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ORIGINAL PAPER

Compound geotourism and mine tourism potentiality of Soma region, Turkey

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Abstract
Geotourism is carried out in order to draw public attention to our common geological heritage, to increase our knowledge of geology, and to contribute to the local economy. Mining tourism also aims to show the importance and necessity of mining activity despite its difficulties and to contibute to the economy of local mining community. Moreover, mining tourism can transform the image of the mining region from negative to positive, after major mining accidents and raise morale of the local miners. The aim of this study is to investigate the feasibility of the region for geotourism and mining tourism. Among a wide variety of geotourism elements in the region, there are Kula Volcanic Geopark, Soma coal mines, and lignite-fired thermic power plant, Salihli geothermal energy plants, Spil Mountain National Park. This geodiversity in the region has led us to suggest the concept of compound geotourism. The richest lignite deposits in western Anatolia are in Soma. Here we offer a glimpse into the possibilities of mining tourism. A qualitative and pre-quantitative assessment was carried out to make a geodiversity inventory of the region. Scientific, educational, and tourism values of the proposed geotourism elements were found high, and fortunately the risk of deterioration of geodiversity in the region is found low. The geodiversity in Manisa province and its districts, Soma, Kula, and Salihli, is very suitable for geotourism; also Soma is an excellent area for mining tourism.

Keywords Geodiversity · Mining tourism · Geopark · Geo-energy tourism · Neotectonics

Introduction

In recent years, many studies have been conducted on the presentation of geotourism for the protection and promotion of geological heritage (Dowling and Newsome 2006; Errami et al. 2009; Chen et al. 2015; Çetiner et al. 2018; Çiftçi and Güngör 2016; Kazancı 2012; Yürür et al. 2018). We are here proposing compound geotourism concept which is obtained by combining at least two different earth science-based tourism types such as mining tourism and geotourism, for the first time. Cahyadi (2016) used a similar approach to integrate geotourism and archeotourism.

Our study area is in west Anatolia and general structural elements of western Anatolia are also shown in Fig. 1a. In this study, we are proposing compound geotourism concept for Soma and its environs which are in west Anatolia where there is a rich variety of the geotourism elements with mining tourism values. Soma covers 826 km^2 and is one of the 17 districts of Manisa Province with 13,810 km^2 surface area. The district is a neighbor to İzmir to the west and Balıkesir to the north. Soma has the richest lignite deposits in western Anatolia, and the basic economy of the region is based on lignite mining. Because of the surrounding wealthy geoheritage entities around Soma, it is also an ideal place for the launch of the first mining tourism in Turkey.

This study is based on field observations made in Soma and its vicinity (Fig. 1b, Fig. 2) in the summer of 2016 and 2017. The primary objective here is to search a new way of life and economic support for the Soma mining community after the mining accident in Soma in 2014. Mining and geotourism

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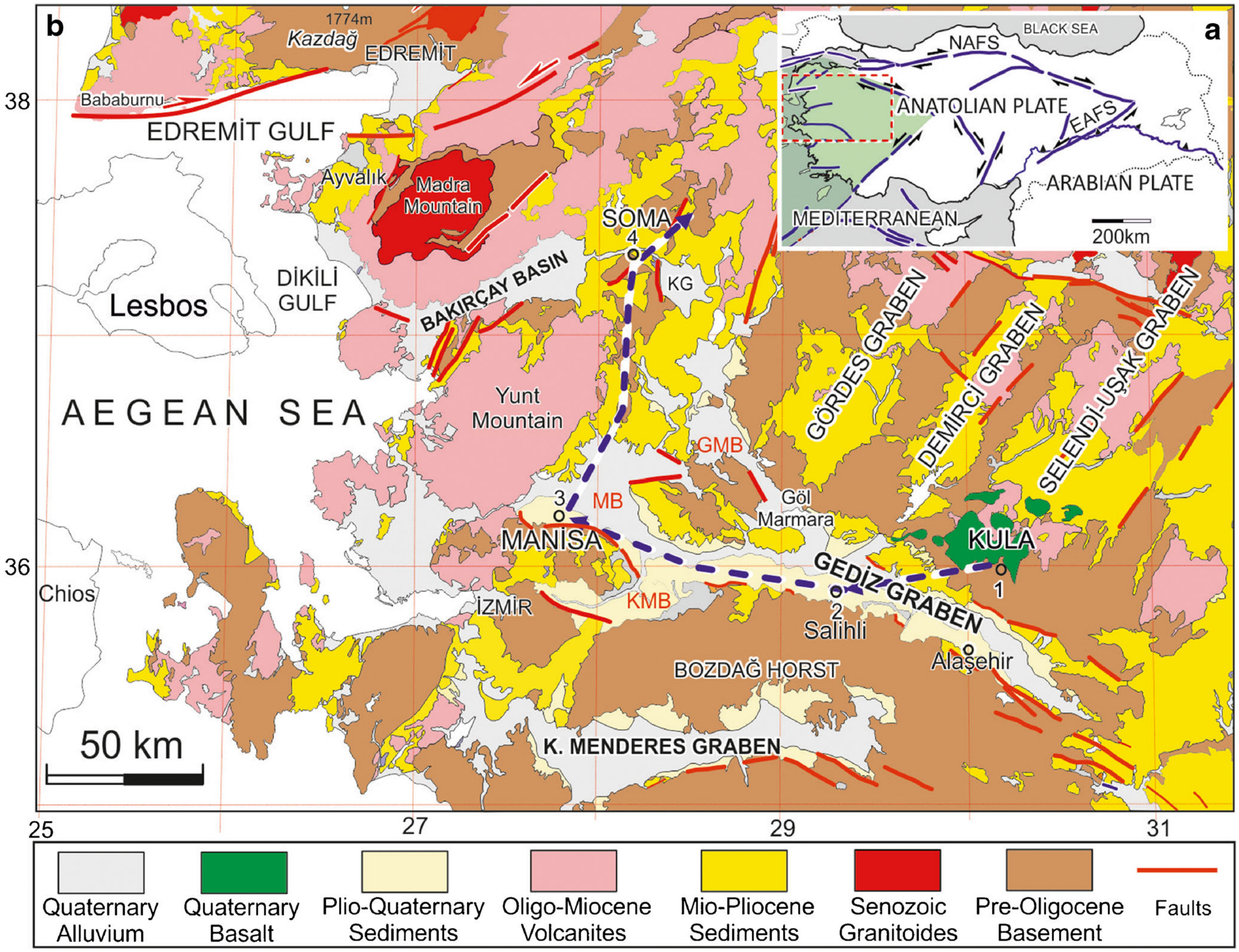

Fig. 1 a Tectonic map of Turkey showing major tectonic structures. b. Geological map of Manisa province and its environs, and the proposed schematic tour route for compound geotourism on this map. *MB* Manisa Basin, *GMB* Gölmarmara Basin, *KMB* Kemalpaşa Basin (Modified from MTA 2002)

activities to be planned in the region can provide these aims. Soma has a significant change in this sense. Turkey's only geopark, the Kula Volcanic Geopark, is very close to Soma and also Spil Mountain National Park in Manisa and geothermal power plants in Salihli are located around Soma. Moreover, Aegean extensional tectonic regime (Yılmaz et al. 2000; Bozkurt 2001; Gürer et al. 2016; Sangu et al. in press) can be observed in the region. All of these components of compound geotourism for the region were shown as a diagram in Fig. 3. All these geological and mining features make it significant to start Turkey's first mining tourism in Soma.

Since history, the interaction between human and geological environment has been very prominent in the region. The region has been home to many historic settlements since 3000 BC and also some prehistoric settlements around the Kula district (Maddy et al. 2015). Therefore, the region has been offering interesting tourism opportunities with its cultural and historical prosperity belonging to Hittite, Phrygia, Lydia, Macedonian, Roman, Byzantine, Beylikler, and Ottoman civilizations. In fact, in historical periods, Manisa (ancient Magnesia), Salihli (ancient Sart) cities gave their names to the geological entities in their surroundings (Rapp and Hill 2006). The word "Sard", the name of the orange quartz mineral, which is a gemstone, comes from the city of Sardis where the stone was removed in ancient times. Socrates in 470–399 BC recognized the magnetite mineral (loadstone), for the first time in Manisa (ancient Magnesia), which could attract or repel the iron rings mysteriously (details in, Keithley 1998). Therefore, Magnesia has given the name to the modern terms such as magnet and magnetism. These stories show that the unique geology of the region has been affecting the human being culture since historical times.

The regional tectonic activities cause mobility and lead a large number of different scales of earthquakes that destroy the historic cities. These tectonic and volcanic activities also formed significant underground resources and visual-valued

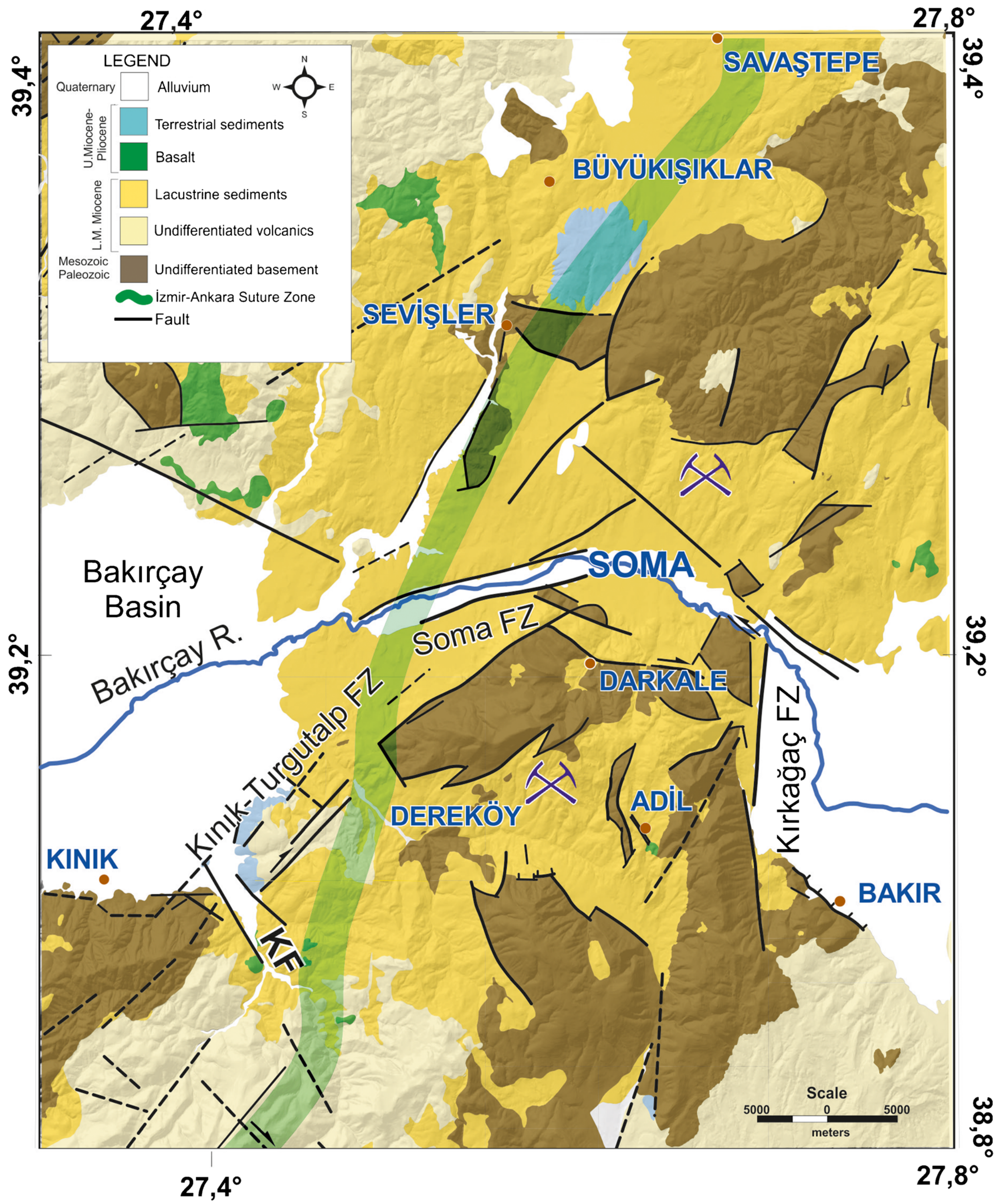

Fig. 2 Geological map of the Soma district of Manisa province and its environs, and the proposed schematics tour route for Soma mining and geotourism on this map. İASZ: İzmir-Ankara Suture Zone (Modified from MTA 2002)

geo-entities in Manisa province and its Kula, Salihli, and Soma districts. These rich natural heritages, including geoheritage and underground resources, of the region, are as interesting as the cultural attractions. The dominant geomorphological and geological entities are horsts (elevation fields) and grabens (depression fields) which create beautiful landscapes. Manisa fault is one of the major elements forming Gediz Graben and Spil Horst which are in Manisa province.

Current research topics and discussions on geotourism are about conservation of local culture, traditions, geosites, and landscapes despite geotourism activities (Henriques et al. 2011; Brazier et al. 2012and references there in). The concept of sustainability (Henriques and Brilha 2017), which is closely related to this protection, is also in the attention of current researches. In this study, we examined the geoheritage potential of Soma and its vicinity for the first time. After field

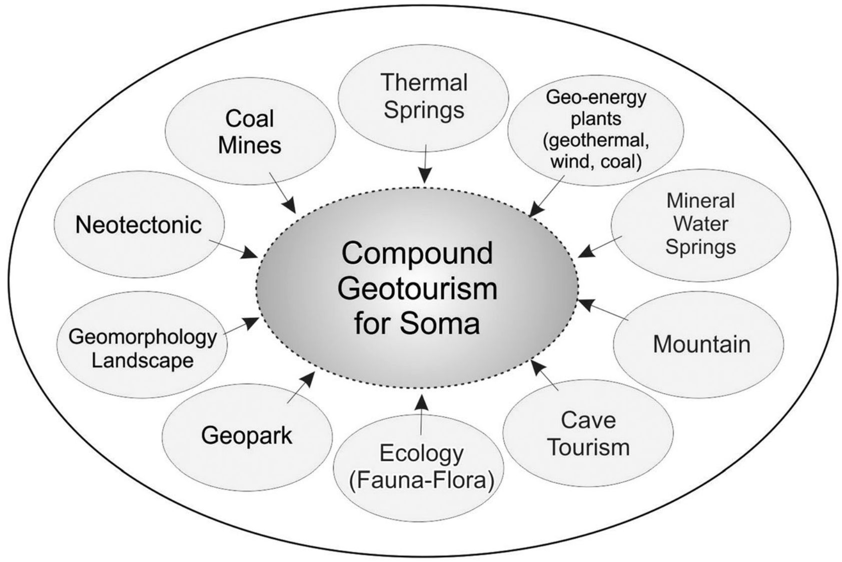

Fig. 3 Elements for the compound geotourism for Soma and its surroundings

observations, we first proposed the concept of compound geotourism. We made a preliminary assessment of the region's geotourism potential quantitatively and qualitatively (using the method by Brilha 2016). This assessment showed that the risk of deterioration of the region is low. Therefore, it is foreseen that the geotourism to be initiated in the region will be sustainable. At the same time, the region has a high value in terms of geotourism and geo-education.

With these findings, a pilot implementation of geotourism planning and management in the region can be initiated, as suggested by Mulec and Wise (2012), with the contribution of local governments. Thus qualitative data for a scientific assessment of planning and management can be provided as a next step.

In the flow of this article, the methodology of the study, the tourism potentiality of the region, and conclusions are presented consecutively.

Methodology

The first step of the used method includes bibliographic studies and field observations. Afterward, to identify and select potential geoheritage objects, qualitative and preliminary quantitative assessments of these observations were conducted using the method proposed by Brilha (2016). The main aim of the author is to conduct a review and present a systematic approach to inventory and quantification methods applied to geological heritage and geodiversity sites, under the scope of geoconservation (Brilha 2014). For this aim, we have created tables by combining various criteria to evaluate geodiversity qualitatively and quantitatively.

In this study, we applied qualitative and quantitative evaluation criteria to our field observations and presented them on the same table using different columns for qualitative and quantitative criteria. We created our tables, for qualities and quantities of the geodiversity sites in our study area, by selecting from the detailed tables given by Brilha (2016).

Geotourism potentiality of Soma and its environs

We discussed mining tourism potential of Soma and its surrounding from compound geotourism perspective because of the rich geodiversity around Soma. Figs. 4 and 5 show most prominent natural geoheritage entities with the geotourism route for the region and Mineral map of Manisa Province. In the following section, firstly, the geodiversity of the region (Kula, Salihli, Manisa, Soma) will be introduced. Then, with the Brilha (2016) method, the geotourism potential of the region and the risk factor of deterioration were examined and presented.

Geodiversity entities of Soma and its environs

Kula

The Kula region with its black volcanic lava flow, with lavas mostly in the form of coal fragments, has attracted people's attention throughout the history. Famous Geographer Strabo (63 BC–24 AD) was the first one recorded the Kula volcanic area with the name of Katakekaumene (fire-born) (Gümüş and Zouros 2014). A detailed, up-to-date, geographical description of the Kula volcanic area is given in Koçman (2004). The volcanic deposits around Kula consist mainly of scoria, basaltic lava flows, and minor tuff and tephra deposits (Heineke et al. 2016 and references therein). Kula Volcanism has been studied in details by various researchers with

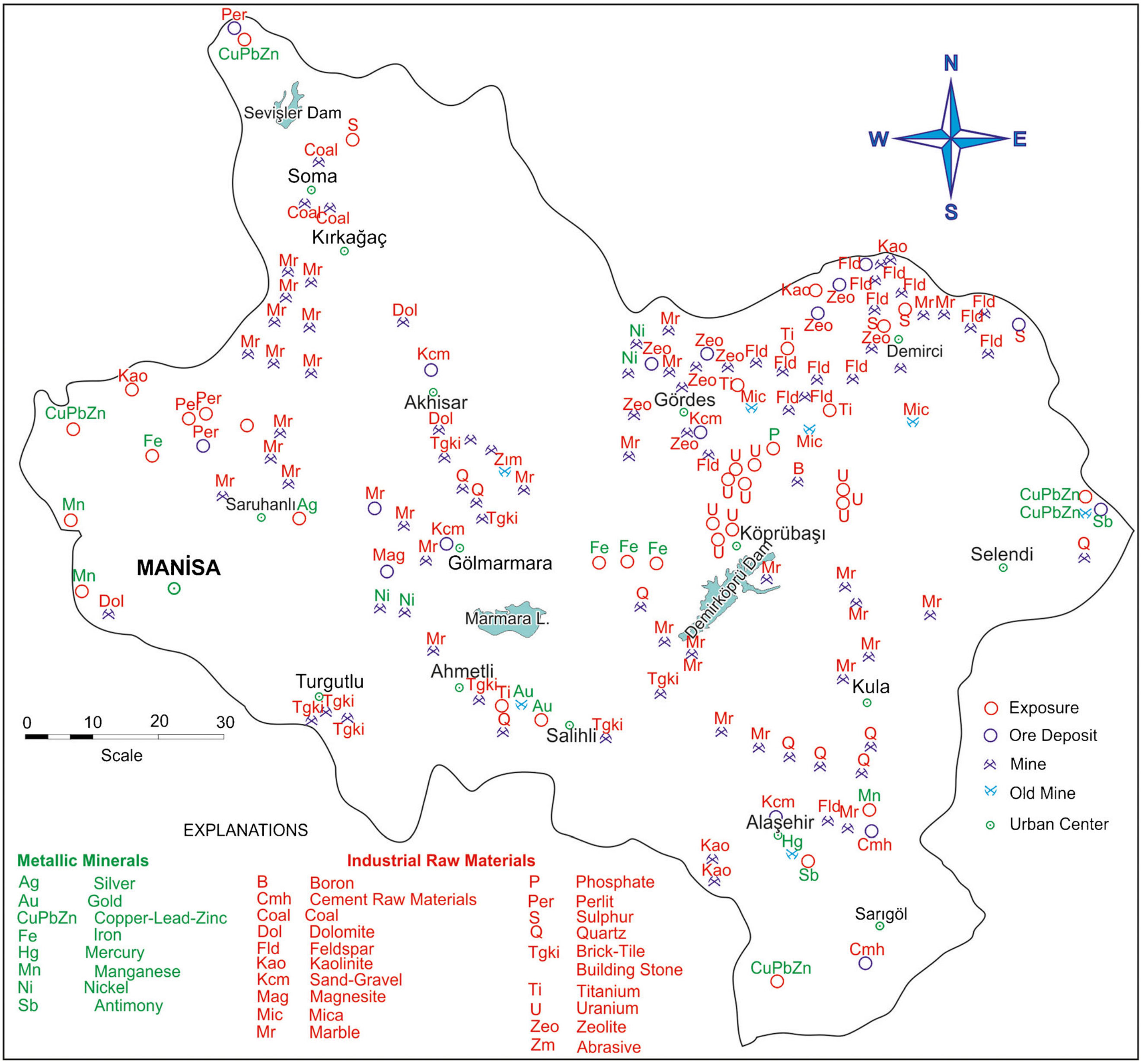

Fig. 4 A map showing geotourism route, with most prominent natural and geoheritage sites of the region, starting from Kula and ending in Soma

different aspects (Richardson-Bunbury 1996; Aldanmaz 2002; Ersoy et al. 2012; Şen et al. 2014). A landscape of these basaltic lava flows, covering a large part of the area, can be seen from Sandal Tepe Volcanic Cone (Fig. 6). The unique volcanic structures in Kula were exhibited by establishing a geopark which was approved by UNESCO in 2013. Gümüş and Zouros (2014) reported that Kula geopark in Manisa Province is the youngest volcanic region of western Turkey that covers 300 km^2. Eigthy cinder cones which are not higher than 150 m rise in Kula volcanic sequence form a land of small volcanoes with craters (Fig. 6b) in the geopark. They also reported that "Geopark area is awarded with high geodiversity representing about 300 million years of earth history from Paleozoic to Holocene including maars, monogenic cinder cones, successive lava flow plains, lava caves and tubes, basalt columns, xenoliths, contact metamorphism, ash deposits, waterfalls in volcanic canyons, active karstic caves, badlands, and fairy chimneys and mesa structures, as far as 15 thousand years of fossil human footprints preserved in volcanic lava and tuffs." All of these entities form interesting geosites of the Kula geopark geotour routes. Perhaps one of the most interesting aspects of this geopark is human footprints showing volcanic activity in the region lasted during human prehistoric times. The age of the footprints has been poorly constrained until the recent studies (Maddy et al. 2015, 2017). Heineke et al. (2016) reported the eruption ages of

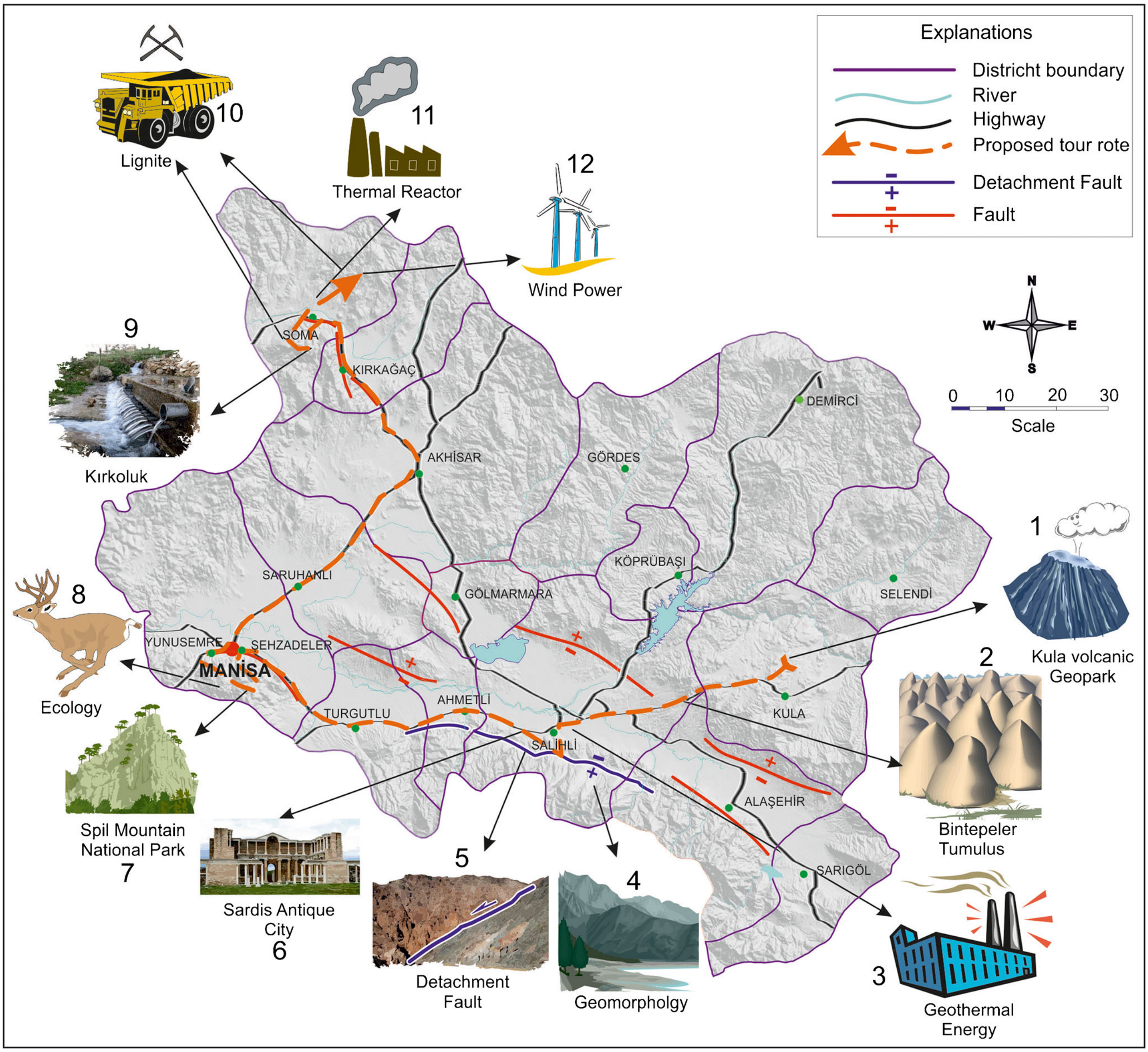

Fig. 5 Mineral map of Manisa Province

cinder cones and basaltic lava flows of Kula Volcanism, and they reported a 10Be age of 11.2 ± 1.1 ka for Çakallar Tepe cone, which dates the last eruption of this cone and also the human footprints in the related ash deposits. Their results also demonstrate that the youngest phase of Kula volcanism started less than four thousand years ago. All of these entities form new geosites of the Kula geopark geotour routes. The Kula Geopark area can be visited for different purposes such as education, scientific research, and geotourism. However, a general route may start with the Kula geopark museum. Walking through the wooden road leading to the top of the Sandal Tepe (Hill) volcanic cone and taking a basalt stream landscape from the top (Fig. 6) and/or walking on a lava flow plain segment, constitute 1-day visit to Kula Geopark.

Salihli

Salihli stands out as a field of geotourism, where neotectonic and geothermal items dominate. Western Anatolia is one of the fastest extending continental zones in the world (Taymaz et al. 1991). This extension led to the formation of E-W directional mountains (horsts) and eight basins (grabens) in between these mountains. The Gediz Basin, 150 km long, 5–15 km wide, is located in the middle of western Anatolia and is the largest of these basins where modern Salihli city is located in. This tectonic setting is not only the central element of geotourism in the region but also it is the leading cause of the other geoheritage entities in the area, such as geothermal fluids and geomorphology.

Fig. 6 a A view from the Kula volcanic geopark, b. A view of the Divlit Tepe (Hill) volcanic cone, the basaltic lava flows cover a large part of the area. c. The Gediz graben and the Bozdağ horst, 6d. Salihli geothermal energy plants, 6e. A panoramic view of the Manisa graben, from Spil Mount National Park

There has been a continuous settlement of different civilizations in Salihli, throughout the history due to its abundant natural resources (fertile lands, hot and cold mineral water springs and mines). The most important of these civilizations is the ancient city of Sardis, which entered the UNESCO Temporary List of World Heritage Sites and is located 7 km west of Salihli. Sardis, where money was invented as a means of exchange, is the capital of the Kingdom of Lydia. Today, the region is also of great interest both economically and socioculturally. For this reason, the region is affluent both in terms of cultural and geotourism elements.

The Gediz Graben and the horsts on both sides form a morphologically and geologically asymmetrical structure (Fig. 6c). The Bozdağ horst at the southern part of the basin is quite steep and high (mean 1500 m), while the north is composed of broad and low (mean 500 m) hills. Very young Plio-Quaternary (3 Ma-Recent) sediments are present in the basin, while metamorphic rocks of aged (1 Gya-50 Ma) in the north and south horsts of the basin are exposed. This detachment fault and other high-angle faults in the region are the most important geological structures. The horst-graben structure of western Anatolia and the detachment fault which are the result of the rapid crustal extension can be well observed in Salihli.

Özen et al. (2012) investigated the reservoir and hydrogeochemical characterizations of geothermal fluids in Salihli, Turkey. They showed that thermal waters are mostly supersaturated with carbonate minerals, and aquifer temperature is about 160°C. Hot liquids generated along the detachment fault in the south of the basin are used by several thermal energy enterprises. Fig. 6d shows a geothermal energy plant from the region.

Manisa

Throughout the history, Manisa, where trade routes have passed, is attractive with its cultural and natural resources. The region is also engaging in terms of geotourism. Manisa is the city that geomagnetism is recognized for the first time, and the term of the magnet was named after it. Socrates (470–399 BC) wrote about the mysterious stone (magnetite) in Magnesia Ad Sipylum (Manisa) that could attract the iron rings. Not only this unique historical record but also the presence of the Spil Mountain (Spil Mountain National Park) in Manisa (Fig. 6e), the province is important for compound geotourism due to the mountain, landscape, ecology, geomorphology, and neotectonics. Bozkurt (2001) describes Manisa graben as the bifurcation of the E-W directed Gediz Graben toward the west, forming three depression areas Gölmarmara, Manisa, and Kemalpaşa Basins (Fig. 1b). The neotectonics of Gediz graben has been studied by several researchers (Gürer et al. 2001; Bozkurt and Sözbilir 2006; Çiftçi and Bozkurt 2009; Öner and Dilek 2011, 2013; Yılmaz 2017). These works form a basis for the identification of geodiversity sites by geological frame work in qualitative analysis of the region (see Table 1). The Çal and Spil Mountains exist along the WNW–ESE direction in between these basins. Natural heritage of these mountains are investigated by several researchers (Hepcan and Coşkun 2004; Özkaymak and Sözbilir 2012; Başar and Yücel 2019). The modern Manisa Basin is an L-shaped asymmetric basin, bounded on the west by Yuntdağı High and in the south by Spil Mountain High. The Manisa graben, between Yunt and Spil Mountain horsts, can be clearly seen from the Spil Mountain as a panoramic view (Fig. 6e). The National Park is an important recreational area suitable for mountaineering sports as well as geological, morphological, archaeological, and mythological features. The remains of the Tantal Castle, the Niobe Crying Rock, which is mentioned in the mythology, the remains of the Magnesia Castle from the Byzantine period, are on the skirts of the Spil Mountain. Moreover, there is a Mevlevihane (lodge for dervishes, now a museum) on the skirts of Spil Mountain, which was constructed in 1368–1369, by the architect Osmanoğlu Emetullah on an order by Sarunhanoğlu İshak Bey (Tezcan 1994).

There are about 120 kinds of endemic plants in Spil Mountain national park. The most famous plant on the mountain is the tulips grown in clusters called Spil or Manisa Tulip. An Ottoman period practice, leaving the horses to Spil Mountain in the winter, led to the formation of free horse groups which are now under protection, on Spil Mountain National Park area.

Soma

Soma is located in an E-W directional narrow basin (Figs. 1, 2), in the northern part of the west Anatolian extensional tectonic system. Soma basin, which is an asymmetric graben with a high slope on the south side, is one of the places where faults and volcanic and sedimentary deposits of the extensional system are well observed. Four different Plio-Quaternary grabens meet in Soma, and the basin merges with Savaştepe in the north, Bakırçay in the west, and Kırkağaç basins in the east (İnci et al. 2001, Sangu et al. in Press). Therefore, Soma will present important contributions to the tectonic section of geotourism. Mineral map of Manisa Province covering its Kula, Salihli, Soma Districts. However, the district has the most massive lignite deposits of western Anatolia (Fig. 7), and it has 688 million tons of lignite reserves with more than 10 million tons of annual production (TKİ 2015) and coal mines provide employment for 15,000 people. Detailed geological information about lignite fields can be found in İnci et al. (2001). Briefly, the Soma coal basin formed on mainly karstic and possibly fault-bounded topographic depressions according to the authors. Paleoecology and geology of the basin were studied by (Akkiraz et al. 2015; Karayiğit et al. 2017). The primary tectonic structures in the coalfield are high-angle oblique-slip normal faults with a small-lateral component (Fig. 7b).

Another reason why Soma is the best place to start mining tourism is that the Soma mines are also widely reported in national and international press due to the biggest mining disaster in Turkey in 2014. However, this accident can be turned into an opportunity, as in the case of the Beaconsfield mining accident (White 2011), by starting mine tourism in this area. The story of Beaconsfield mine accident is a surprising example of how a severe mine accident can improve the economy and the image of a mining town through tourism (White 2011).

Without making any arrangements for mining tourism, at present, there is an excellent story of the town and its surroundings to tell about lignite mining (Karadağ 2012). Therefore, Soma can be visited within the context of compound geotourism, without waiting for the mines to open for tourism. These pre-visits can also support the desire and the process of preparing the city in the future to provide traditional mining tourism subjects. Besides, the beautiful and untouched historical, cultural, natural, and geological beauty of Soma and its surroundings will promote this geotourism activity.

Table 1 Quantitative evaluation of the scientific value of geosites according to sequential assignment table (Brilha 2016) for geosite inventory. Criteria, indicators, and parameters used for the quantitative assessment of the geosites are also chosen from Brilha (2016)

<table>
<tr><th colspan="2">Scientific Value (SV) (Scale 1,2, 4 according to Brilha (2015)</th></tr>
<tr><td>Geological Framework</td><td>Extensional regime in and related geological structures</td></tr>
<tr><td>Scientific Characterization of Each of the geosites in Geological Framework</td><td>Yılmaz et al. (2000), Bozkurt (2001)</td></tr>
<tr><td>Identification of geodiversity sites by geological frame work</td><td>KULA (K): <u>Kula Volcanic Geopark</u>, thermal and mineral water springs
SALİHLİ (SL): Geothermal springs (>160° water temperature), <u>Geothermal energy plants</u>, <u>Detachment fault</u>
MANİSA (M): <u>National park</u>, fault and graben
SOMA (SM): <u>Largest Lignite mines of west Anatolia</u>, Graben</td></tr>
<tr><td colspan="2">Field observations for the identification of new geodiversity sites</td></tr>
<tr><td>IDENTIFICATION CRITERIAS</td><td>FIELD OBSERVATIONS EVALUATED BY IDENTIFICATION CRITERIAS (FOR QUALITATIVE AND QUANTITATIVE ASSESMENT)</td></tr>
<tr><td>1)representativeness: To illustrate a geological process or feature contribute understanding of geological process, feature ext.

×(Weight of this criteria, for the QTT assessment =<u>39%</u>)</td><td>→Qualitative (QLT) and primary quantitative (QTT) assessment of the scientific value of geodiversity sites
<u>QLT</u> parameters | <u>QTT</u> parameter point (×weight%)× geodiversity site number having the criteria.
K, SL,M,SM: All of these geodiversity sites are the best examples in the study area. | 4(×39%)×4</td></tr>
<tr><td>2)Integrity: related to the present conservation status of the geodiversity site, taking into account both natural processes and human actions.

× (Weight of this criteria, for the QTT assessment = <u>23%</u>).</td><td>→ <u>QLT</u> | <u>QTT</u>
K: Conserved by geopark org. | 4(×23%)
SL: Conserved by energy plant companies and very low Degradation risk for Listric Fault | 4(×23%)
M: Natural park conserved by state | 4(×23%)
SM: Ores conserved by state and private companies | 2(×23%)</td></tr>
<tr><td>3)Rarity: number of geodiversity sites in the study area presenting similar geological features.

×(Weight of this criteria, for the QTT assessment= <u>23%</u>)</td><td>→Each feature at each area is unique in the region (K,SL,M,S) | 4(×23% ×4)</td></tr>
<tr><td>4)Scientific knowledge based on the existence of scientific data already published about the geodiversity site.

×(Weight of this criteria, for the QTT assessment = <u>15%</u></td><td>→Each area (K, SL, M, SM) have been very well studied and many papers have been published in international journals. | 4(×15%×4)</td></tr>
<tr><td colspan="2">Quantitative assessment of SV: (<200, low, 201-300 moderate, >301-400 high)
SV=[points for the first QTT parameter * its weights* number of geosite having this parameter+…+points of the last QTT parameter * its weight* number of geosite having this parameter]/Number of geosites
SV=[4*39*4+(4*23*3+2*23)+(4*4*23)+(4*4*15)]/4=339,Scientific Value (SV) is HIGH for the region</td></tr>
</table>

Fig. 7 a A view from the coal mine in Kısrakdere, b. High-angle faults in coal seams with a lacustrine layer in Deniş, c. The road from Soma to Darkale village, (a closed lignite mine on the east, and the proposed location of the mining museum on the west), d. Köseköy Horst where. e the Darkale village was established above, 4 f. Kırkoluk springs in Darkale village. g, h. Dereköy village, i. Almost a ghost town neighbor to the most prominent mine quarry Eynez

The tectonism that opened the Soma graben also formed the water and geomorphological structures like Bakırçay River, Menteşe thermal water springs, small Yırcalı waterfalls, Yağcılı volcanic fairy chimneys, and Kösedağ horst at the south. The geological and natural resources are intertwined in the Darkale village on this horst, which houses the oldest civilizations of the region.

The proposed route extends from the Soma district (Figs. 2, 7c) to Darkale village, which was established above Kösedağ Horst (Figs. 2, 7d, e). There is no mining museum in the city. This area at the beginning of the Soma Darkale road can be an ideal place to establish a mining museum (Fig. 4c). This road leads to metamorphic rocks of Kösedağ horst. Kırkoluk springs (Figs. 2, 7f) can be reached by walking through the cultural, historical, and architectural texture of the Darkale village. The role of faults, in forming Kösedağ horst and in transporting groundwater, as springs, to the earth, is observed here. After Darkale, Dereköy (Fig. 2) which is adjacent to Eynez mine can be another interesting site. Eynez quarry is Soma's largest open quarry and also had a significant effect on Dereköy village. As mining progresses, many people have left their homes, and the town is almost turned into a ghost town (Figs. 7 g, h). From here, the Eynez mine and the change it makes in the topography can be seen (Fig. 7i).

An aim of geotourism is also contributing to the economic development of the people of the region. The Soma mine disasters show that families of miners also need an additional source of income. Geotourism may be able to meet this need. Besides the coal mining and lignite-fired thermal power, Turkey's largest wind farms are in Soma, with 119 wind turbines and a total capacity of 140.4 MW (ISPAT n.d.). This region may also be an essential area for energy tourism. Soma thermal power plant, wind energy plants, and Salihli geothermal energy plants are important geo-energy sources that come together in the region.

Geotourism potentiality of the region

In this study, the qualitative and quantitative evaluations for the region based on Brilha (2016) were shown in Table 1 (for scientific value (SV)) and in Table 2 (for potential educational (PEV) and potential turistic uses (PTV)) and Table 3 (for degradation risk (DR)). The first columns and the rows in Table 1 shows the scientific definitions of the sequential tasks and geological framework in geodiversity sites. Geological framework, scientific characterization of each geological framework, and determination of geological diversity sites by geological framework study are the initial steps of scientific evaluation studies (Table 1). The gray-shaded part of the first column shows identification criteria to evaluate scientific value of a region. These criteria can be listed as representativeness, integrity, rarity of the region, and scientific knowledge about the sites. The qualitative (QLT) and quantitative (QTT) assessments for SV of Soma and its environs, according to the mentioned criteria, are shown in the second column. The quantitative evaluation for SV of the region is shown in the last row of Table 1. Similar evaluations were made for potential educational (PEV) and potential turistic uses (PTV) in Table 2 and for degradation risk (DR) in Table 3.

On the quantitative evaluation, we gave values (from 1 to 4) to the parameters and multiplied them by different weighting coefficients (in %) for each criterion Brilha (2016). Although there are some criteria for the evaluation of potential geoheritage objects, we have only selected four basic criteria, and we have distributed the weighting coefficients of the other criteria equally. The quantitative values for each category (SV, PEV, PTV, DR) were obtained by collecting these values and dividing them by the number of geodiversity sites (Table 1).The scientific value (SV) of our sites can be calculated as follows;

$$\begin{aligned} SV = [&\text{points for the first QTT parameter} \times \text{its weights} \\ &\times \text{number of geodiversity site having this parameter} \\ &+ \ldots + \text{points of the last QTT parameter} \times \text{its weight} \\ &\times \text{number of geodiversity site having this parameter}] \\ &/\text{Number of geodiversity sites}, \end{aligned} \quad (1)$$

$$\begin{aligned} SV = [&(4 \times 39 \times 4) + (4 \times 23 \times 3 + 2 \times 23) \\ &+ (4 \times 4 \times 23) + (4 \times 4 \times 15)]/4 = 339 \end{aligned} \quad (1a)$$

Table 2 Quantitative evaluation of the educational and touristic value of geosites according to sequential assignment table (Brilha 2016) for geodiversity sites inventory. Criteria, indicators, and parameters used for the quantitative assessment of the geosites are also chosen from Brilha (2016)

Potential Educational USES/PEU (Qualitative assessment (QLT))	Quantitative (QTT) assessment parameter points (scale: Low-1,2,3,4-High)			POTENTIAL TOURISTIC USES/PTU (Qualitative assessment (QLT))	Quantitative (QTT) assessment parameter points (scale: Low-1,2,3,4-High		
Didactic potential: related to the capacity of a geological feature to be easily understood by students of different educational levels (primary and secondary schools, universities).	K SL M SM	The site presents geological elements that are taught in all teaching levels	4×34%	**Scenery:** associated with the visual beauty of the geological occurrence (landscape or outcrop)	K M	Site occasionally used as a tourism destination in national campaigns	2×28%
					SL	Site occasionally used as a tourism destination in local campaigns	3×28%
					SM	Site occasionally used as a tourism destination in local campaigns	1×28%
Geological diversity: number of different types of geodiversity elements present in the same site	K M	There are 3 types of geodiversity elements in the site (Volcanological, Morphological, Techtonic)	3×22%	**Interpretative potential**: related to the capacity of a geological feature to be easily understood by lay people	K SL M	The site presents geological elements in a very clear and expressive way to all types of public	4×24%
	SL	More than 3 types of geodiversity elements occur in the site Techtonical, (Morphological Geothermal Petrographical, Stratigraphical)	4×22%		SM		
	M	There are 3 types of geodiversity elements in the site (Techtonical Morphological Paleontological)	3×22%				
	SM	More than 3 types of geodiversity elements occur in the site (Techtonical Morphological paleontological stratigraphical Morphological, lignite mine geology)	4×22%				
Accessibility: conditions of access to the site in terms of difficulty and time spent on foot for ordinary students	K SL M	"Site located less than 500 m from a paved road	3×22%	**Accessibility:**	K SL M	"Site located less than 500 m from a paved road	3×24%
	SM	Site accessible by bus but through a gravel road	2×22%		SM		
Safety: related to the visiting conditions, taking into consideration minimum risk for students.	K	Site with safety facilities (fences, stairs, handrails, etc.), mobile phone coverage and located less than 5 km from emergency services	4×22%	**Safety:**	K	Site with safety facilities (fences, stairs, handrails, etc.), mobile phone coverage and located less than 5 km from emergency services	4×24%
	SM SL M	Site with no safety facilities (fences, stairs, handrails, etc.), mobile phone coverage and located less than 5 km from emergency services	3×22%		SM SL M	Site with no safety facilities (fences, stairs, handrails, etc.), mobile phone coverage and located less than 5 km from emergency services	3×24%
Potential Educational Use [(PEU) <200 low, 201-300 moderate, >301-400 high] PEU=[points for the first QTT parameter × its weights× number of geodiversity site having this parameter+…+points of the last QTT parameter × its weight× number of geodiversity site having this parameter]/Number of geodiversity sites				**Potential Touristic Use [(PTU)** <200 low, 201-300 moderate, >301-400 high] PTU=[points for the first QTT parameter × its weights× number of geodiversity site having this parameter+…+points of the last QTT parameter × its weight× number of geodiversity site having this parameter]/Number of geodiversity sites **PTU= 302 high for the region**			
PEU=312 high for the region							

Table 3 Quantitative evaluation of the degradation risk of geosites according to sequential assignment table (Brilha 2016) for geosite inventory. Criteria, indicators, and parameters used for the quantitative assessment of the geosites are also chosen from Brilha (2016)

1. Deterioration of geological elements *(Weight for this criteria for degradation risk (DR) assessment = 35%	SOMA (SM):possibility of deterioration of secondary geological elements points	2(*35%)
	SL, M, K: minor possibility of deterioration of secondary geological elements	1(*35%*3)
2. Proximity to areas/activities with potential to cause degradation 20%	SL, M, K: site located less than 500 m of a potential degrading area.	2(*20%*3)
	SM: Site located less than 1 km of a potential degrading area/activity	1(*20%)
3. Legal protection 20%	SL, M, K, SM Site located in an area with legal protection and control of access	1(*20%*4)
4. Accessibility 15 %	M Site located less than 500 m from a paved road	3(*15%)
	SL, K, SM site accessible by bus through a gravel road	2(*15%*3)
5. Density of population 10 %	M: site located in a municipality with 250–1000 inhabitants/km^2	3(*10%)
	SL, K, SM: site located in a municipality with less than 100	1(*10%*3)

Quantitative assessment of the degradation risk: (< 200 low, 201–300 moderate, > 301–400 high)
DR = [2(*35) + 1(*35*3) + 2(*20*3) + 1(*20) + 1(*20*4) + 3(*15) + 2(*15*3) + 3(*10) + 1(*10*3)]/4
DR = (70 + 105 + 120 + 20 + 80 + 45 + 90 + 30 + 30)/4 = 148
Degradation risk (DR) is low for the region

SV was described in range of < 200, low; 201–300 moderate; > 301–400 high, by Brilha (2016). So, scientific value of our area is high as seen from the equation (1a) as an application of equation (1). In Table 2, we evaluated two parameters, potential educational value and potential touristic value. Gray-shaded areas show qualitative assessment, and unshaded areas show quantitative assessments. Using the above method in equation (1) (see the last line of Table 2, for assessments of PEU and PTU), we found high scientific, educational, and touristic values for our geodiversity sites.

Degradation risk (or vulnerability) of a geosite is an important concept to make the decision to start geotourism in a region (Köroğlu and Kandemir 2019). We use the same method to calculate the quantitative assessment of the degradation risk (in Table 3) which is given in the range of < 200 low; 201–300 moderate; > 301–400 high. Fortunately, degradation risk (DR) is found as low (148) for the region (see Table 3).

Conclusions

In this study, three districts of Manisa province, Soma, Kula, and Salihli, were discussed concerning geotourism potential. Geotourism potential of the region is evaluated under the following headings, by the method from Brilha (2016). The scientific value of the geotourism assets in the region, tourism potential and educational potential, are examined in Table 1 and 2 and found to have high values. The fact that these values are large shows that the geotourism potentiality of the region is high. The risk of deterioration, which is a parameter indicating the vulnerability of the geodiversity in the region, is examined in Table 3, and, fortunately, this risk is low. These parameters gave very supportive results to develop geotourism in the Soma and its environs. Moreover, it has been observed that our study area includes many different kinds of items of geotourism, such as a geopark, coal mines, neotectonic structures, hot and cold water springs, geo-energy resources and plantations, geomorphology, and a national park. Because of this rich geodiversity, we have proposed a concept of compound geotourism, including the mining tourism component, for Soma and its surroundings. The following conclusions can be drawn about the regional distribution of compound geotourism elements:

1. *The Geopark*: The geopark is only in *Kula*, in the region. In fact, Kula volcanic geopark is Turkey's only UNESCO-approved geopark. The most essential element of the proposed route is Kula geopark in the context of geotourism.
2. *The coal mines*: Lignite mines are only in *Soma*. Soma has the largest lignite mines of Western Anatolia and forms the most exciting part of this geotourism route. Soma has the potential to create a mining tourism segment of compound geotourism route.
3. *The neotectonic structures*: The evidence of the extensional tectonic regime is horst-graben structures and faults forming them. *Salihli, Manisa*, and *Soma* show these horst-graben structures very well. Young volcanism in *Kula* is also related to this extensional regime.
4. *The water springs*: *Kula, Salihli,* and *Soma* have hot and cold water springs.
5. *The geo-energy resources and plantations*: the most important characteristic of *Salihli* is that the temperature of the thermal waters (160 °C). There are geothermal energy plantations and thermal spring baths. In Soma, there are lignite-fired thermal power plants and the biggest wind power plant of Turkey. The existence of Soma power plants, together with Salihli geothermal power plants, can add geo-energy part to this geotourism route.

6. *The geomorphology*: *Kula, Salihli, Manisa,* and *Soma*, all of the geodiversity sites, have interesting geomorphological features and landscapes. In Soma Darkale, the existence of a cave that can be explored not only concerning geomorphology but also regarding cave tourism is expressed by local people.
7. *The national park*: One of the geotourism entities of Manisa is the Spil Mountain National Park, with its 120 kinds of endemic species. The park is the most important geotourism and ecotourism asset of Manisa such as erosional landforms, many exciting landscapes, its unique fauna, and flora.

All of these geotourism elements observed in the field were assessed by the method given by Brilha (2016), and scientific, educational, and tourism values of the proposed geotourism elements were found high. As a positive result in the planning of geotourism, the risk of deterioration of geodiversity in the region is calculated to be low.

We also suggest a geotourism route, within the context of these compound geotourism elements, ending in Soma (lignite mines) by following Kula (volcanic geopark), Salihli (geothermal) and Manisa (national park) geodiversity sites. Another tour route was also proposed as part of the mining tourism, in Soma. The tour starts with the sight of the thermal power plant in Soma center continues to see neotectonic structures, springs, and geomorphology in Darkale. Afterward, Dereköy is reached, and Eynez ends with the observation of the mine bed from a distance and watching of the effects of the mine on Dereköy.

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