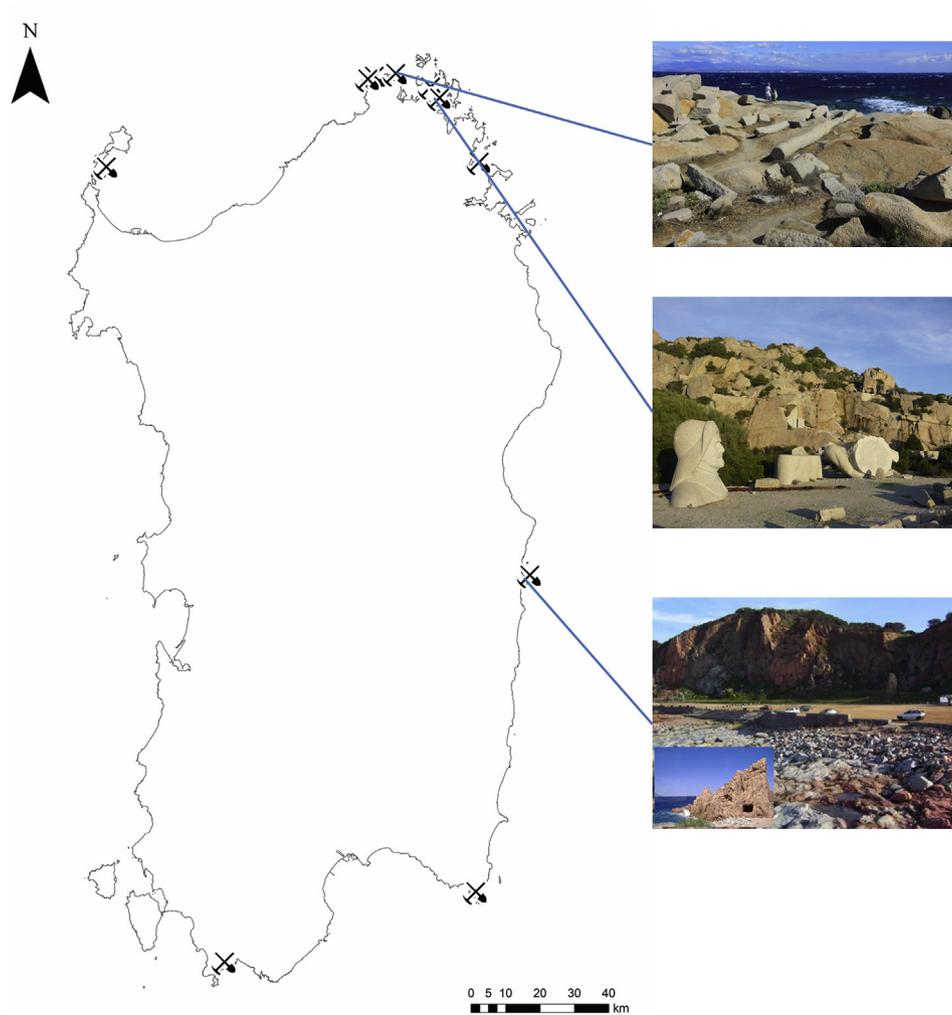


Fig. 4. Location of Sardinian quarries of historical and archaeological interest (Careddu et al., 2019).

adequately discussed and geoethical training could come alongside technical training to prepare future technicians and operators to act by having clearly in mind the ethical and social dimension of their role.

Responsible politicians cannot prevent mining/quarrying only on

the basis of environmentalist protests or electioneering purposes: they should assess any extracting activity on the basis of the outcome of scientific studies. Their final decisions, that in any case which are political decisions, need to be grounded on the evaluation of socio-



Fig. 5. View of a polishable limestone quarry in Orosei.

Table 3

How some fundamental geoethical values as stated in the Cape Town on Geoethics (Di Capua et al., 2017) and the Geoethical Promise (Matteucci et al., 2014) are considered by entrepreneurs acting in the Dimension Stone sector.

Geoethical values	Adhesion of Entrepreneurs/Companies to geoethical values
Competence, including regular training and life-long learning	NOT ALWAYS A lot of quarry-owners are simply landowners with high quality stone resources but poor entrepreneurial skills, although some of them (or their employers and consultants) studies new technologies and market strategies (Careddu et al., 2017)
Sharing knowledge at all levels as a valuable activity	USUALLY NOT Entrepreneurs working in dimension stone industry are always jealous about own knowledge; due to this fact they are not inclined in sharing knowledge and data (Careddu et al., 2017).
Working with a spirit of cooperation and reciprocity, which involves understanding and respect for different ideas and hypotheses	USUALLY NOT - Dimension Stone companies are almost all Small and Medium Enterprises (SME); although they are often too small if compared to the size of the problems that require of being addressed, there is a wide lack of interest in creating partnerships (Careddu et al., 2017).
Respecting natural processes and phenomena, where possible, when planning and implementing interventions in the environment	YES, BUT NOT ALWAYS In the developed countries, companies are pushed to follow regulatory frameworks and, when required, to submit an Environmental Impact Study to minimize the environmental and social impact of activities. In the developing countries, the lack of strong legal frameworks and high level of corruption can lead to cases of irresponsible activities toward local human communities and the environment
Protecting geodiversity as an essential aspect of the development of life and biodiversity, cultural and social diversity, and the sustainable development of communities	YES, BUT NOT ALWAYS As explained in the previous point, it depends on the environmental and mining law adopted by each country. There are valuable examples of dimension stone activities. In several cases, geoparks show how the co-existence of mining/quarrying activities with the local geo- and bio-environment conservation can lead to virtuous examples of responsible development.
Enhancing geoheritage, which brings together scientific and cultural factors that have intrinsic social and economic value, to strengthen the sense of belonging of people for their environment	YES, BUT NOT ALWAYS As indicated in the Introduction, companies which are involved in the production of a "GSHR recognized stone" might have some potential commercial benefits arising from GHSR designation.
Ensuring sustainability of economic and social activities in order to assure future generations' supply of energy and other natural resources	USUALLY NOT "robbery mining/quarrying" should be internationally banned. Responsible mining/quarrying is always more in the agenda of big companies, but more needs to be done in the case of medium to small ones.

economic benefits, risks for the safety of local residents, and the minimization of impact on ecosystems and landscape.

A good example is the mining legislation of the Italian region Valle d'Aosta (C.R. Valle d'Aosta, 2008); the article n. 3, specifies how to pursue the objective of making the needs of a sustainable mining compatible with those of environmental safeguarding.

Entrepreneurs (or more generally companies) should be more aware that social respectability and environmental credibility are industrial assets of modern times. Even if economical profit remains their main goal, this cannot be achieved without respectful and responsible behaviour, that follows (geo)ethical values, toward local communities and lands, the result of a compromise between the operating space and social acceptance (Table 3).

Mass-media should not create alarm every time a mine/quarry is going to be open, or worse, when only the exploration phase is meant to happen (in most cases, "exploration" is regarded as a synonym of exploitation): media cannot forget, they should have the duty to inform citizens in the sake of transparency and, as much as possible, impartiality, based on proven scientific information. In this perspective, they should incentivize companies and decision-makers to produce convincing scientific data which can support decisions.

Professionals have to support decision-makers with environmental and socio-friendly solutions that are able to guarantee adequate levels of safety for the environment and people, while respecting laws and regulations. Their fundamental role is to provide a link between geoscience theory and practice in activities which are meant to impact a territory.

Citizens have the right to receive an adequate level of information on pro and cons about mining projects and to be involved in the decision-making process, but at the same time they have the duty to search for information based on reliable scientific and technical data. They

should avoid evaluating a project only on the base of irrational and groundless fears.

A strong cooperation among all these actors is necessary to guarantee a (geo)ethical approach to mining/quarrying activities.

5. Conclusion

This paper argues that geoethical values as stated in the Cape Town Statement on Geoethics and in the Geoethical Promise, should be strongly introduced even in the Dimension Stone Industry, especially considering that this economic sector has been greatly increasing its activities. Companies and geoscientists working for them need to raise their ethical profile and implement responsible practice if they want to assure social respectability and environmental credibility to the sector.

The Sardinia case is meant to show how many delicate topics can be directly and/or indirectly involved in the Dimension Stone industry: sustainable development, geoheritage, geotourism, relationships with local populations and traditions, corporate responsibility.

(Geo)ethical matters involved in the Dimension Stone sector are numerous, and this paper, far from presenting an exhaustive and detailed lists of them, have had the goal to be a first attempt to highlight some of the ethical issues involved in order to stimulate a more articulated and in-depth analysis.

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