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Procedure for evaluation of the attractiveness of the quarries' landscape

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ABSTRACT

Post-mining workings, especially after the exploitation of the rocks, become attractive mainly because of their landscape forms. These new forms of landscape can be an important element of tourist interest, and can cause the regional tourist revival. Quarries, as a quite specific forms, may, however, be received by individuals, as more or less attractive. The existing methods of landscape attractiveness evaluation cannot be directly applied to assess the attractiveness of abandoned quarries without the introduction of some partial criteria. The article attempts to present the methodological basis of the procedure for evaluating the attractiveness of the landscape of the quarries by setting new criteria for such an assessment. To do this, the method of semantic differential, called the Osgood's Method, was used, as well as principles of entropy and point bonitation. The evaluation of the attractiveness of the quarries' landscape consists of the results of these methods. On such basis, four classes of the attractiveness of the landscape of abandoned quarries have been defined.

Keywords: mining, quarry, landscape, attractiveness, evaluation, rocks exploitation.

INTRODUCTION

During the mining activity, quarries are mainly associated with a negative influence on the environment. The situation changes after the mine has closed when interesting and sometimes even extraordinary geological structures are revealed. Much later, one can notice precious species of fauna or flora settling in a place of that kind. The quarries also happen to be attractive with regard to morphologically differentiated landscape (Chwastek et al., 1998). Therefore, one can consider them in terms of the combination of natural and cultural (industrial) values and post-industrial tourism. One can also assume that rock mining gives one a possibility of creating, shaping and perceiving the landscape. Therefore, the landscape of a quarry should be discussed since it forms a separate unit characterised by separate natural conditions and features. However, former quarries may be perceived by individuals as more or less attractive, therefore, there is a need of analysing the attractiveness these specific places after the mining has ceased.

The literature gives numerous examples of attempts of analysing land attractiveness after mining has been completed (Kruczek, 2011; Nowacki, 2007; Shoval & Raveh, 2003; Lew, 1987); still, sometimes they are lacking a clear distinction between post-mining areas and quarries which are characterised by different features and may perform different functions, locally significant from the human and natural perspective. What is more, quarries constitute a more durable environmental component than places after mining for sand and gravel, and thanks to harmonising with the surrounding landscape through interesting morphological forms, they become a specific flagship of a place. The studies on landscape quality or selection of the way of utilising post mining area with the use of different methods and analyses are different with regard to assessment, approach or education of experts conducting the research. Each landscape is an individual component and it should be approached as such; therefore, the previous methods have not been bearing the expected fruit. A lack of unified methods and treating other ones as experiments are the main reasons for the situation and this results from the difficulties with using measures of quantitative changes of qualitative assessments and, consequently, attributing numeric values to aesthetic sensations related to attractiveness (Eben Saleh, 2001). The aim of this article is to offer the method of assessing the attractiveness of areas after rock mining has been completed with the use of the procedure for evaluation of the attractiveness of quarries landscape.

ATTRACTIVENESS EVALUATION OF QUARRIES' LANDSCAPE

The existing methods of landscape evaluation cannot be directly applied to the quarries' attractiveness evaluation. Multi-step method to distinguish the types of tourist attractions, then the study a preference of tourists, evaluating the uniqueness of the given attraction and the analysis of its availability and location was proposed by Piperoglou (1966). Ferrario (1976) has applied a similar method by designating 22 types of tourist attractions. Geo-botanic methods of assessment used by Kostrowicki (1970) and Mazurski (1981) based on bonitation of natural attractions for the purposes of sightseeing tourism. In contrast, Lew (1987) had proposed the division of tourist attractions into following research perspectives: ideographic (description of a given attraction), organizational (in terms of location, size, tourist capacity, period of operation), and cognitive (the study of perception). To assess the natural attraction Saaty (1987) used a method of Hierarchical Analysis Process, based on a comparison of different groups of factors and giving the appropriate grade of importance to the analysed elements. Shoval and Raveh (2003) have applied a similar method but using variables such as the number and duration of visits or the analysis of tourists in terms of the number of stranger visitors in relation to the number of locals. All mentioned above methods study the tourist and natural attractions or they analyze the preferences of tourists. None of these methods at the same time does not take into account factors such as: the preference of society with respect to the assessment of attractiveness of the post-mining sites, their social acceptance, geomorphology, the state of preservation of the workings or the current progress of natural succession. Moreover, research using these methods were not organized on a large scale but only locally, and therefore they did not have so far nationwide application. Therefore, determining additional partial criteria and confronting them with the criteria of the existing methods seem to be essential as it will constitute the foundations for the procedure of attractiveness assessment of quarries' landscape. In order to achieve the assumed goal, the three following methods were used: (1) semantic differential, (2) assessment of a number of signals coming from the landscape through assessment of landscape entropy and (3) point evaluation. Modification of these three mentioned above methods by their respective complementation will be presented in details in the following chapters below.

SURVEY WITH THE USE OF SEMANTIC DIFFERENTIAL

This method is based on the assumption that the more surveyed people there are, the more similar mean value of independent evaluations to the objective assessment will be. The survey combined with a statistical analysis of the results constitute an important component of design works, and, especially, those connected with reclamation and development of a particular area; and using semantic differential for analysis and then evaluation of landscape attractiveness of the closed quarries will enable one to show preferences of the surveyed in relation to these areas and constitute one of the factors of the method used to evaluate quarries' attractiveness. What is more, an important aspect is the fact that this method enables one to consider a human factor in attractiveness evaluation and feelings towards a particular area.

The semantic differential is a type of a measuring scale used to assess connotations and means linking contents with a word by means of words established in social consiousness. This process was presented by Osgood (op. cit.) by means of a simplified model composed of three stages: I – stimulus which enters human consciousness and is recognised as a sign meaning a certain feeling to a particular individual; II – positive or negative word expression and comparing it to the current event; III – staying in or leaving a particular place, depending on positive or negative stress (Kowalczyk, 2004). The distinguishing feature of this method is a scale which outermost points are two antonyms: bad – good, inexpensive – expensive, useless – useful, etc. (Kruczek, 2011; Babbie, 2010; Osgood et al., 1957). Between them, there are several "in-between" categories marked with natural numbers by default. The analysis consists in drawing up a graphic profile which is formed by connecting numerical values obtained by an analysed structure with a line on each scale of evaluation (Steinberg and Jakobovits 1971, Kruczek 2011). In order to achieve that, one calculates the mean value for each pair of contrasting features and a synthetic index of the evaluation of a structure in a form of a mean value calculated for total evaluative features. Advantages of the scale are, most of all, easiness of communicating conclusions and a reliable measurement of intensity of attitude towards the analysed structure.

The results of the survey showed the mean evaluation of respondents for a particular quarry which can be assigned to six groups and then given points (Tab. 1).

EVALUATION OF A NUMBER OF SIGNALS COMING FROM THE LANDSCAPE THROUGH LANDSCAPE ENTROPY EVALUATION

Within this method, the landscape is perceived as a multisensory unit received by a human being with many senses which have various impacts on him/her. The notion of multisensory landscape was coined by Bartkowski in 1986 who in this way determined a psychological and geographical reality perceived with senses providing a set of signals becoming stimuli for receptors (Bartkowski, 1992; Bernat 2004). The occurrence of signals is determined by the structure and functioning of a landscape (Kowalczyk, 2004). Possible sources of signals coming from a quarry's landscape are received with the senses of sight, hearing, smell and touch. The most (80-90%) information is received by a human being with the sense of sight, and the rest (10-20%) with other senses

Tab. 1 Indicator of the mean evaluation of the surveyed

Mean of the surveyed	Points
from 2,00 to 1,30	5
from 1,29 to 0,60	4
from 0,59 to 0,10	3
from -0,09 to -0,60	2
from -0,61 to -1,30	1
from -1,31 to -2,00	0

(Młodowski, 1998). Therefore, the received signals can be divided into two groups: perceived with sight, and the one perceived with other senses.

This discussion assumed (Baczyńska, 2014) that a source may send 19 different (positive or negative) messages, hereinafter marked as 1,2……19 for the reasons of simplicity. It was assumed that messages are divided into two groups: I: 1-9 and II: 10-19. The occurrence of signals from group I is equally probable as in the case of group II. Messages 1-9 are equally probable while messages from II group form three equally probable subgroups: IIA (10-13), IIB (14-17), IIC (18,19). The probability of the occurrence of messages in groups IIA, IIB, IIC is assumed to be equal (Turski, 1989). The signals sent by a landscape are hereinafter referred to as notices. If the sent signal is received with a sight then one of 9 notices will take place, while when the signal form the second group appears, one of 10 notices will take place. This division is shown in Fig. 1.

Therefore, if there is notice P(1|2|3|4|5|6|7|8|9) then one of nine notices must take place, that is ¼, while when one of the notices from group II P(10|11|12|13|14|15|16|17|18|19) takes place it will be $^{1}/_{8}$. Additionally, one should assume that the landscape does not provide all the assumed signals, but some of them, which causes that this method can be used to evaluate a certain landscape. The probability of signals' occurrence is determined by the features of landscape components, that is, the assumed sources of signals. One may assume that a signal coming from certain components of landscape, with p probability, includes $k = \log_2(\frac{1}{2})$ co = - $\log_2 p$ of units of information. The applied assumptions show that when the discussed source sends only one message, which probability is 1, then it is $\log_2(\frac{1}{1}) = 0$. Therefore, if a landscape may send n signals - according to the provided example there are 19 with the probability of occurrence p_i, a $i = 1,2, \ldots n$ - then the weighted mean amount of information in messages coming from the landscape, that is, information entropy of the information source can be calculated from the following formula (Turski, 1989):

$$H = \sum_{i=1}^{n} p_i \log_2\left(\frac{1}{p_i}\right)$$

On the basis of entropy analysis one can distinguish three types of landscapes and decide whether the potential landscape will turn out attractive to the tourists and encourage them to come again with regard to a number of stimuli occurring there. The closer to 0 the entropy rate is, the less emotions it elicits so one can assume it is less attractive. The suggested distribution of points could be as follows: Strongly stimulus landscapes over 6.00 – 2, moderately stimulus landscapes from 6.00 to 3.00 – 1, little stimulus landscapes below 3.00 – 0.

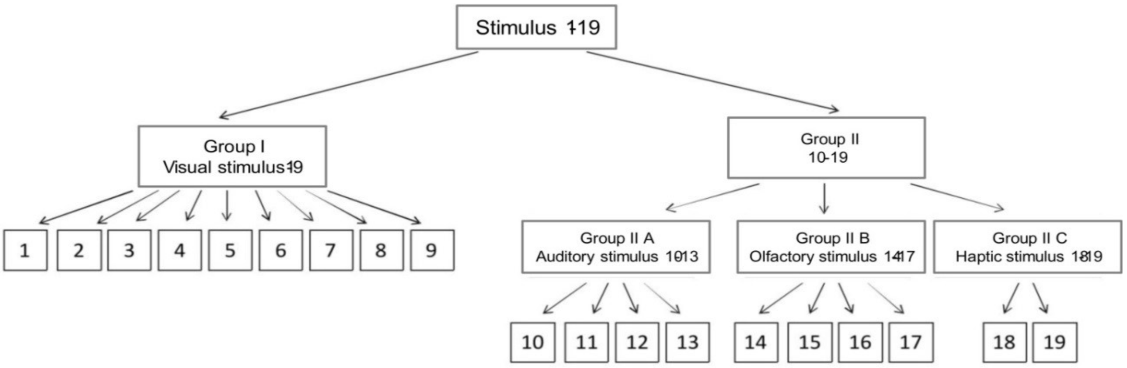

Fig. 1 Division of notices (after Kowalczyk, 2004)

Point evaluation method

The aim of this analysis is to distinguish components of natural and anthropogenic environments, which are carriers of possible values, from the area of a quarry's landscape, and determine their attractiveness. In order to achieve that we offer to conduct analysis by means of point evaluation method based on the works of Bartkowski (1986), Śleszyński (1999), Dubel (2000), Bezkowska (2005). This uses an evaluation scale which shows a relation between the assumed natural or landscape variable and a number of points (Kożuchowski, 2005). Usually, the points are given to some conventional areas which are interiors of quarries. However, with regard to different sizes of quarries, this method has been modified, otherwise there was a possibility that a bigger quarry would receive more points and a very attractive quarry (with regard to its structure, profile exposures, etc.) would receive few points due to its small area. Therefore, there was an additional assumption concerning a narrowed-down understanding of area attractiveness excluding tourist infrastructure and negative environmental impact resulting from tourist use.

What is more, this method assumed the following criteria forming the basis for classificaton and evaluation of physio-geographical phenomena. These are:

- **vertical differentiation of the area** – indicator influencing values of a particular area, determining a flexible value and utility in relation to different activities. On the basis of height differences calculated from the centre of a quarry, the particular heights are assigned to pre-determined factor values: over 25 m – 5 points, 21-25 m – 4 points, 16-20 m – 3 points, 10-15 m – 2, 5-10 m – 1 point, below 5 m – 0 points.
  If there are considerable height differences occurring in a quarry (different height at every wall), we offer to calculate a point value from the following formula:

$$W_p \frac{(P_1\ x\ T_1\ x\ P_2\, x\, T_2\, x\ P_n\ x\ T_n)}{100}$$

where:

W_p – indicator of vertical differentiation of the quarry
P_n – percentage of quarry slope area of certain n height
T_n – point predictor of vertical differentiation of the area of n type

- **percentage of natural succession** – it was assumed that the quarries with strong natural succession should obtain a small number of points since the vegetation covers interesting morphological forms developed as the result of mineral mining: below 10% – 5, 10-29% – 4, 30-49% – 3, 50-69 % – 2, 70-89% – 1, 90-100% – 0 point.
- **state of quarry preservation** – well-preserved quarries of low natural succession and with interesting geological exposures will be components of particular tourist interest: good – 2 points, average – 1 point, bad – 0 point.
- **boundary contrasts for particular types of land cover** – quarries with strong natural succession demonstrate little contrast in relation to adjacent areas (forests, fields, pasturelands, meadows), and the tourist will find a more contrasting area more attractive (Tab. 2).

If one quarry borders with many types of adjacent areas, the points were awarded according to the formula:

$$W_k = \frac{(L_1\ x\ K_1 + L_2\ x\ K_2 + L_n\ x\ K_n)}{100}$$

where:

W_k – indicator of boundary contrasts
L_n – percentage of the area bordering with n-type area
K_n – point-indicator of contrasts for the border with n-type area

Tab. 2 Indicator of boundary contrasts for particular types of land cover

Dominating type of adjacent lands cover	Dominating type of quarry land cover			
	trees	shrub-like vegetation	grasslands	slight traces of natural succession
trees	0	1	2	3
shrub-like vegetation	1	0	1	3
grasslands	2	1	0	3
other contrast land cover	3	3	3	3

- **number of adjacent area types** – depending on a number of area types adjacent to the quarry, the points are as follows: 3 and more – 3 points, 2 – 2 points, 1 – 1 point, lack of differences between the quarry and adjacent area – 0 points.
- **presence of surface waters** – the tourist will be more attracted to areas with surface water thanks to a wider range of possibilities making the place more attractive with regard to tourism (Tab. 3).
- **Road and tourist routes accessibility** – the better accessibility to the quarry the more points are given: good – 2, average – 1, Very aggravated – 0.

Tab. 3 Indicator of presence of surface waters

Presence of surface waters	Points
entire quarry interior	4
close vicinity of a huge reservoir	3
huge reservoir making 40-60% of quarry area	2
small reservoir making 10-30% of quarry area	1
lack of surface waters	0

Additionally, this method offers giving 1 point if the quarry has a form of nature conservation established since this can have a considerable influence on tourists' willingness to visit the quarry and frequency of the visits. What is more, the research study should take a negative anthropological factor into account which can have a considerable influence on the perception and evaluation of a particular quarry. Each analysed structure within which one notices the presence of disfiguring anthropogenic structures should be given a negative point (-1 point). A similar situation should take place in the case of structures located at busy streets or operating processing plants.

Procedure for evaluation of the attractiveness of quarries' landscape

The procedure for evaluation of the attractiveness of quarries' landscape consists in the results of the above-mentioned evaluation criteria:

- Indicator of the mean evaluation of the surveyed;
- The entropy rate;
- evaluation criteria selected and assessed with the use of point evaluation.

Total evaluation of the particular criteria can be expressed the following way:

$$AKK = (W_p + W_{sn} + W_{sz} + W_k + W_g + W_w + W_d + W_a + W_e + W_o) - W_n$$

where:

AKK – attractiveness of quarry's landscape

W_p – indicator of vertical differentiation

W_{sn} – indicator of percentage of natural succession

W_{sz} – indicator of state of quarry preservation

W_k – indicator of boundary contrasts

W_g – indicator of a number of adjacent area types

W_w – indicator of presence of surface waters

W_d – indicator of road and tourist routes accessibility

W_a – indicator of the evaluation of the surveyed

W_e – indicator of entropy evaluation

W_o – indicator of legally protected areas

W_n – indicator of unfavourable human impact

As the result of using the offered procedure, four qualification groups are offered concerning attractiveness of the abandoned quarries' landscape (Tab. 4). The point scale was determined on the basis of the research on the abandoned quarries carried out in Poland, Austria and Great Britain (Baczyńska, 2014; Baczyńska et al., in press).

EXAMPLES OF APPLYING THE PROCEDURE FOR EVALUATION OF THE ATTRACTIVENESS OF THE ABANDONED QUARRIES' LANDSCAPE

In order to show the procedure for evaluation of the quarries' landscape attractiveness, two extremely different quarries were selected. Białe Krowy gabbro quarry with area of 3000 m^2 is located on the slope of Sadno natural elevation which is 230 m high and situated within Ślęża Landscape Park in the South West Poland. The abundance of trees and shrubs as well as road infrastructure are considerably impeding access to the quarry (Fig. 2). Winspit limestone quarry is located at Jurassic Coast in Dorset, Great Britain. It covers the area of approximately 10000 m^2; road accessibility is good and the structure itself in protected by the National Trust (Fig 3).

The first stage of the research was conducting a survey which comprised seven questions concerning associations with the "quarry" word, frequency of visits, distance to be travelled by the surveyed to use the area of the abandoned quarry and determination of the values through evaluating the attractiveness on the basis of choosing negative or positive features. On the basis of the answers of the surveyed concerning evaluative features, the polarised graphic profiles were drawn up (Figs. 4, 5). Next research stages consisted in evaluation of entropy of information sources concerning the particular quarries and application of the point evaluation which results were shown in Table 5.

The analysis of the results showed that

Tab. 4 Qualification groups for the attractiveness of abandoned quarries' landscape

Group	Qualification categories	Total points
I	Very attractive quarry landscape	over 24
II	Attractive quarry landscape	from 24.00 to 16.00
III	Little attractive quarry landscape	from 15.99 to 8.00
IV	Unattractive quarry landscape	below 8

Fig. 2 Białe Krowy quarry

Fig. 3 Winspit quarry

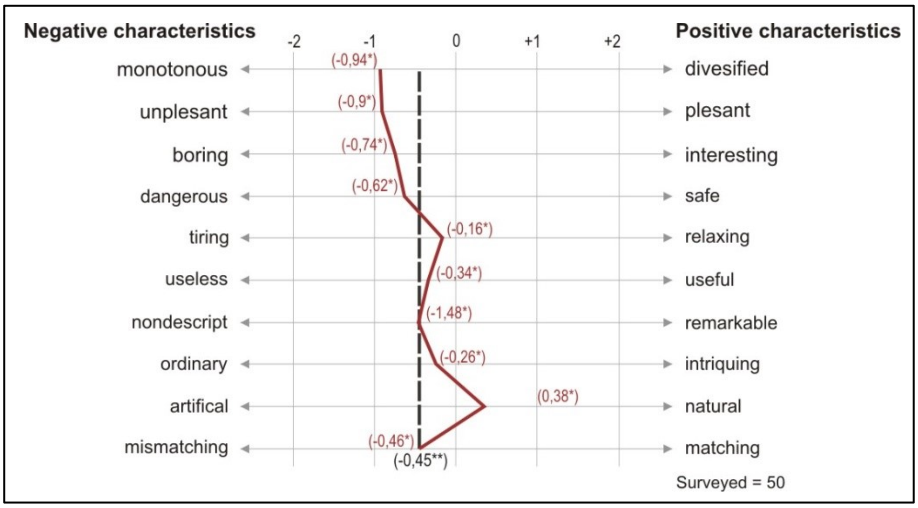

Fig. 4 Polarised profile of the evaluative characteristics of the Białe Krowy quarry

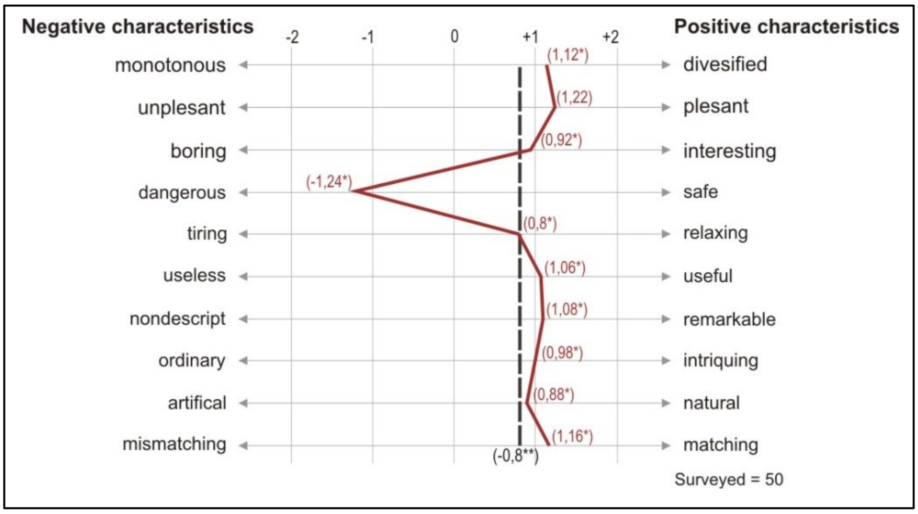

Fig. 5 Polarised profile of the evaluative characteristics of the Winspit quarry

Tab. 5 Detailed results of the evaluation of the landscape attractiveness of the abandoned quarries

Evaluation criteria	**Białe Krowy quarry**	**Winspit quarry**
Vertical differentiation	0	4
Natural succession	0	5
Preservation state	0	2
Contrast	0	2,25
Neighbouring lands	0	2
Surface waters	0	3
Accessibility	0	2
Evaluation by the surveyed	2	4
Entropy evaluation	0	2
Protected areas	+1	+1
Unfavourable impact	-1	-
Total	2,0	27,25

the exemplary gabbro quarry, Białe Krowy, was qualified to IV group of landscape attractiveness (below 8 points) and is little attractive with regard to considerable natural succession and impeded accessibility. On the other hand, great landscape attractiveness of Winspit limestone quarry (I group of landscape attractiveness qualification of the abandoned quarries – over 24 points) results from great vertical differentiation, good preservation state, low natural succession, high contrast, good accessibility and the fact of legal protection.

CONCLUSIONS

The offered procedure for evaluation of the abandoned quarries' landscape attractiveness was established through confronting it with the criteria of the existing methods and determining additional partial criteria. The result of the total evaluation of the particular criteria is qualification of the particular structure to one of the four qualification groups (I-IV). The quarries from I group are characterised with great landscape attractiveness thanks to: great vertical differentiation, high contrasts in relation to the adjacent areas and the location within the areas legally protected. They are also described with the highest entropy rate which makes the be perceived as highly stimulating structures. On the other hand, unattractive quarries are qualified as group IV and characterised by the lowest parameters. They have small vertical differences, preservation state is very bad, natural succession is considerable, they do not have road access and are not characterised with contrasts so they are hardly noticed. The quarries characterised by landscape attractiveness (group II) usually show lower vertical differentiation than in group I, natural succession slightly covers some valuable and interesting geological profiles, and road accessibility is good. In case of little attractive quarries (group III), there are structures incorporating elements influencing the evaluation as: small height differences, impeded access due to natural succession, no surface waters, and no contrasts in relation to adjacent areas.

As a result, the application of the offered procedure enables one to determine the level of attractiveness of the abandoned quarries and show whether they create new values which could constitute e.g. an important element of tourist, recreational or educational interest. To show the potential of the quarries can encourage the use of such sites by arranging there special events, concerts, art-exhibitions, etc. Moreover, these very special areas can be used for popular social education, being a good didactic place, that could be a part of programme of various kinds of trips, including those focused on education. Such a way of development will be associated with the large-scale promotion of the quarries' landscape values, release of the popular guide-book, information booklet and proper signposting of these sites as both tourist- and/or geo-sites. Another option is to create a trail of old quarries along with explanation of the rock exploitation process, extracting techniques and tools, etc., as it was successfully done and fully accepted by tourists in Adnet region (Austria). It is worth noting that such objects are testimony to the rich mining history of the area, becoming at the same time, historical heritage of the region.

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Unveil the traces of ancient mining

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ABSTRACT
The Archaeological Mines Park of San Silvestro is part of the Campiglia mining area. It represents its most important historical core. The Park covers a surface of around 450 hectares on the mountains Calvi, Rombolo, Poggio all'Aione and along the valleys Temperino, Lanzi and Manienti. The main characteristic of the Park is the richness of mining activity traces towards copper, lead and silver. The mining activity started during the 7th century BC with the Etruscan civilization and continued until 1979, when the last mine was closed. Many karst cavities of the Campiglia are "cave-mines': they are the result of a natural event and the action of ancient miners, who searched metalliferous minerals. In Campiglia there are traces of hundreds of Etruscan, medieval and modern mining operations, tunnels from the 19th and 20th centuries. The aim of the Archaeological and Mining park of San Silvestro is to highlight historical landscape, the result of centuries of mining activities. Some of the buildings, originally used for productive and administrative purposes, have been restored to house exhibitions and services for visitors. The impressive ruins of the medieval village of San Silvestro and two of the modern mining tunnels, have been equipped for guided tours. The accessibility of ancient mining works is however still difficult and this represents a limit in the enhancement and protection of these sites. Speleologists, archaeologists and geologists will be involved in making a project to let everyone discover the most ancient underground mines. We have three main targets: (1) produce high quality pictures of the most interesting and impressive mining traces; (2) create 3D models useful for scientific and cultural purposes; (3) equip some of the ancient shafts with light structures to allow small groups to visit them. We will describe the morphological characteristics of one of these ancient mines, giving some advice for the production of high quality picture in this contest. We will also describe the technique used for the production of a 3D model and how to equip the mine for the visit of small groups of people.

Keywords: mines, Etruscans, Middle Age, research, tourism, accessibility

INTRODUCTION

The Archaeological Mines Park of San Silvestro is located in the southern part of Tuscany, in front of Elba Island. It represents the most important historical core of the Campiglia mining area. The Park covers a surface of around 450 hectares on the mountains Calvi, Rombolo, Poggio all'Aione and along the valleys Temperino, Lanzi and Manienti (Fig. 1). The main characteristic of the Park is the richness of mining activity traces towards copper, lead and silver. The mining activity started during the 7th century BC with the Etruscan civilization and continued until 1979, when the last mine was closed.

During the Etruscan period and the Middle Age, ores were mined by the simple method of "following the veins". Miners started searching from the surface, then followed the vein widening the excavation when they met interesting concentrations of metals.

Rocca San Silvestro, where miners and smiths lived during the Middle age, was

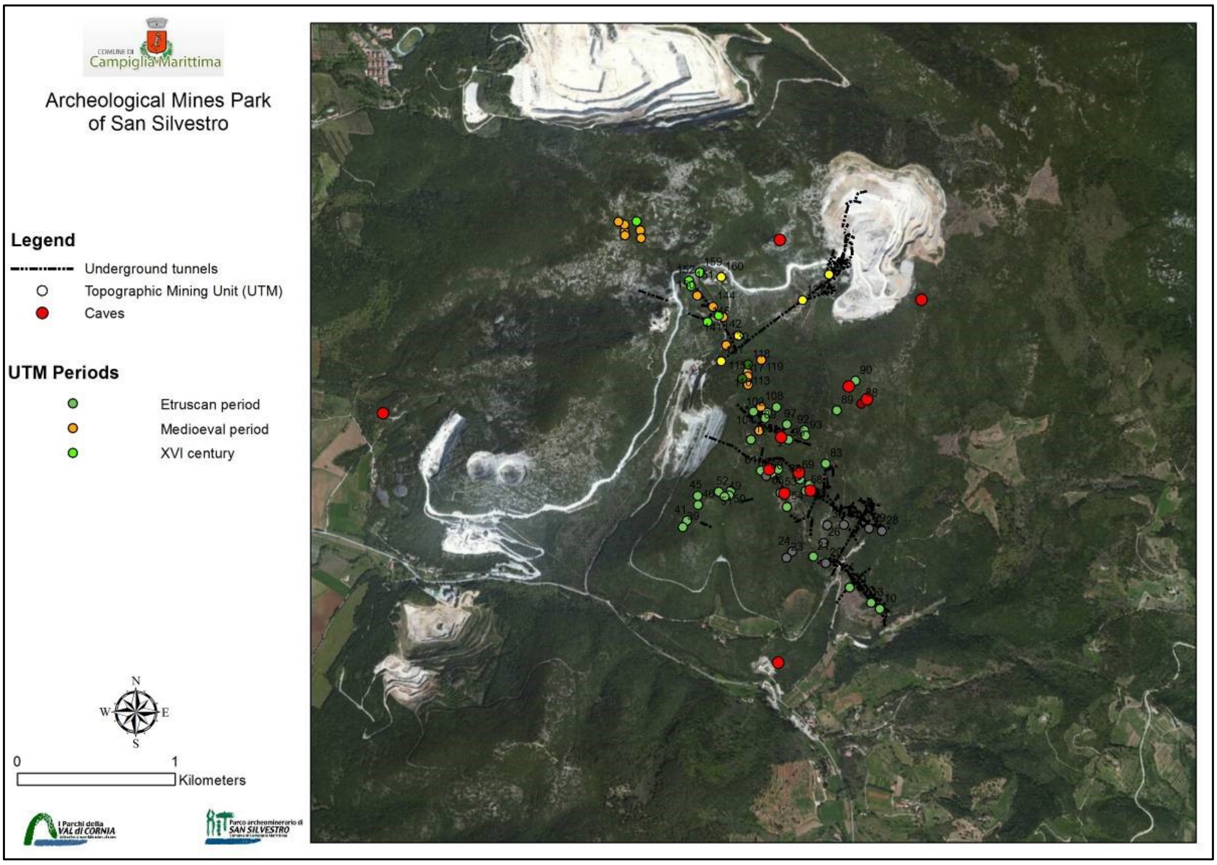

Fig. 1 The San Silvestro Park area. Colored points indicate the location of the ancient Topographic Mining Units (UTM)

abandoned in the second half of the 14th century. Mining activity started again, for a short time, between 1549 and 1559. Skilled workers coming from Carinthia and from Tyrol were called by Cosimo I de' Medici for their renowned experience. The 16th century mining technique was to dig out opencast mines that frequently cut across the workings of the previous age. During the 17th and 18th century, mining activities were sporadics. In the first half of the 19th century scientific interest in the Campiglia area was sharpened. French companies first and then English societies achieved mining claims. Tunnels were excavated on several levels connected by shafts due to upgraded skills and more advanced tools. They were used for the transport of miners and minerals. New excavations were always restarted from the previous ones; this gave privileged access to deeper ores or to finish the exploitation of metal bearing rocks identified in earlier times (Semplici, 2011).

In the Park, it is possible to visit two mining tunnels excavated between the middle of the 19th century and the 60's of the 20th century. The Temperino tunnel was excavated to check out ancient diggings. During the visit, you can see some of them. In the Lanzi-Temperino tunnel, you can observe mining works and equipment of the 20th century. The paths of the Park allow a view of the main curiosities of mining archaeology in the area, from the openings of the ancient and medieval mines to the 16th century quarries, from the remains of old extraction shafts to modern tunnels. Nevertheless ancient diggings had not yet been enhanced enough. It's important to work on the accessibility of these diggings and to equip them for the visit, real or virtual. This work represents a first rating about the ancient diggings that could be restored and the methods to improve their cultural and physical accessibility. Buca della Faina, an ancient mine of the Park, is one of the easiest to be equipped for the visit, due to its small dimension and shape.

GEOLOGICAL SETTING

The Campiglia area is characterized by a N-S trending horst of Mesozoic carbonate rocks (Tuscan units), with the massive limestone outcropping widely. Its borders are high-angle faults that connect sediment of the Tuscan Nappe with the Jurassic Eocene Ligurian sediment (Fig. 2). In the Miocene, the southern part of Tuscany was interested by a widespread magmatism, with the emplacement of plutons, dikes and effusive products. The Campiglia carbonate horst was intruded by a monzogranite pluton (5.7 Ma; Borsi et al., 1967) cropping out at Botro ai Marmi and intercepted by borings till a depth of about 1000 mt below Monte Valerio. Circulation of hydrothermal fluids coming out from the granitic body is at the base of the formation of the distal Zn-Pb-Ag skarn deposits. Later a mafic porphyry was emplaced in the Temperino area; hydrothermal fluids released by this magma were responsible of the genesis of Zn-Pb-Cu-Ag skarn deposits of the Temperino mine (Dini et al., 2013; Vezzoni et al., 2016). A second felsic porphyry dike (Coquand dike) cross cutted the other magmatic and metasomatic rocks (Vezzoni, 2014).Magmatic activity ended with the effusion of rhyolitic products, outcropping to the west area of the carbonate horst (sanidine ^{40}Ar-^{39}Ar date of 4.38±0.04 Ma; Feldstein et al., 1994).

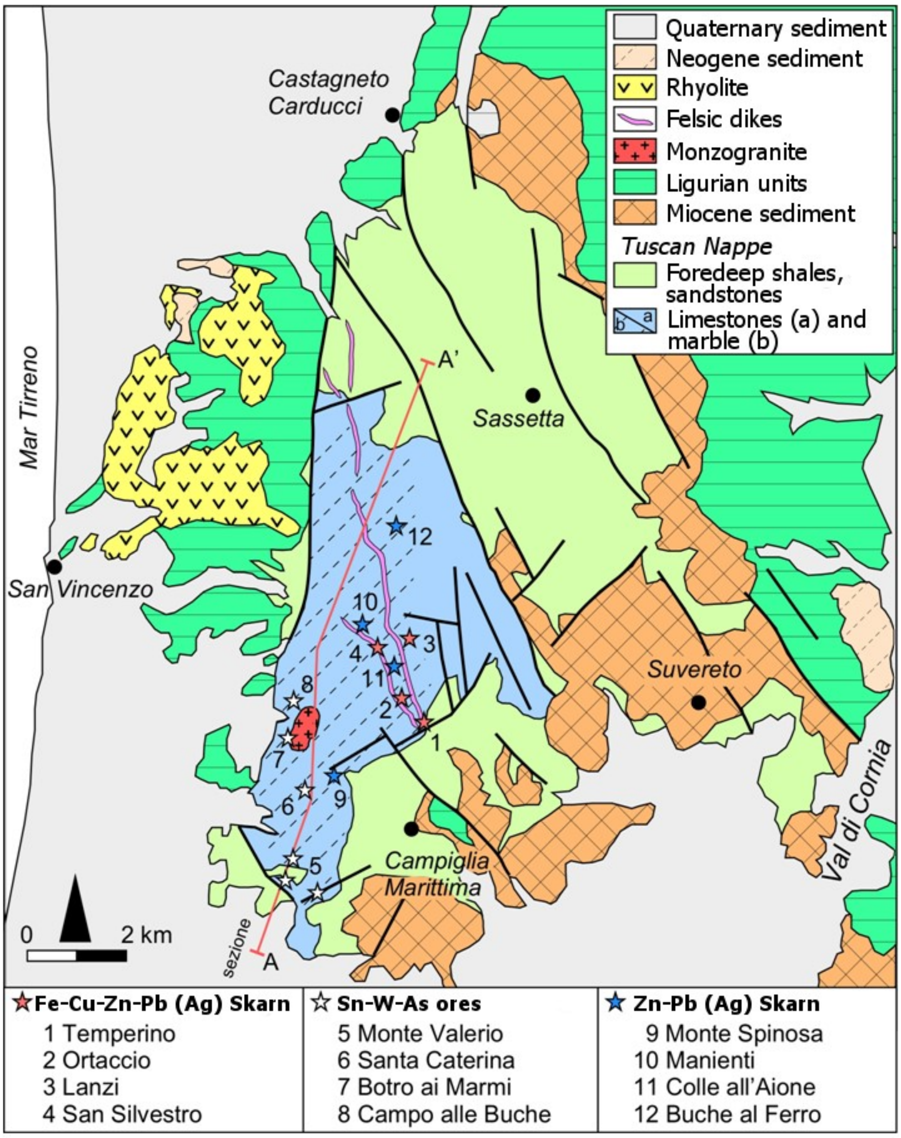

Fig. 2 Schematic geological map of the Campigliese area. (modified from Dini et al., 2013)

Skarn indicates a rock composed of calcium, magnesium and iron silicates. We refer to "skarn deposits" when they contain economically attractive concentrations of metal ores, such as magnetite or copper, lead, silver, zinc and iron sulphides. The skarn in the Temperino area is essentially composed of hedenbergite and ilvaite, in addition to quartz, calcite, epidote and johannsenite. It contains copper, lead and zinc sulphide, such as chalcopyrite, galena and sphalerite

In the Campiglia Hills there are lots of karst cavities, some of them surveyed in the "Catasto delle Cavità Naturali" of the "Federazione Speleologica Toscana". The cavities are mostly vertical due to the tectonic that conditioned the trend (Cascone, 1993). Karst cavities were used by ancient miners for underground explorations in the searching of ores. Some of them were enlarged, lengthened and cut by mining works during the Etruscan and Medieval period, using the technique of "following the veins" (Casini, 2001). For this reason these cavities, partly natural, partly artificial, are defined as cave-mines (Cascone, 1993). The entrance of several ancient mines was found in the Campiglia hills (Cascone & Casini, 1997; Cascone & Casini, 2001) (Fig. 1). The largest ancient mining complex inside the Park of San Silvestro is the one of Poggio all'Aione. This complex dates back to the 1st century B.C., owing to the finding of a piece of a DRESSEL 1 type amphora.

METHODOLOGY

The relief and the representation of natural or artificial underground cavities is difficult, owing to the complexity of the access, the darkness and the high humidity level. Production of a photographic documentation valuable from a scientific, archaeological and cultural point of view, needs to be well finished and meaningful as attestation.

In the preparation of the photographic set of an underground cavity, it could be useful to locate one or two people in different positions, in order to let the scale and the structure of the cavity. The right light positioning is an important aspect, essential to underline mining and archaeological features. The radiant light, for example, could emphasize shapes and colours, typical of the mining complex, as far as the ancient mining traces, artificial niches, galleries and tunnels.

A photographic documentation is moreover essential for the creation of 3D detailed models. These models could allow a virtual visit of the mining cavity, an efficient means in touristic, educational and didactic field.

The photogrammetry technique, used also in panoramic and architecture field, allow to rebuild a 3D model of an object, taking stereometric frames, in particular digital pictures.

Photogrammetry is the totality of all the analytic, graphic and optic processes with which we can reproduce an object or different projections of it. Stereographic pictures of the object should be taken from various positions, in order to have detailed documents of it and a base for the three-dimensional metric relief for 3D models.

This technique is particularly useful for the relief of narrow underground cavities, since the basic tools are a camera with flashlight and few lights. The modern laser scanner are not always suitable for the relief of narrow cavities, due to their size and weight.

THE BUCA DELLA FAINA, AN EXAMPLE OF AN ANCIENT CAVE-MINE

The *Buca della Faina* is one of the most ancient cave-mine of the Park. Its entrance is on the Via delle Ferruzze, one of the paths of the Park and can easily be reached by foot or by an off-road vehicle.

During the Etruscan period and the Middle Age, mineral prospecting in the

Campiglia area was carried out through the location and identification of outcrops of the oxidized part of the skarn deposits, usually made up of iron oxides and hydroxides and copper sulphate and carbonate.

Even the mafic and felsic porphyry, some of which strictly connected with the formation of the metalliferous ores, could be a useful clue to define the area from which to dig mining wells. The *Buca dell'Aquila,* another ancient mine located a few meters away from the *Buca della Faina,* was dug at the contact between porphyry and limestone.

Ancient miners sought iron ore, copper, lead, silver and tin. Excavation techniques were rather crude, since the available tools were picks, awls (with pyramidal and conical tips) and sledge hammers for manual use. Etruscan and Middle Age mines usually consist of a shaft, no more than one meter in diameter, and tiny tunnels, which followed an irregular winding course. The most highly oxidised mineralisation masses were crushed and sorted; the undesired material was accumulated at the bottom of the mine and only the material rich in metal was transported to the surface. Where mineralisation was more substantial, larger hollows were created.

At *Buca della Faina* ancient miners started their activity from a karst cavity, located near a small outcrop of oxidised skarn. They followed the vein underground through an artificial tunnel around 20 meters long and 1.60 meters wide. The cave-mine has an easy entrance, with a natural side, where stand beautiful flows of calcite. All along the irregular tunnel there are small excavation chambers and shafts, that connect the first level with other two lower levels.

Seven meters from the entrance it opens a small mineral search of 1 x 1 meter, which ends after four meters. A three meter deep well opens nine meters from the entrance, and continues in a 10-meter-long, one-meter-high tunnel, which in turn overlooks a well that connects the first and the second level tunnels with a tunnel at the third level, the lowest of the mine.

At 11 meters from the entrance a further deep well opens, continuing in the third level tunnel, five meters long and 0.80 meters high. The tunnel continues with a four meter jump and ends in an elongated excavation chamber of 2 x 2 x 9 meters. On the opposite side, the three meter well ends in another five meters high and four meters wide excavation chambers, from which two filled galleries leave. The last well opens 16 meters from the entrance, it is about seven meters deep and ends in an elongated shaped excavation chamber. This well is the only that allow to reach all levels.

The ancient mine was mainly dug in iron oxides and hydroxides, while copper minerals are visible only in limited areas. Gypsum is widespread in concretions and small crystals, and this could attest to the original presence of sulphides. On the walls of the artificial excavation, traces left by four different types of tips are still visible: conic big and small, pyramidal big and small. The tools used for the extraction were pickaxes, mallets and awls.

There are no traces of the use of fire, black powder, or explosives, a sign that the mine has not been used in the 19th and 20th century. Outside the mine there is a dump of ores, that begins at the entrance of the shaft, goes straight down the valley and is crossed by the path.

RESULTS

The protection and the valorisation of a cultural site depend from its physical and cultural accessibility. The visitors cannot understand and appreciate the cultural site without evidences and documents. Where the physical access is complicated, photography can be used as a first enhancing tool. A picture can explain and communicate if it represents of the context.

A picture truly represents the context if the photographer has technical competence and scientific knowledge of it.

The Fig. 3 and the Fig. 4 are pictures taken for this purpouse. The first was taken at the entrance of Buca della Faina and allows to evaluate physical accessibility and dimension of the entrance.

The second picture was taken inside the mine, at the cross point of two shafts. It allows describing dimensions, structure and geological nature of this part of the mine. The picture emphasizes the colours typical of the iron oxides present in the most superficial part of skarn deposits.

3D models created by means of photogrammetry technique, could allow to have a detailed view of the excavated area, and highlight the volumes, the shapes and excavation technical features.

Three-dimensional model and detailed reliefs are extremely important for the protection of the underground mining sites and useful from a scientific point of view, for example to calculate the different volumes of the ores extracted. The three-dimensional relief could also be used for virtual 3D guided tour. Two of the ancient mines of the Park have been selected for the realization of a 3D model: Buca della Faina and the Manienti medieval mine.

One example of the enhancement of underground cavities is the 3D virtual tour realized inside the Grotta di Gianninoni, in the Parco della Maremma. Inside this cave were found the remains of an Ursus Spelaeus. This is the link to see the video http://youtu.be/PA42RvlYxCI.

It could be very important, where possible, making ancient mines accessible. The Buca della Faina, is the easiest mine in the Park of San Silvestro to be equipped for the visit with small groups of people, followed by specialized guides.

The personal equipment necessary is a light suit, a helmet with front light and a light harness. Securing the site could be easy: steel ropes and cables anchored to the walls with pressure nails, few lights in the lower levels that let every part of the mine to be visible.

In the section part of the Buca della Faina there is the detail of the lights, the ladder and the denial of access (Fig. 5). Visitors will be assisted in the short downwards on the steel stepladder, with a security rope.

These few low environmental impact arrangements, could let the site of Buca

Fig. 3 The entrance of Buca della Faina (Photo by G. Dellavalle)

Fig. 4 The inside of Buca della Faina mine (Photo by G. Dellavalle)

della Faina visible, and allow tourists to appreciate the mining technique of the Etruscan and Medieval time.

CONCLUSIONS AND FUTURE PLANS

The Campiglia area is characterized by the traces of hundreds of Etruscan, medieval and modern mining operations, a medieval castle, 16th, 19th and 20th century buildings and mining infrastructures.

The aim of the Archaeological and Mining park of San Silvestro is the protection and the valorisation of this cultural site that results from centuries of mining activities. Some of the buildings, originally used for productive and administrative purposes, have been restored to house exhibitions and services for visitors. The impressive ruins of the medieval village of San Silvestro and two of the modern mining tunnels have been restored and equipped for guided tours.

The accessibility of ancient mining works is however still difficult and this represents a limit in the enhancement and protection of these sites. The Buca della Faina, an ancient cave-mine of the park, is one of the easiest site to be equipped for the visit of few people groups, thanks to the fact that it is quite easy to reach and small in size. The artificial ancient excavation, small galleries, niches, linking shafts between the three level of the mine are limited in length and not so steep. Securing the site could be easy and of minimum impact: steel ropes and cables anchored to the walls with pressure nails, few lights in the lower levels, that let every part of the mine to be visible. The personal equipment necessary for the visit is a light suit, a helmet with front light and a light harness.

A first guided tour test at the Buca della Faina was conducted on May 28, during the IX National Day of Mines. The test, attended by about fifteen people, proved that the visit is feasible up to the second level of the mine with the simple support of staff with speleological preparation. We got into the mine groups of four people, and in this way each group took about 30 minutes to do the visit.

The introduction of simple safety measures, such as those mentioned in the article, will allow not only to get to the

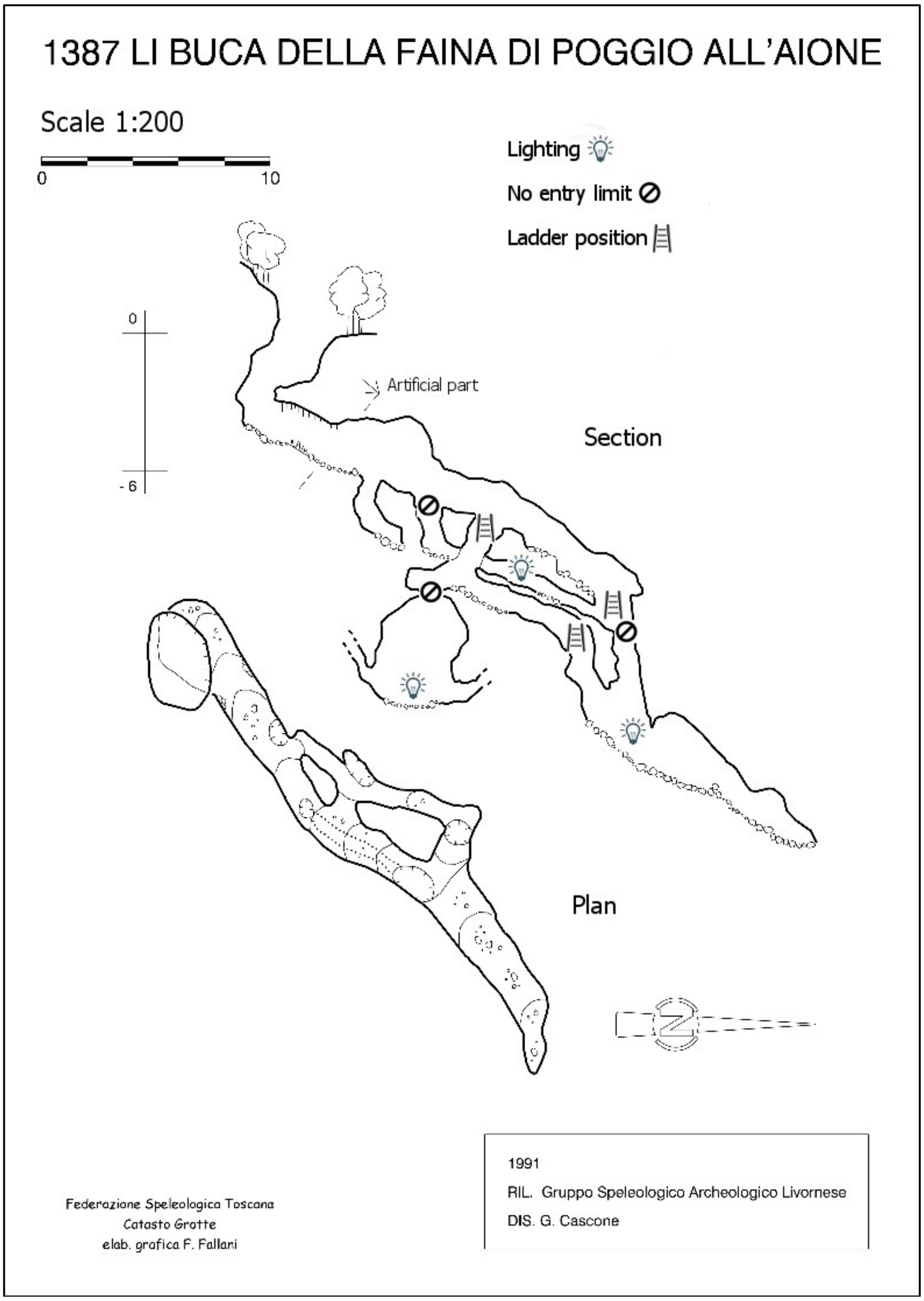

Fig. 5 Buca della Faina relief (Gruppo Spelelogico Archeologico Livornese). The detail of the lights, ladders and denial of access positions are indicated.

third level of the mine but to speed up the visit, although we believe that for the understanding of the site and its articulation it is necessary to spent at least 20 minutes into the mine. Starting from the entrance tothe Park, the time to walk to Faina's Buca entrance is about an hour. At least two guides are needed, one that follows the visit inside the mine and the other one that remains outside and deepens the archaeological-mining issues with the people who are waiting to enter.

We have evaluated that such visits, which can be organized by reservation, can be opened to groups of not more than 15 people, due to the necessary waiting time spent outside of the Buca della Faina. During the same day, more visit time frames may be scheduled, at least one hour and a half away from each other. The feedback we had on the visitors who took part in the tour on May 28 was definitely positive. The experience has been considered to be of a cultural and emotional point of view, involving the visitors in the discovery of such a complex and articulated mining context as the one that can be visited in the San Silvestro Park.

The other ancient mining works of the park, quite impossible to reach, could be enhanced with the production of detailed photographic material, 3D models, virtual guided tours, thematic guides and video. These material could be part of the visit of the Park and could be shared on the web.

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Identification of prospective geosites that show features of the active continental margin in eastern Kii Peninsula, Southwest Japan

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ABSTRACT

The eastern Kii Peninsula exhibits a variety of rock outcrops, fossils, and other geological features that illustrate the formation history of the Japanese Islands. This work aims to describe the geotourism potential of the region based on the significant rock exposures, and sets out the basis for establishing geosites in this region in the future. Geologically important sites have been selected, together with places of unique history and culture within the northern part of the eastern Kii Peninsula, including the Ise and Toba areas. The results of this study include a detailed description of the geology and history of the region, together with an evaluation of the relative value of each selected locality as a geosite. Proper development and promotion of the proposed sites would make the sites available for education and tourism, and provide opportunities for suitable development and the popularization of geological knowledge.

Key words: Kii Peninsula, Ise Jingu Grand Shrine, MTL, geosite

INTRODUCTION

The Japanese Islands were a part of the Asian continent until the opening of the Japan Sea during the Early–Middle Miocene (c. 20−15 Ma). This led to the development of the islands that currently form an active subduction-related arc–trench system at the junction of four major plates: the Pacific and Philippine Sea oceanic plates, and the Eurasian and North American continental plates. The complex geological history of the islands formation is reflected in a remarkable diversity of geological elements whose variety and character offer substantial potential for geotourism. Publication of the first list of 100 geosites in Japan has resulted in a great expansion of Japanese geoparks and a growing interest in geotourism. The current list includes 120 sites, with 43 areas in the country certified as national geoparks (JGN) in December 2016, 8 of which are also recognized members of the UNESCO Global Geopark Network (GGN).

Since the establishment of the JGN in 2008, a number of large disasters have damaged Japanese geopark areas; e.g., volcanic eruptions in Kirishima Geopark in 2011, and many landslides caused by heavy local rains in Aso Geopark in 2012 and in Izu-Oshima Geopark in 2013. The recent Kumamoto Earthquake damaged Aso Geopark in 2016. The Sanriku coastal areas of NE Japan were affected by the destructive tsunami caused by the 2011 Tohoku earthquake, and were subsequently incorporated into the Sanriku Geopark in 2013, which provides an excellent example of using the recognition afforded by geosites to assist with reconstruction and disaster prevention.

The eastern Kii Peninsula (Fig. 2) contains a range of geological features illustrative of an active continental margin formed by plate subduction, such as accretionary complexes and high-pressure metamorphic rocks, as well as offering outstanding local culture and historical elements. Increasing knowledge about the geology of the region may open new opportunities for geotourism development, with potential accompanying economic benefits. This paper aims to identify several significant locations for geosites in the Ise and Toba areas (Suzuki, 2014), and to determine the quality and accessibility of each site with respect to geotourism potential that is currently unfulfilled, with most of the significant geological sites being poorly known.

BRIEF GEOLOGICAL HISTORY OF THE JAPANESE ISLANDS

The core of Japan's basement geology developed from the off-scraping of sedimentary cover from oceanic plates subducting along the Asian continental margin over the past 500 Myr, resulting in the episodic development of accretionary complexes stepping progressively farther seaward over time. Phases of accretion are well preserved from the Permian, Jurassic, Cretaceous and Paleogene periods, alternating with episodes of tectonic erosion (Fig. 1; e.g.; Isozaki et al., 2011). Parts of the Paleozoic accretionary complexes were metamorphosed under high-P/T conditions to generate the metamorphic rocks of the Renge belt (~350−280 Ma; Tsujimori and Itaya 1999), the Suo belt (~220 Ma; Tsutsumi et al., 2000), and the Chizu belt (~180 Ma; Shibata and Nishimura, 1989). Cretaceous accretionary complexes were metamorphosed, forming the high P/T Sanbagawa belt in the Late Cretaceous (e.g., Miyashita and Itaya, 2002) and the highest-grade rocks in the Kamuikotan zone (145–100 Ma; Shibakusa and Itaya, 1992).

Subduction of the Izanagi-Kula and Pacific plates beneath the former eastern Asian continent (130−85 Ma) produced a large volume of granitic magma that intruded the pre-Cretaceous accretionary complexes and thermally metamorphosed surrounding rocks, forming the low-P/T metamorphic rocks of the Abukuma metamorphic belt (~110 Ma) and the Ryoke metamorphic belt (100−90 Ma; Suzuki, et al., 1996).

The Median Tectonic Line (MTL), a major fault zone separating the Ryoke and Sanbagawa metamorphic belts, formed initially as a normal fault that presumably affected the emplacement of older Ryoke granitic rocks (Okudaira and Suda, 2011) and juxtaposed the low-P/T Ryoke metamorphic belt against the high-P/T Sanbagawa belt at c. 60 Ma (Takagi et al. 2010). These two belts are commonly described as forming a paired metamorphic belt system (Miyashiro, 1961).

Cretaceous–Paleogene accretionary complexes are exposed in the Shimanto belt and in the eastern Hokkaido (Hidaka and Tokoro) belts. Back-arc spreading in the Shikoku Basin (19−15 Ma) caused the opening of the Japan Sea, accompanied by volcanism (e.g., Kano et al., 1991). Continued rifting of the Shikoku Basin during the Miocene led to eastward migration of the Philippine Sea plate, bringing the Izu–Bonin Arc into contact with central Honshu, with which it collided after c. 17 Ma (Sako and Hoshi, 2014). The spreading that formed the Japan Sea produced a 30°–40° anti-clockwise rotation of Northeast Japan (Hoshi and Takahashi, 1999) and clockwise rotation of Southwest Japan by ~45° to its present position at ~15 Ma, consistent with a 'double-door' model for the opening of the Japan Sea (Otofuji et al. 1994). Between these two blocks of the Japanese Islands, a large basin structure (*Fossa Magna*) developed, which was filled by a thick sequence of Neogene sediments and volcaniclastics. The Itoigawa–Shizuoka Tectonic Line (ISTL) is the western bounding fault of the *Fossa Magna* (e.g., Takeuchi, 2004).

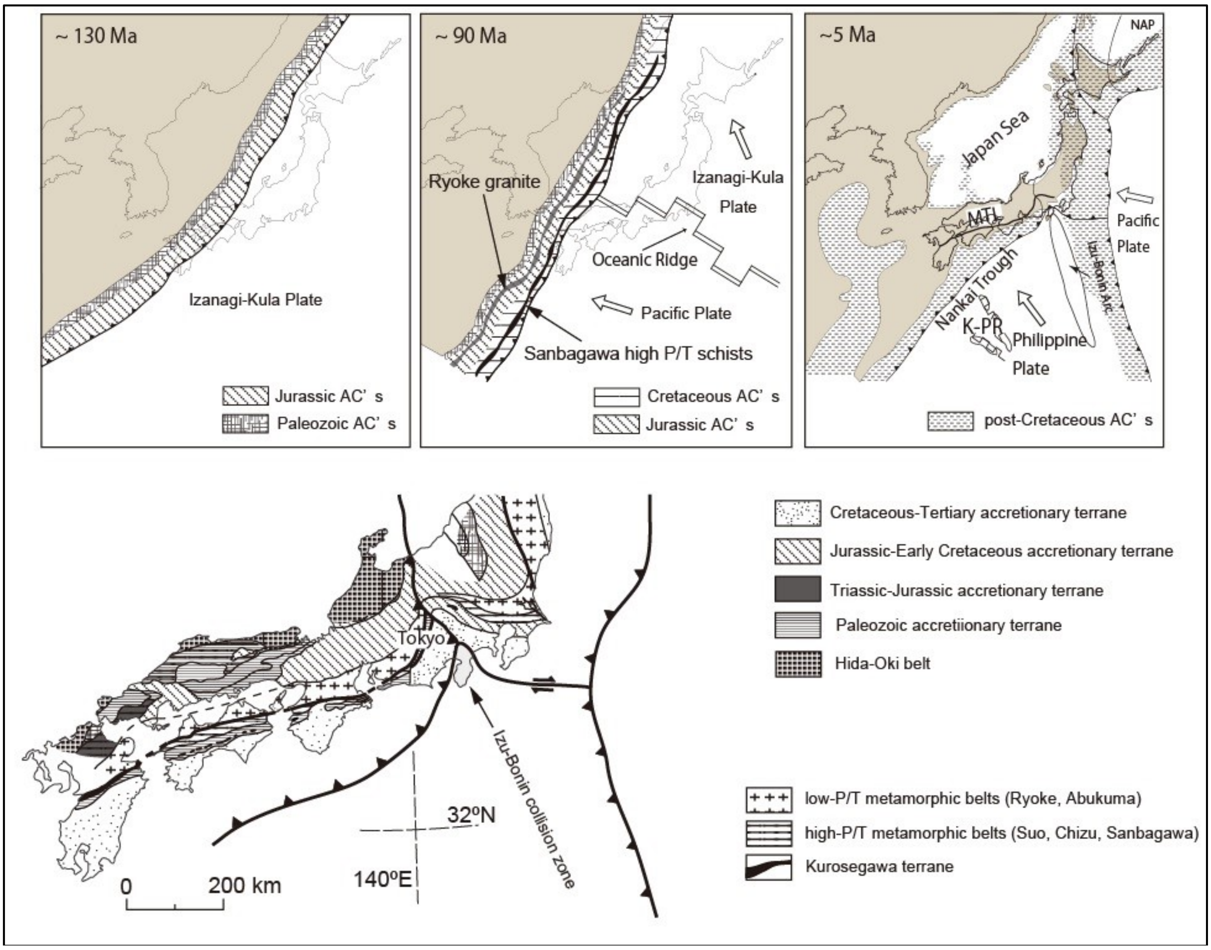

Fig. 1 Post-Jurassic tectonic development of the Japanese Islands (after Maruyama, 1997; Taira, 2001; Isozaki et al., 2011). AC: accretionary complex, ISTL: Ito–Shizuoka Tectonic Line, K-PR: Kyushu–Palau Ridge, MTL: Median Tectonic Line, NAP: North America Plate.

Since the Quaternary, the Japanese island arc system has been strongly compressed by westward to northwestward subduction of the Pacific plate and the Philippine Sea plate. Arc–arc collision and further accretion of the Izu–Bonin Arc to the Honshu arc after 15 Ma has resulted in intensive deformation of central Honshu (e.g., Takahashi, 1994). Deep subduction of the Philippine Sea plate at the Nankai Trough has formed a frontal accretionary prism to the Southwest Japan forearc (e.g., Hayman et al., 2012). The western side of the MTL is currently active, and accommodates dextral motion.

GEOLOGY OF THE STUDY AREA

The geology of Shima Peninsula located at the east side of Kii Peninsula, the northern and eastern parts of which are studied here, is a product of oceanic plate subduction. In this area, the eastward-trending belts of variably metamorphosed Jurassic–Cretaceous accretionary complexes and associated igneous rocks are dissected by faults, illustrating the dynamism of the formation of the Japanese Islands.

The Upper Cretaceous Ryoke granites in the north of this region are juxtaposed against schists of the Sanbagawa metamorphic belt along the Median Tectonic Line (MTL). The precise location of this ENE–WSW striking fault has recently been confirmed in the region (Suzuki et al., 2015). The surface trace of the MTL starts to bend gradually eastward as it crosses the peninsula into the Chubu region, as a result of the middle Miocene (c. 15 Ma) to recent collision of the Izu–Bonin arc with the Honshu arc.

The Sanbagawa metamorphic belt is distributed continuously across the region to the south as the Mikabu greenstone unit, which includes large ultramafic bodies. To the southeast of the Mikabu unit, the Chichibu belt, composed mainly of Jurassic accretionary complexes with Cretaceous forearc basin deposits, extends parallel to the MTL. These sedimentary sequences are divided into the Northern and Southern Chichibu belts by the Gokasho–Arashima Tectonic Line (G–A Line), a group of faults within serpentinite mélange. The G–A Line is considered to represent the extension of the Kurosegawa Terrane, which comprises lenticular bodies of pre-Jurassic sediments and metamorphic rocks with serpentinite (Saka et al., 1988). The southern margin of the Chichibu belt is defined by the Butsuzo Tectonic Line, along which the sedimentary sequences of the Chichibu belt are thrust over the Cretaceous Shimanto belt to the south (Kato & Saka, 2006).

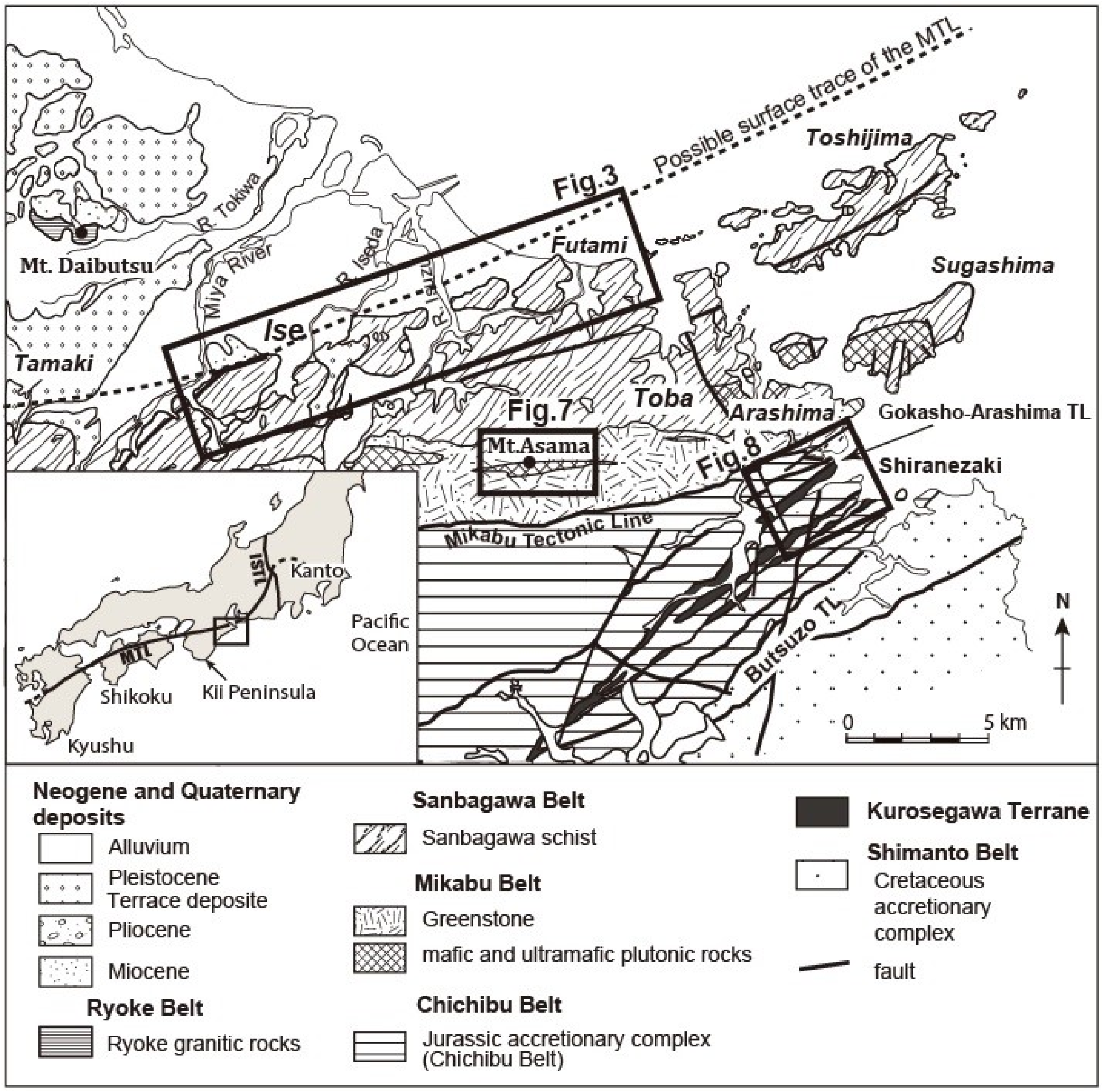

Fig. 2 Geological map of the Ise and Toba areas (compiled from the 1:200,000 geological map "Ise", after Nishioka et al., 2010).

METHODS

We identify and describe the most significant geological localities in the Ise and Toba areas in order to facilitate later discussion of their potential use as geosites, and their consequent transformation into geotourism destinations. The analyzed area can be divided into three principal domains: the Ise (Fig. 3), Mt. Asama (Fig. 7), and Arashima Coast areas (Figs. 8). Initial identification of prospective sites was based on a survey of literature describing the geomorphology and history of the Ise and Toba areas (references are given in the following sections), together with geological data collected from surface exposures to define a detailed distribution map of potential geosites. Each site of interest was then classified and evaluated using the method proposed by Suzuki and Takagi (2017), with a set of six main values (listed in detail in Table 1) assigned to every location, using a four-point (1 to 4) scale to, to determine which of their attributes are currently favorable for the establishment and promotion of a geosite, and which would need improvement. The results are displayed on radar graphs with axes corresponding to each of the six primary geosite attributes (Fig. 9).

GEKU SHRINE

Ise Grand Shrine is Japan’s holiest Shinto shrine complex, and is located in the most beautiful part of Ise City, surrounded by sacred mountains and forests. The buildings of the two main shrines of Naiku (Inner Shrine) and Geku (Outer Shrine) are examples of the pre-Budhist architectural style called *shinmei-zukuri*, characterized by extreme simplicity (Havens and Inoue, 2003). Both the main sanctuaries and the Uji Bridge in front of Naiku are rebuilt every 20 years during the *shikinen sengu* ceremony that was established over 1300 years ago. This ritual plays an important role in preserving and conveying the roots of Japanese culture to the next generation. Japanese people have made pilgrimages to the sacred sites on the Kii Peninsula since ancient times, using a series of trails today called Kumano Kodo, which is one of only two UNESCO World Heritage registered

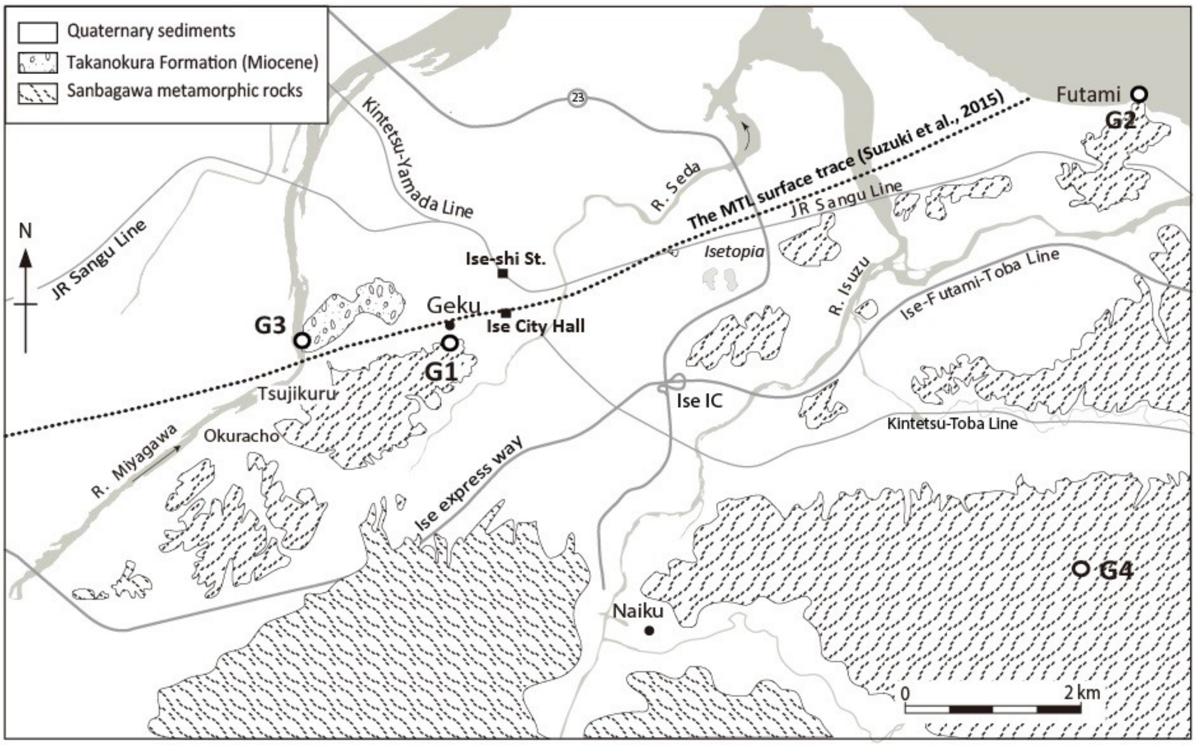

Fig. 3 Simplified geological map of the Ise city area along the MTL surface trace with location of proposed sites G1-G-4 (source: own research)

Tab. 1 Criteria for the evaluation of geosites (after Suzuki & Takagi, 2016).

Educational value (Ved)	**Scientific value (Scv)**	**Tourism value (Vtr)**
Ved$_1$: Ease of understanding the geosite's story	**Vsc$_1$**: Research significance	**Vti$_1$**: Emotional/aesthetic value such as beauty or impressiveness
Ved$_2$: Representativeness	**Vsc$_2$**: Clarity and up-to-date nature of the scientific story on information panels, guidebooks and web sites	**Vti$_2$**: Other natural/ anthropogenic values
Ved$_3$: Ease of understanding information panels at the geosite	**Vsc$_3$**: Rarity in the region	**Vti$_3$**: Other tourist attractions in the vicinity
Safety and Accessibility (Vsa)	**Conservation and site sustainability (Vcs)**	**Value of tourism information (Vti)**
Vsa$_1$: Safety condition of geosite and footpath access	**Vcs$_1$**: Current state of conservation	**Vti$_1$**: Information panels describing the approach to the geosite
Vsa$_2$: Travel time from the base (information) point to the area's attractions	**Vcs$_2$**: Legal protection	**Vti$_2$**: Geosite information on web sites, pamphlets, guidebooks, etc
Vsa$_3$: Walking time from bus/train stops or parking lot	**Vcs$_3$**: Site sustainability	**Vti$_3$**: International usefulness of information panels and web sites (multilingual)

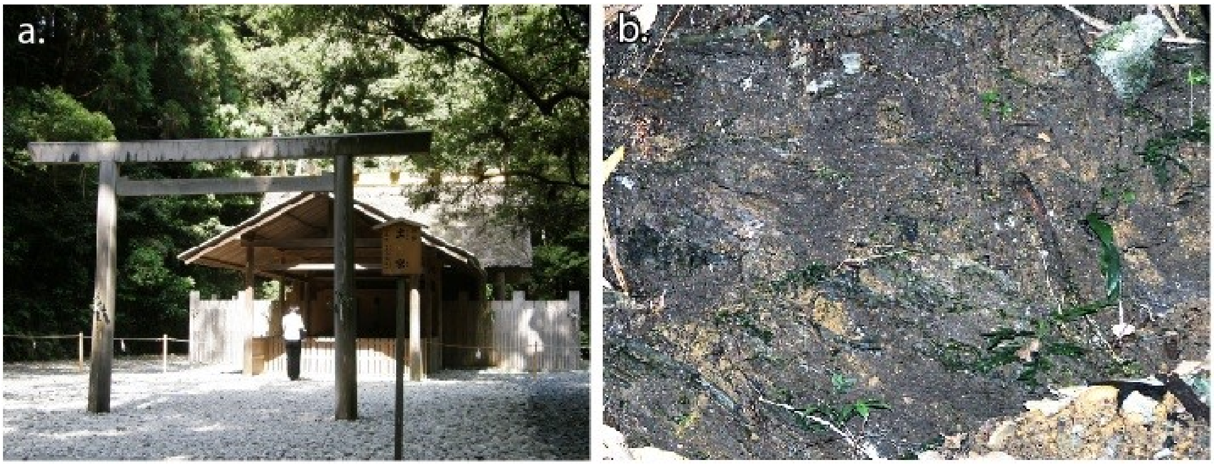

Fig. 4 Sanbagawa schist at the Geku Grand Shrine is exposed in (a) the hillside behind Tsuchinomiya Shrine, and (b) at Shimonomii Shrine where the MTL fault transects the area. (Photo by: H. Takagi)

pilgrimage routes in the world (Kumano Kodo Route official web site).

The Ise Shrine Naiku (formally known as *Kotai-jingu*) was originally built in the 4th century AD as a place to worship the Sun Goddess (*Amaterasu*), who is believed to be the ancestral spirit of the Imperial Family and guardian of Japan. The sanctuary stands along the Isuzu River in the foothills of Mt Shimaji and Mt Kamiji, which are densely covered with cedar and cypress trees. The Outer Shrine (*Toyouke-Daijingu*) was built several kilometers to the northwest in the 5th century AD to honor the Goddess of Agriculture and Industry (*Toyouke*). Its ancient buildings are situated at the northern foot of Mt Takakura in a sacred park of cedar trees (e.g. Rambelli, 2014; Ise Grand Shrine. Ancient History Encyclopedia, 2017).

In contrast to its history, the region's geology is poorly known to most visitors. The flat topography of the northern Isea area is characterized by a thick succession of Quaternary sediments several tens of meters deep, the thickness of which increases eastward. In the central part of this area, the Sanbagawa schists form mountainous topography, including Mt Takanokura near Geku Shrine. These rocks are composed mainly of pelitic schist and greenschist, with minor amounts of quartz schist, and are sporadically exposed near the MTL fault trace. To the south of the

Sanbagawa schist unit, the hills and mountains of Naiku territory are underlain by the Mikabu greenstones, transected by the Isuzu River.

MEOTO-IWA, ISE CITY

The Sanbagawa schist is well exposed along the coast of Futami Bay, where a pair of symbolic rocks, *Meoto-iwa* (Fig. 5), sits in front of Futami Okitama Shrine. These outcrops have been shaped over time by coastal erosion, and represent the northernmost exposure of the Sanbagawa metamorphic belt in Ise city. The *Meoto-iwa* (couple rocks) comprise well-preserved greenschist stacks displaying a distinctive schistosity. Further exposure of this lithology continues in front of the site, along the footpath to the shrine.

Of historical interest, the name ‘Futami’ derives from the Japanese term for ‘looking twice’, and is probably related to a myth reflecting the particular beauty of the landscape. The famous Futami Okitama Shrine was established at this site about 1300 years ago because the rock formation was thought to possess spiritual qualities. It is said that the best season to observe the rocks is around the summer solstice, with viewing at sunrise offering a particularly high aesthetic value. In a special ceremony the rope of rice straw (called *Shimenawa*) connecting the *Otoko-iwa* (man rock) with the *Onna-iwa* (women rock), symbolizing marriage, is replaced several times each year by worshippers from the shrine (Shinto Shrines of Japan. Futami Okitama Shrine, 2012). As a result, the Futami Okitama Shrine is a popular destination for visitors seeking matchmaking and marital harmony.

Rock samples of the Sanbagawa schist were collected from Futami by Kenji Miyazawa, the famous Japanese poet and fairytale writer. However, the geological origin of the *Meoto-Iwa* is unknown to most visitors. Promotion of the geology of the region, including the presence of the MTL fault in the Geku Shrine and inferences that can be made from surface outcrops, could attract people to the geological history of the area.

MIOCENE CONGLOMERATE ALONG THE MIYA RIVER

Miocene conglomerate is locally exposed near the Geku Shrine (Kimura et al., 1965), particularly at the Miya River outcrop known as *Hira-iwa* (Fig. 6). This is part of the Miocene Takakura Formation, which is correlated with the upper part of the middle Miocene Ichishi Group and consists of conglomerate containing well-rounded and poorly sorted pebble, cobble, and occasionally boulder clasts. These sediments are considered to have originally been deposited in a shallow sea to the north of the MTL (Ryoke belt) at c. 18 Ma, as shown in Fig. 3, and they must therefore have been rotated together with the MTL during the Miocene opening of the Sea of Japan, as mentioned above. The rock types of clasts include granite, sandstone, chert, gneiss, hornfels, granitic mylonite or cataclasite, greenstone, and greenschist, and the conglomerates are locally intercalated with sandstone layers (Suzuki et al., 2015). The granitic, gneissose and mylonitic, and hornfels clasts were derived from the Ryoke belt, while the schist and greenstone clasts are correlated with the Sanbagawa metamorphic rocks. These relationships suggest that the paired metamorphic belts juxtaposed along the MTL were already exposed in the Ise area during the lower Miocene.

The scientific significance of this exposure would allow the Miya River site to serve as an open-air geological museum, providing an important education facility for understanding the geological processes that have shaped Japan, such as the origin of the paired metamorphic belt. The river is also known for its pristine waters and is used during the Grand Geku Shrine relocation ceremony in Ise City. These combined aspects offer substantial value for

Fig. 5 Ggreenschist exposure (*Meoto-Iwa*) in front of the Futami Okitama Shrine in Futamigaura, Ise city. Photo by: D. Suzuki

the creation of a geosite at this locality, which could serve to both protect the conglomerate exposure and promote geotourism in the region.

ASAMA MOUNTAIN (ASAMAGATAKE) IN TOBA CITY

Mt Asama is the highest mountain (555 m) in Ise-Shima National Park. The mountain consists of the Asama igneous body, which is intruded into Jurassic Mikabu greenstones that were metamorphosed to low grades during the high-P/T Sanbagawa metamorphism. As reported by Nakamura (1971) and Agata (1998), the igneous complex consists of a layered sequence of mafic and ultramafic rocks that are lithologically divided into three zones. The lowermost zone consists of peridotites, the middle zone of alternating gabbros and peridotites, and the upper zone of gabbroic rocks (Fig. 7). Most of the olivine and orthopyroxene grains in the peridotites from the lower and middle zones are replaced by serpentine, the formation of which was possibly related to the Sanbagawa regional metamorphism. The petrology of the Asama plutonic rocks indicates that their parental magma was generated in an oceanic island setting, and covered by accreted sediments.

This mountain area is one of the most popular tourist spots in eastern Mie prefecture, and is currently easy to access. The historical status of the "holy mountain" led to the development of an important pilgrim road through the area to connect travelers from Toba to the Ise-Jingu Shrine. The famous Zen temple Kongoshoji is located near the top of the mountain. This temple was originally built in the middle of the 6th century AD to worship *Uhou-Douji* as *Amaterasu,* and to protect the Ise shrines from the northeast.

Mt Asama is also of growing interest to collectors looking for valuable minerals. A number of rock exposures exist along roads crossing the mountain and near the mountain observatory, which also provides a panoramic view over the Futami area, and in particular the MTL-fault-related linear alignment of islands to the NE. The serpentinite-derived soil of the area, which is dry and low in essential nutrients, supports unusual plant species of significant conservation value, such as Japanese Buxus and Jingu Azalae**.** An existing information board offers a brief introduction to the geology and related plant life of the mountain area.

Fig. 6 Conglomerate outcrop along the Miya River in Ise City. (a) explanation board about the MTL already in place in front of the exposure; (b) conglomerate exposure visible from the eastern bank of the river. (Photo by H. Takagi)

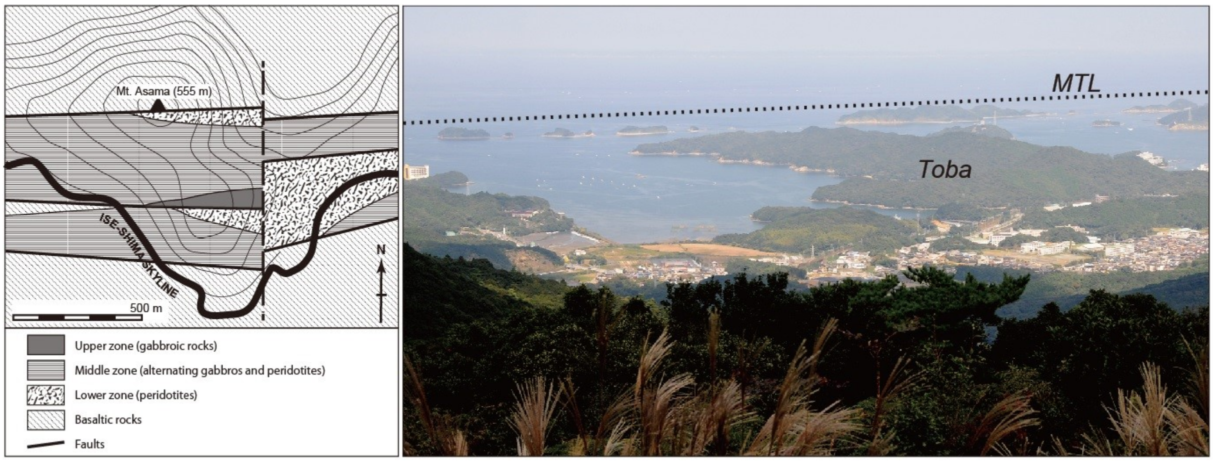

Fig. 7 Geology of Mt. Asama area, illustrating the structural layering of the igneous complex and the main faults (after Agata, 1998). The photo on the right, taken from the mountaintop observatory,demonstrates how the inferred MTL trace (dotted line) and related lineaments continue to the northeast from the Kii Peninsula (Futami area) to the Chubu Region in Japan. Photo credit: H. Takagi.

SIGNIFICANT ROCK EXPOSURES DEMONSTRATING GEODIVERSITY ALONG THE ARASHIMA COAST, TOBA CITY

The prospective geosite consists of four sections of rock exposures along 1.5 km of coastline, from the east of Arashima town to the northwest of Uramura town in Toba city. The first two sites (Gt-1 and Gt-2 in Fig. 8) show shallow-marine deposits along the seashore in the Arashima area, commonly consisting of sandstone, mudstone, chert, and locally acidic tuffs. An exposure in the middle part of this sequence shows the recently recognized Shiranezaki Formation in unconformable contact with the Matsuo Group (Ohta, et al, 2012). In the Futaji area isolated masses of chert crop out along with locally adjacent bedded sandstone and mudstone (Gt-3). These sediments are known for the significant fossils they have yielded, including a partial skeleton and footprints of a sauropod and concentrated beds of oysters and other bivalves (Mie Prefecture Excavation and Research Group for Dinosaur Fossils, 1997). The last section includes the Shiranezaki area (Gt-4), where the Aonomine Group of the Chichibu belt is exposed (Fig. 8b). This section contains a weakly metamorphosed mélange of flattened sandstone and chert blocks of various sizes, together with small

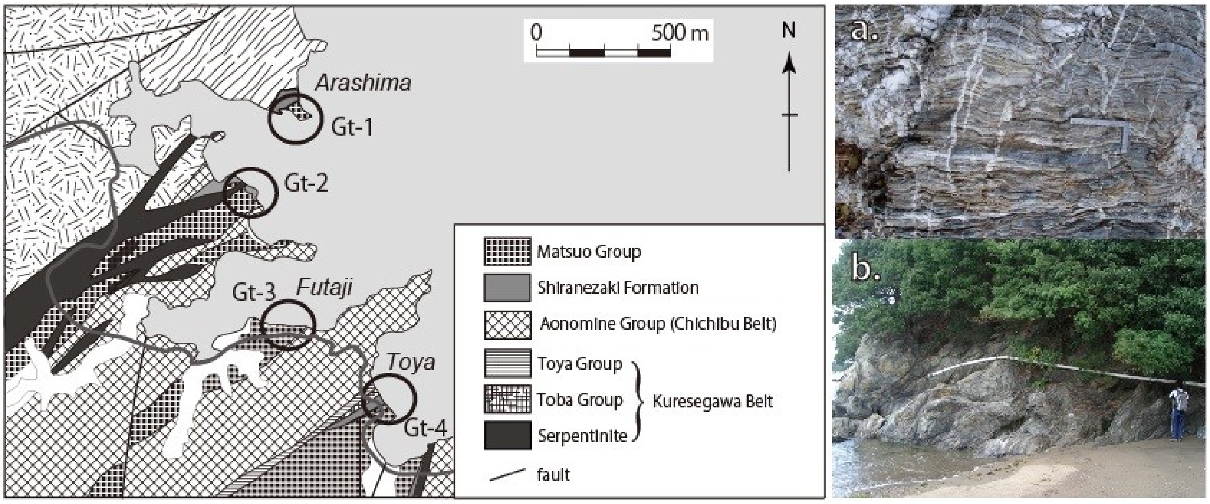

Fig. 8 Geological map of the study area showing details of its geology and the distribution of proposed geosites (after Ohta et al., 2012). Photos on the right side: (a) white and red chert, exposed south of the Arashima Swimming Beach; (b) outcrop of glaucophane schist of the Kurosegawa Terrane along the coast south of the Shiranezaki area.

amounts of greenstone and limestone set in a muddy matrix. Small masses of glaucophane schist are visible within the serpentinite mélange, which probably branches off from the G-ATL; therefore, these high-P/T metamorphic rocks are likely to correspond to the Paleozoic Kurosegawa belt.

Although all of these sites are located within a popular tourist area that offers pleasant coastal scenery, the geology of the area is poorly communicated to the public at present. Other than the famous site at Futaji, most of the significant rock exposures are generally outside the knowledge and interest of visitors. This situation might be improved by the provision of proper information on boards placed next to relevant exposures. Further promotion of the geology by local organizations, which are currently focused primarily on the fossil sites, could also enhance the popularity of the new localities and help emphasize the role of accretionary complexes in the formation of Japanese Islands.

RESULTS AND DISSCUSSION

This paper highlights five potential geosites in the Ise−Toba area, and offers suggestions outlining how their development might help tourists to better understand the geological background of the area when visiting. The locations identified could also play an important role in supporting the education of people in Japan about the geological history of their country, helping to mitigate the impacts of natural disaster that can result from or be enhanced by a lack of knowledge and awareness of natural hazards, as well as from a fear of the unknown. For example, a large typhoon (Isewan typhoon or Typhoon Vera) struck a wide area around Ise Bay in 1959, with nearly 5000 fatalities. Exploring the Ise-Shima coast area and understanding its history might increase public awareness of the occurrence of such unexpected events and other potential disasters such as tsunamis, which are thought to be highly likely to occur within the next c. 50 years as the result of a large earthquake along the Nankai Trough.

The rating results for each of the selected locations may serve as a basis for future activities in regard to their planning and management for geotourism. The Miocene conglomerate (G3) and Meoto-Iwa (G2) geosites received the highest overall score in this exercise, and the Arashima area (G5) the lowest, due in large part to the lack of information about this site that is suitable

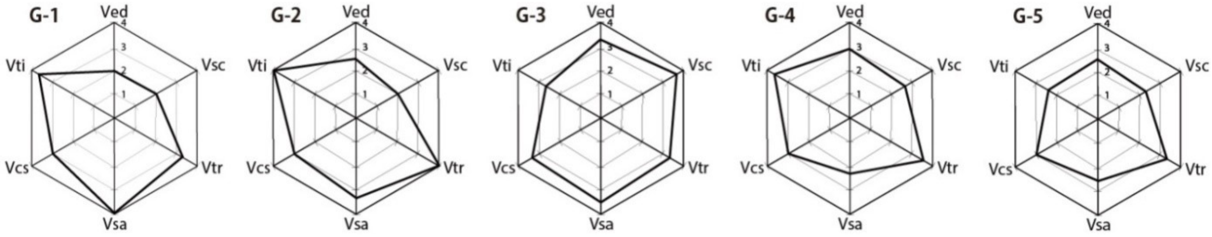

Fig. 9 Evaluation result for the proposed sites employing the criteria of Suzuki and Takagi (2017).

for education purposes. Significant differences are noted between the relative education and safety values for the prospective geosites. Other than the conglomerate exposure (G3), most of the sites are characterized by low representativeness; however, a dominant anthropogenic value may raise the total attractiveness of all the sites studied in Ise city. In fact, an integration of cultural and geological experience in future tourist programs would have increased people’s interest in and satisfaction from visiting this region.

The Grand Geku Shrine could offer a substantial attraction to assist with the promotion of the sites located in its vicinity. Restrictions on tourism within the shrine territory should be taken into account, however, as these may place limits on the accessibility and popularity of the proposed geosites. Urban areas of Ise City might also have a negative impact on the representativeness of site G2, reducing its importance. A number of the highlighted rock formations are exposed in coastal areas and are therefore vulnerable to typhoon and tsunami damage, as well as destructive landslides that may occur in serpentinite-dominated areas. Consequently, appropriate measures aimed at the use and protection of the sites should be incorporated into plans for their development.

Overall, the locations presented require more promotion activities. Information boards are currently only available in front of the Miya River outcrop and at the discovery site of the Toba Dinosaur in Toba City. The significance of other sites is probably only known to individual researchers, and thus better access to geological information might enhance their attractiveness. Furthermore, geosite development should give regard to the most efficient and/or attractive ways of disseminating geological information throughout society. It can be, for example, a geo-tour, educational or local festival, during which can be introduced the geo-story of each object, made with the help of local authorities and tour operators. A geo-route connecting the geosites in Ise city, together with improvements to existing facilities, might offer original experiences of great value for geotourism activities in this area. For example, the Japan Railways Sangu Line between Iseshi and Futamigaura stations, originally built for pilgrims to the Ise Grand Shrines, runs approximately along the MTL surface trace across the region (Fig. 4), and thus might offer the conceptual option of a ‘geo-tetsu’ (geo-train) connecting the sites. The geological importance of the Arashima area might be linked to other natural and cultural sites in Ise Shima. In regard to the individual needs and motives of geotourists, selected localities might be more or less attractive, and thus further study on geotourist expectations in the region should be undertaken.

CONCLUSIONS

The combination of interesting geologic features with the unique history of the Ise and Toba areas could offer a popular attraction and support future geotourism development in the region. The evaluation of selected locations was carried out in relation to three main assessment categories, with the aim of indicating both the relative potential and specific demands required for development of each locality as a geosite. Further steps should include conservation and protection planning, which would require broad cooperation between local authorities and geoscientists, and the approval of local communities for the creation of geosites. Development of geosites should also be accompanied by the distribution of high-quality information on the Internet and within Ise-Shima National Park that would attract tourist's attention in a particular site.

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