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ORIGINAL ARTICLE

What a Geologist May Do When the Geological Heritage Is in Danger?

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Abstract
In Turkey, extensive and fast housing works put in danger large surfaces of geological outcrops. These activities provide housing to citizens, but the lack of sensibility to the geological heritage notion among construction-related institutions and the very high speed of the process result in the lost or degradation of geological exposures in a few months. In a hopeful case when a geologist comes to understand the situation and is able to work, we propose a simple method, based both on a classical approach such as lithological and structural observations in such places, and a new approach, that of taking high-resolution photographs, by hand cameras but also if possible by drones in order to enable tridimensional (3D) reconstructions of the site for geological discussions, after surface modifications. We present a case from Miocene andesitic rocks near the Yapracık town, a new district of Ankara having recently experienced extensive housing with approximately new 9000 houses and 40,000 residents. Since the Ankara city expands outside, areas nearby to housing locations may be candidates to new modifications for recreational areas or even new housing sites. In our method, we propose to save high-resolution pictures and associated 3D reconstructions with their geological interpretation together with classical field notes in a directory to be used in case where geological exposures may suffer modifications. With new technologies in data storage, geologists are able to save considerable data that may serve to transfer to future generations some characteristics of the geological heritage.

Keywords Housing activities · Outcrop degradation · Ankara · Central Anatolia · Turkey

Introduction

In Turkey, the concept of the preservation of the natural values begins officially with the 1956 Forestry Law, and efforts to preserve geological values go to the year 2003 (TUJEMAP 2017). Several geosites are defined, and numerous proposals are studied to be declared as geosites (Jemirko 2017). But during last decades, Turkey faces two major issues, an important increase in rural immigration to cities and, more recently, a considerable amount of refugees (several millions) coming from the country's politically unstable southern boundary states. The TOKİ institution, the Housing Development Administration of Turkey, ensures the construction of new cities and provides housing to citizens and refugees in the country. As of the end of November 2016, TOKİ declares the construction of 754,097 various types of social houses (houses, schools, hospitals, mosques, etc.) with involvement of about 900,000 individuals to TOKİ's projects toward the middle- and low-income groups (TOKİ 2017). TOKİ's 2023 vision previews to reach 1,200,000 housing units in different regions of the country. Such a project requires the preparation and modification of large surfaces for constructions and also considerable quantities of raw and industrial materials coming mainly from quarries and factories. To these parameters that sometimes drastically change the geological environment are added land modifications due to works dealing with the electricity, water, natural gas, and Internet cable etc. installations. To our knowledge, these activities are not preceded by official works to protect or to save the characteristics of the geological heritage. In our experience of geological education with field works in Ankara, each year, we remark new degradations of the geological values, and frequently, we are in difficulty to see that exposures we used to show to our students do

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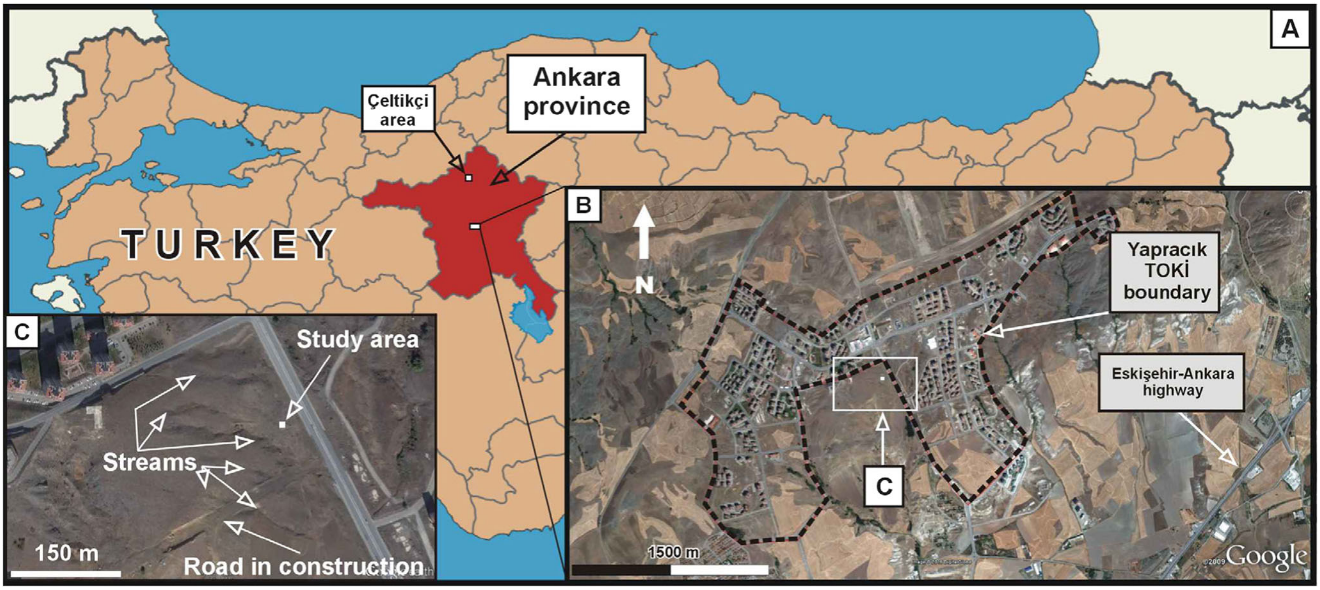

Fig. 1 (A) Location of the Ankara province and of the Yapracık TOKİ housing area. In Google Earth images are the (B) location of the study area and (C) drainage trends near the study area

not exist anymore, or so modified that they become useless. More interestingly, we sometimes discover new geological phenomena due to site excavations, requiring very fast intervention to those sites to be classified by geologists before they are covered by construction activities. We certainly positively evaluate the tasks done for the housing activities, but also think that the loss of some geological exposures, those particularly near to large cities, is crucial since they might have filled some blanks in our knowledge, or also may be used by future generations to alternative

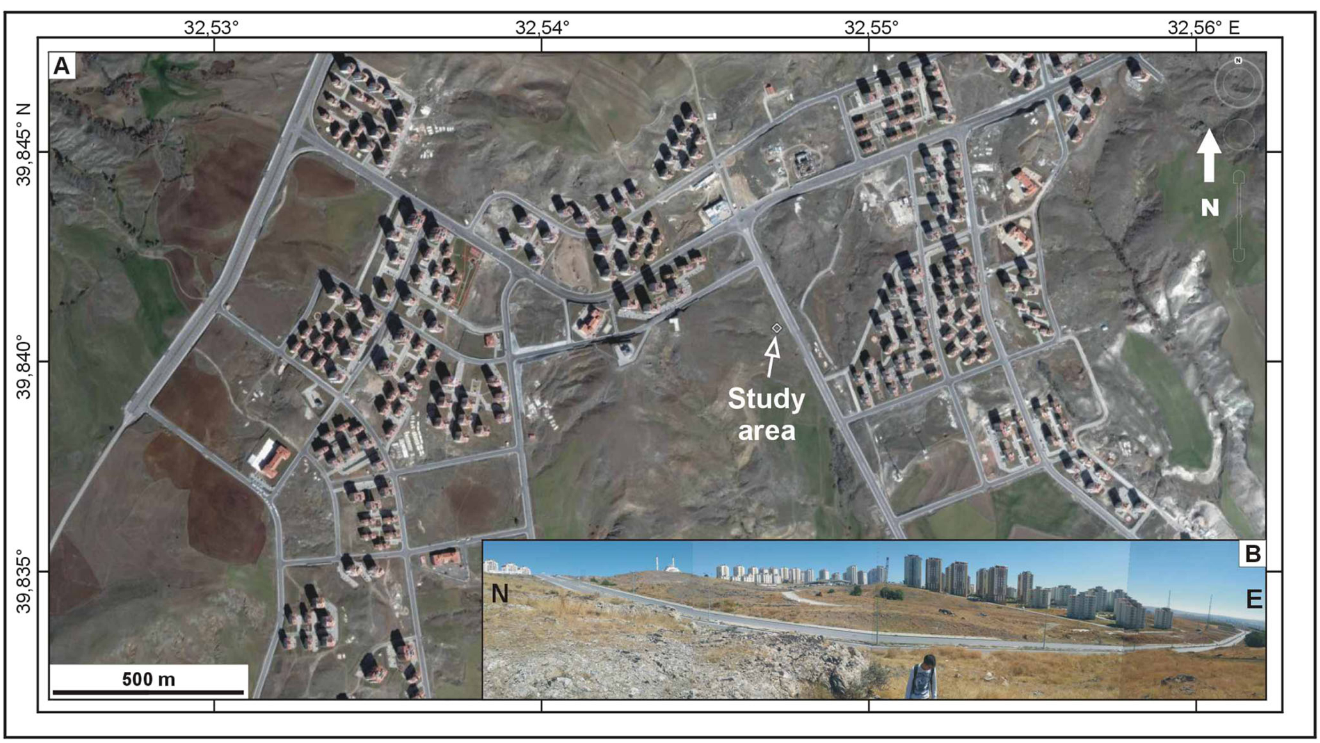

Fig. 2 (A) Google Earth image showing the location of the study area in Yapracık TOKİ. (B) Panoramic view to northeast from the study area. In the middle bottom of the photograph, our third author is near the outcrop

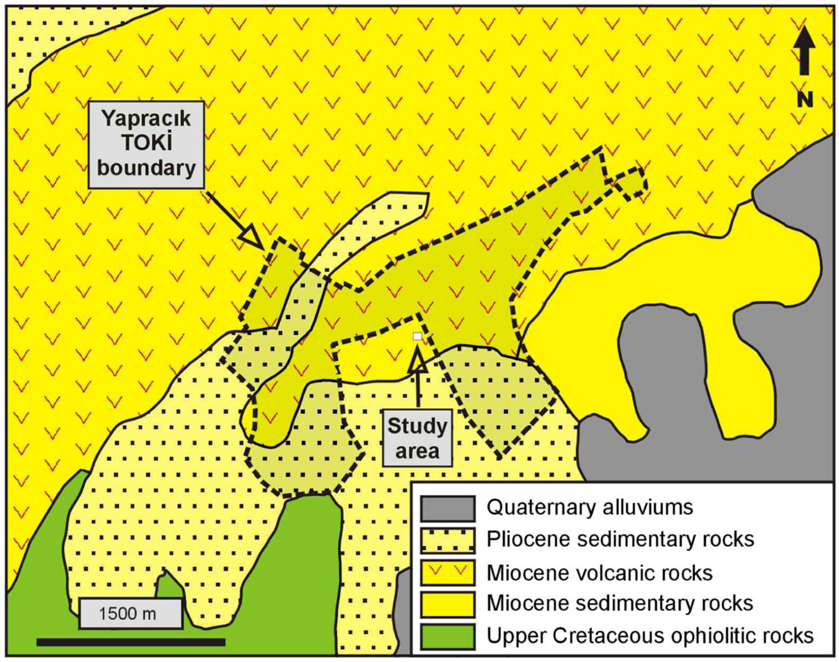

Fig. 3 Geological map of the area near the Yapracık TOKİ (MTA 2002)

hypotheses on geological history of the region. In this paper, we will try to increase the sensibility of our colleagues to pay more attention to this concept by also proposing a fast methodology that may be applied to such cases, emphasizing especially the role of collecting paleontological, mineralogical, and structural data, and obtaining high-resolution field photographs or movies by handy cameras and/or using unmanned vehicles like drones, now easily available, cheap, and easy to use, to construct 3D models of the sites. We hope that some of such disappearing treasures of the geological past may somewhat be saved and used to better understand the geological history of the region.

The Yapracık TOKİ Case of Ankara

Almost each year, we visit field areas near Yapracık, a village at the western vicinity of Ankara (Fig. 1). This site is interesting since it offers to study pedagogically geological features of Mesozoic ophiolitic rocks, and their cover consisting of shallow marine clastics and carbonates of Late Cretaceous age, and Miocene continental sedimentary and volcanic rocks (MTA 2002). In one of these field-training works, we have been near the TOKİ district and did our mapping activities within Miocene lacustrine carbonates and andesitic rocks. In a location where volcanic rocks display systematic fracturing near the Yapracık TOKİ site (Fig. 2), we have collected fracturation data by hand camera and also have measured by compass the fractures of the site, supposing that this site, still intact, may be used and modified for, for instance, recreational area for the nearby Yapracık TOKİ site. In the following, we present the data of this site in a manner that data collected from the site would be necessary in the future to better understand some characteristics of the local and/or regional geology.

Regional Geology

The study area is at the NW of Central Anatolia, in Turkey, where the major geological events are the latest Cretaceous closure of the Tethyan Ocean and obduction of its oceanic material onto the Anatolian crust, and the Miocene initiation of large lacustrine depositional areas accompanied with a widespread magmatic activity (Fig. 3). Loose Plio-Quaternary clastic rocks overlie these older units. One of the largest Early Miocene magmatic activity occurred at the northern vicinity of the study area, at the Çeltikçi district (Fig. 1(A)) (the Galatean volcanic province, e.g., Wilson et al. 1997), where the syntectonic pyroclastic activity is associated with a broadly N-S trending crustal stretching (Adiyaman et al. 2001; Yürür et al. 2002).

Site Characteristics

The TOKİ emplacement stands on mainly dark-colored andesitic and, in places, basaltic rocks. These volcanic rocks do not reveal the tectonic characteristics of the Early

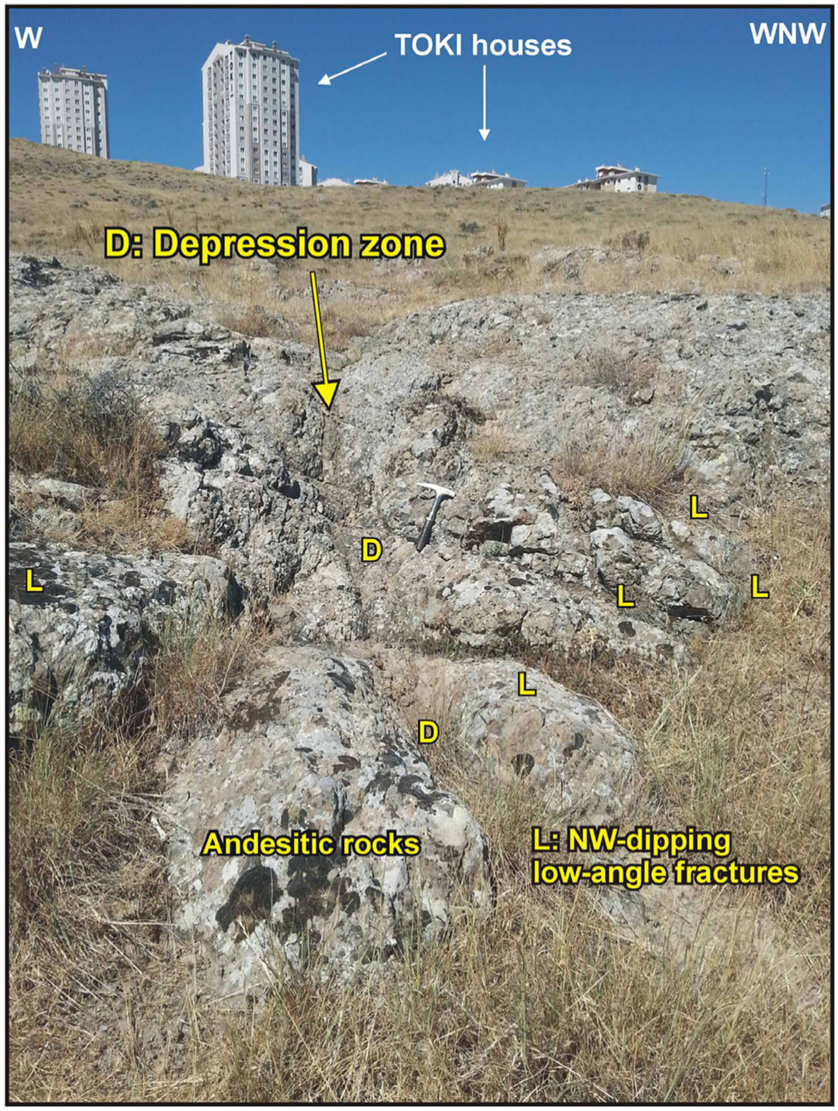

Fig. 4 Field photograph of the study area, showing the depression zone

Miocene period with the exception of a small exposure where a relatively linear depression of metric scale (Fig. 4) is associated with systematic fractures. The depression is floored by a subvertical fracture zone that displays characteristics of faulting, with secondary subvertical fractures joining the main fracture zone by low angles that may be interpreted as Riedel fractures. However, there are no striations along the fracture zone. In the presence of such systematic fracturing at the site, we do think these fractures to develop by jointing due to local faulting. Keeping in mind that the area may be used and modified by later activities, we have collected data from this site to present this structural observation to our colleagues in order to increase their sensibility to the geological heritage that, once modified, will never be recovered.

We emphasize the role and importance of the data to be collected and saved in a 3D format, the best tool for discussions particularly of structural data in further research on local and/or regional scales. We did this with a hand camera, with the highest resolution available and seeking to have about 30% overlapping between consecutive photographs to construct good 3D models. Drones also may be used, especially if they are equipped with high-resolution cameras. Using the field photographs and digital photogrammetry software, we have prepared a few digital 3D models: (1) a small-scale digital shaded terrain model (Fig. 5a, b), (2) a textured model, where the terrain model is draped with hand-held camera field photographs (Fig. 5c, d), and (3) a tentative tectonic model (Fig. 8) constructed with structural data collected in the field (Figs. 6 and 7). Finally, we propose a schematic model concerning what can be done in cases of risk for the geologic heritage (Fig. 9).

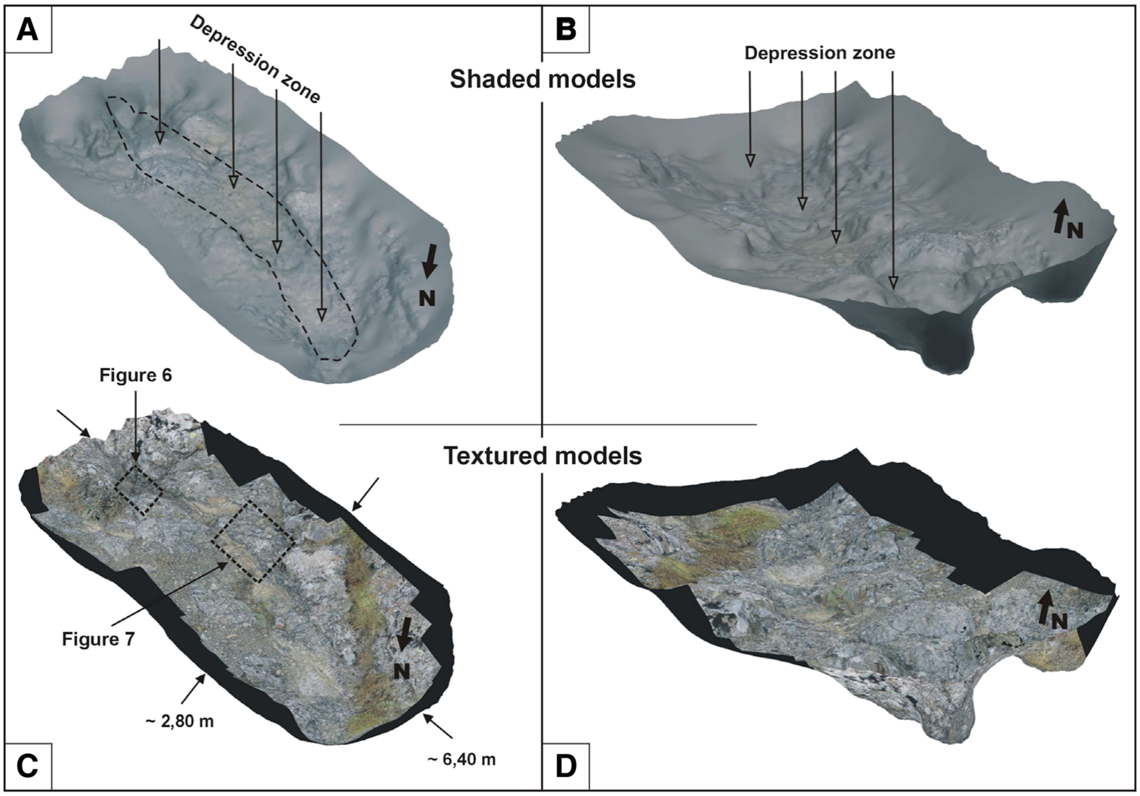

Fig. 5 **a**, **b** Shaded models. **c**, **d** Textured models of the study area obtained using overlapping field photographs

The data acquired from the site should also include some representative rock specimen that might be used to prepare thin sections that may be digitized, and the site may finally be "saved" in a digital format. It would be better to keep rare objects, like characteristic microfossils, to be classified in geological departments of the region.

Field Observations

Morphologically, the outcrop is easily distinguished in the field in the presence of an almost linear depression (Fig. 4), cutting through NE trending and NW dipping, mainly low-angle (e.g., N 63° E/18° NW) and, in places, high-angle dipping (e.g., N 53° E/56° NW) fractures of the andesitic rocks (the outcrop GPS location is 461,309 m E, 4,410,132 m N, on the 36 S zone of UTM WGS 84 projection, at an elevation of 1149 m above sea level). Trending N 78° W and about 5 m long and 80 cm wide, the depression is made up of several subvertical and closely (a few centimeters) spaced fractures.

Structurally, the intersection of the fracture zone with high- and low-angle NW dipping fractures is complex, and in the field, we have been able to find pieces of evidence only in two locations to understand this fracture zone associated with the depression. In the first location (Fig. 6), two differently dipping fractures are observed to terminate against the main fracture zone: one of them (L in Fig. 6) corresponds to a low-angle fracture (N 59° E/23° NW), and the other (S in Fig. 6), a subvertical one (N 55° E/ 84° NW). The type of the subvertical fracture is not clear at the outcrop, but its position suggests left-lateral movement along the main fracture zone. In the second location (Fig. 7), several subvertical shear and tensional fractures (S and T respectively in Fig. 7), some of them open about 1 to 2 mm wide, terminate against or come near the fracture zone. The position of the tensional fractures, also along with that of the shear fractures, implies left-lateral displacements along the main fracture zone. Some of the tensional fractures are observed to be sinistrally offset by very small (almost millimetric) displacements and/or dragged by a fracture of the main zone (letter F in red circles in Fig. 7).

Interpretation of the Outcrop Observations

The main structural issue with the andesitic outcrop is the absence of fault striations along fracture surfaces, and our tectonic interpretation of the site remains, however, hypothetic. We somewhat believe that the pronounced morphologic signature of the subvertical fracture zone and the position of the shear and tensional fractures relative to the main fracture zone, also subvertical structures, most probably structurally associated to the main fracture activity, strongly

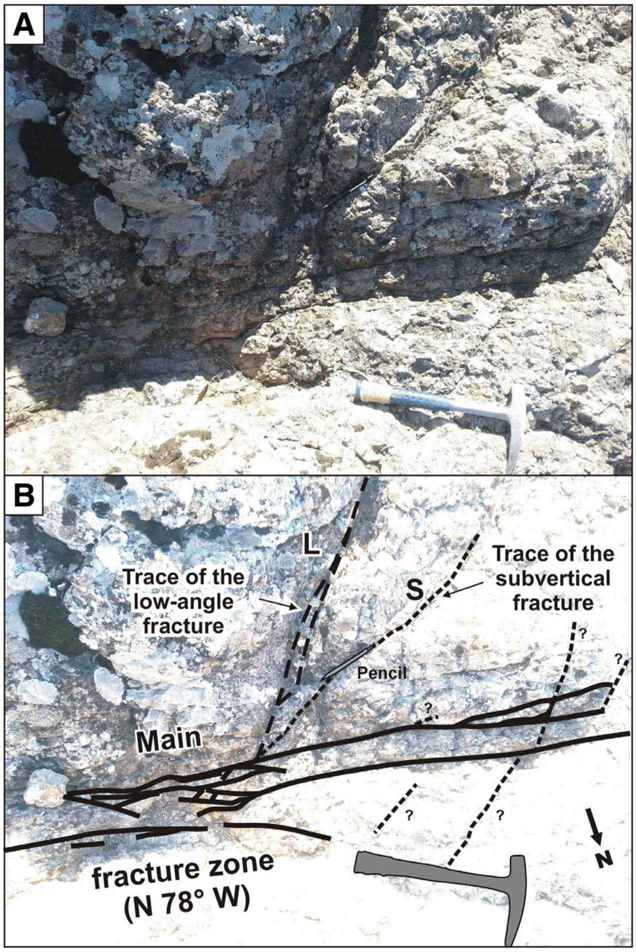

Fig. 6 **a**, **b** Field photograph of a part of the main fracture zone (MFZ) where secondary fractures have different dips. The subvertical secondary fracture (S) is more likely to be structurally associated with the subvertical MFZ. L low-angle dipping fracture

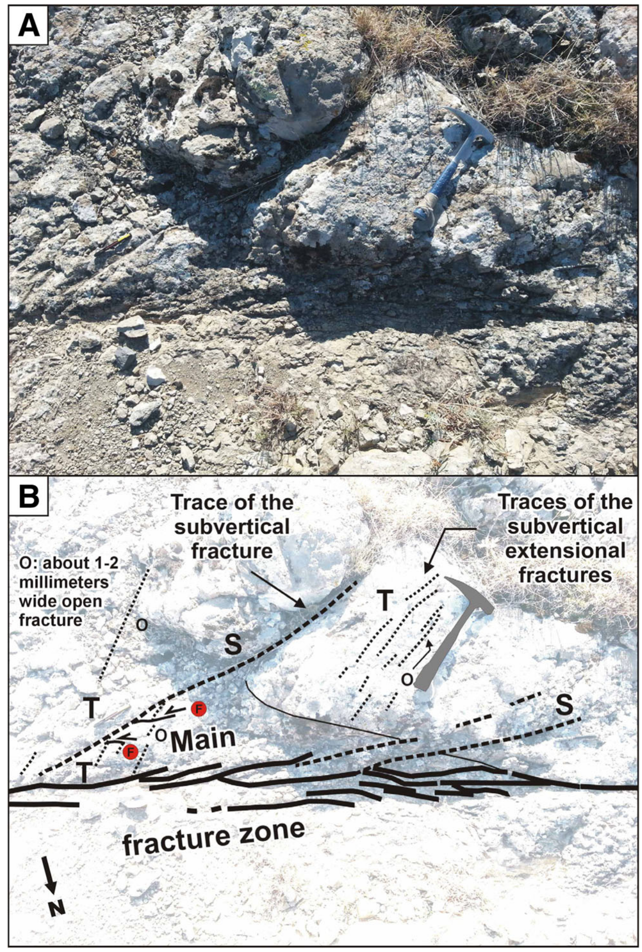

Fig. 7 **a**, **b** Field photograph of a part of the main fracture zone (MFZ) where secondary tensional and shear fractures suggest left-lateral fault movements along the MFZ. Letter F in red circle denotes small left-lateral displacement and dragging features

suggest a fault origin to this zone. The position of both tensional and shear fractures indicates left-lateral fault kinematics to the fracture zone that floors the depression zone (Fig. 8).

Concerning the low-angle and high-angle NW dipping and NE trending fractures, one may interpret them as the cooling fractures associated with the volcanic activity. Alternatively, the appearance of their systematic low- and high-angle dipping, with more or less flat surfaces, suggests a tectonic origin: they may be the synthetic and antithetic fault surfaces developed in an earlier tectonic phase (Fig. 8), possibly similarly to normal faults associated with the contemporaneous (Early Miocene; Wilson et al. 1997) northern Kızılcahamam pyroclastic activity, within an approximately N-S crustal stretching regime (Yürür et al. 2002). That the left-lateral strike-slip fault zone cuts through these fractures means that it postdates the volcanic activity, and whether its formation is linked to active faulting, in a seismically active region, is completely unknown. Microseismic studies may help to understand this point, very important for a location where intense housing occurs.

Conclusion and Discussions

In countries where the landscape experiences large modifications due to human activities, such as extensive housing works in Turkey, we propose a simple method to save geological characteristics for regions particularly potentially subject to geological destructions. In summary, the method aims to collect, along with classical field work, high-resolution pictures by hand-held cameras or by drones, saved particularly in 3D models. We think that this approach will provide some help for future geological studies in such regions where the geological heritage is in danger.

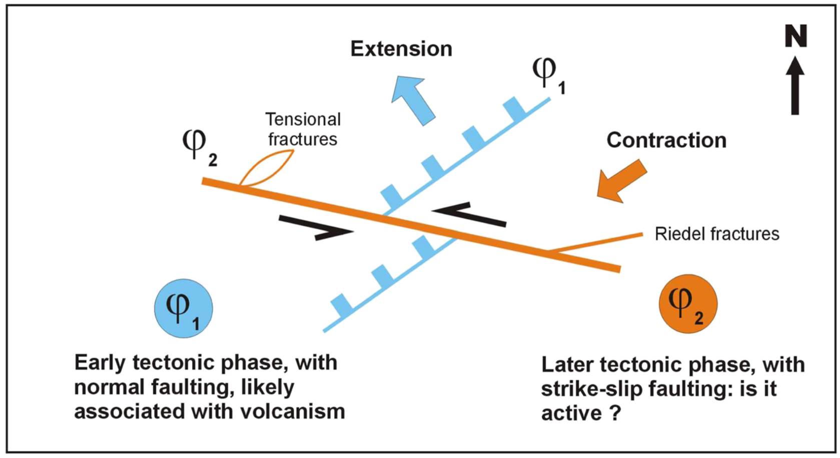

Fig. 8 Tectonic model deduced from field observations

As a case study, we present a zone near an extensive housing project, in Ankara, in the Yapracık town, where Miocene volcanic rocks outcrop. In a small area where the fracturing of the volcanic rocks appears to be related to regional tectonics, we have applied our methodology to several high-resolution photographs to model the zone of interest in 3D. We have collected samples and found that the andesitic rocks may have been deformed by approximately N-S extensional tectonics, in good agreement with previous works. Except for hand specimens, we have documented all data in 3D digital format, in a "Yapracık" folder, particularly in frequently used forms to be able to use them in the years to come.

We also compared our field-based observations in a Google Earth image. Knowing that the centimetric-size resolution of our field photographs cannot be reached in the present satellite imagery, we however see, in the Google Earth image, a series of E- and NW-trending streams (Fig. 1(C)). They may have developed using the fractures we have studied in this work and the correlation between high- and relatively low-resolution images may be fruitful to better understand some geological characteristics.

Conclusively and taking into account our experience, we propose a schema (Fig. 9) of the steps to take particularly in cases where geoheritage may experience modifications,

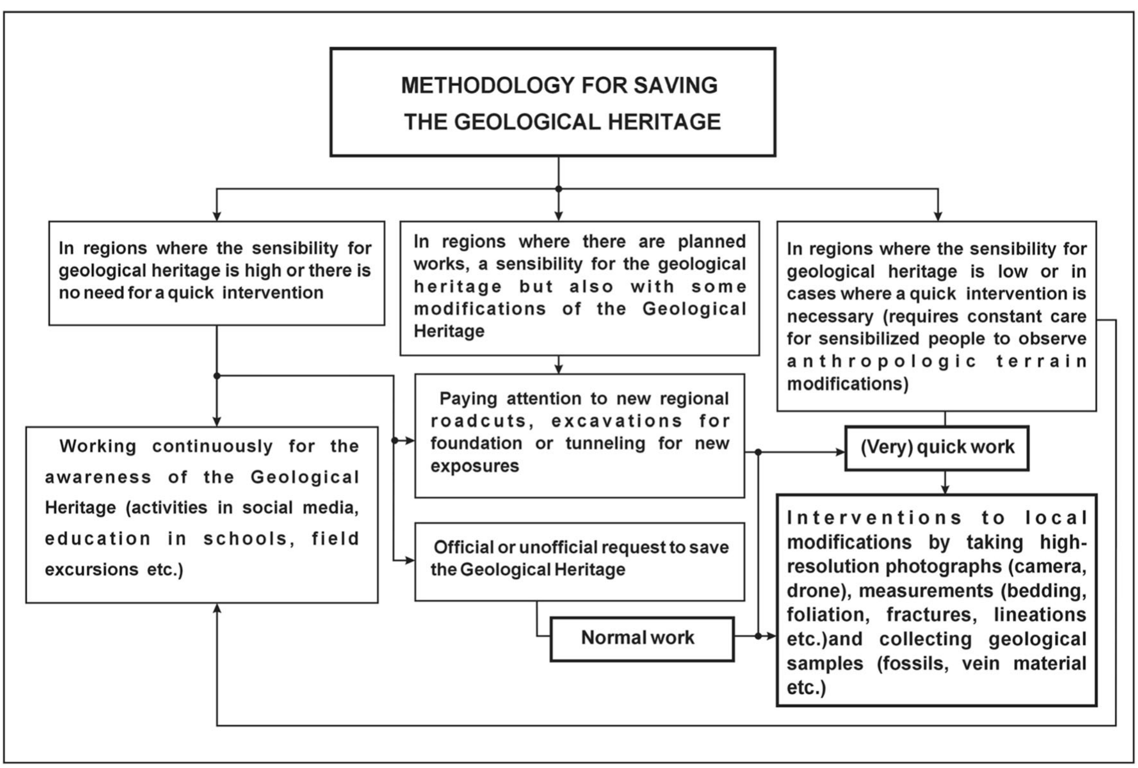

Fig. 9 Schematic diagram showing the possible steps to take when the geological heritage is in danger

knowing that its preservation but also its degradations are human activities, and that finally educational efforts should be deployed to sensibilize more people to this end.

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