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Travertine/tufa resource conservation and sustainable development call for a world-wide initiative

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ABSTRACT

Travertine/Tufa landscape is an important heritage and ecological wealth given to mankind by nature. Travertine/Tufa itself has excellent scientific and aesthetic value, mostly with geological archives such as volcanoes, tectonics, and glaciers, as well as fingerprints referring to climate and evolution of life. However, these travertine/tufa landscapes also face degradation and disappearance caused by climate change, natural disasters, and human activities. Strengthening the conservation and sustainable development of the world's travertine/tufa resources is not only a slogan, but also requires the creation of a linked platform for the conservation of travertine/tufa resources with the participation of people from all over the world. This implies the necessity of sharing of databases and technical reserves, and the involvement of more people in the conservation of travertine/tufa resources through the construction of travertine/tufa culture. By recognizing the urgency of travertine/tufa resource conservation, this paper proposes four initiatives for travertine/tufa research aimed at guiding further research and promoting international cooperation to achieve effective conservation and sustainable development of the world's travertine/tufa resources.

1. Background

Nature is the most precious and easily squandered asset around us, and the travertine/tufa resources within it deserve global cooperation for multidisciplinary research and conservation (Fig. 1). The area of carbonate rocks is 15.2% of the global ice-free continental surface, and the travertine/tufa landscape is located in the key zone of a unique supergene system with natural diversity and biodiversity(Goldscheider et al., 2020). And it is characterized by typical-complex-abundant, unique mountain-water-forest landforms and environmental ecology (Dong, 2021). It is a good paradigm for reflecting certain historical segments of the earth's evolution (such as life records, crust movement, geomorphological evolution, morphology, physiographic features, etc.), exemplifying the development and evolutionary processes of terrestrial-freshwater-biome-forest ecosystems(Cantonati et al., 2016). In particular, travertine is even an outstanding example of global nature conservation symbols and endemic species, natural and aesthetic landscapes that form scenic beauty and demonstrate their outstanding value as a World Natural Heritage site(Zhang et al., 2012). Famous Travertine World Natural Heritage sites include Jiuzhaigou and Huanglong in China, Pamukkale in Turkey, Mammoth Hot Springs in Yellowstone National Park in the U.S.A., Plitvice Lakes in Croatia, and Tivoli Hot Springs of Rome in Italy (Fig. 2). They are all important local tourism and cultural heritage resources, bringing huge socio-economic benefits to mankind.

However, with the evolution of the earth itself, the warming of the

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climate, and the intensification of human activities, travertine/tufa landscape is moving in the direction of degradation. Research proves that the Holocene decline in travertine/tufa development might be mostly driven by human activity(Dabkowski, 2020). For example, Pamukkale in Turkey has been strongly affected by human activities, and the landscape has been severely damaged(Acikel and Ekmekci, 2016; Cukurluoglu, 2017). In particular, the earthquake caused serious damage to the travertine/tufa, and the characteristics of the "sponge geological body" of the travertine/tufa(the porous geological structure of travertine/tufa gives them "sponge" properties) also made it respond very violently to disasters(Dai et al., 2019). The Jiuzhaigou earthquake in China caused landslides, cave-ins, and mudslides to fill the lakes and rivers of the travertine, with two core landscapes, the Norilang Waterfall and the Huohua Sea, severely damaged(Wang et al., 2018). In Yellowstone National Park, the United States, the earthquake caused the hot spring to stop flowing(Fouke, 2011). The travertine lacked the hot spring-fed and the co-deposited microorganisms died in large numbers. The travertine body changed from yellow-orange to gray-white. The earthquake not only caused damage to the superficial strat but also to the subsurface rocks, strata, structures, etc. Will it cause reversible or irreversible changes in the structure of the internal environmental system? What is ecological restoration for the increasingly serious phenomenon of travertine/tufa degradation and the growing demand for travertine/tufa conservation? Further, how about the ecology, original effect and lasting stability after restoration? Travertine/Tufa experts have different views on these issues, which has become a major subject attracting worldwide attention.

After sorting out the existing travertine/tufa research, it is found that it can be summarized into 8 aspects (Fig. 3a): (1) Types and distribution of travertine/tufa; (2) Study on the origin of travertine/tufa deposition; (3) Hydrochemical study of travertine/tufa landscape; (4) Paleoclimate reconstruction of travertine/tufa; (5) Study on travertine/tufa landscape features and landform evolution; (6) Microstructure of travertine/tufa geobodies; (7) Biological regulation of travertine/tufa deposition; (8) Travertine/Tufa landscape degradation and ecological conservation. It can be seen from Fig. 3b that in the early stage, travertine/tufa-related research was mainly based on hydrochemical research and origin research; in the mid-term, it mainly focused on the study of travertine/tufa structure, paleoclimate, and landform evolution; more recently, the focus has been on biological action, climate change and ecological conservation. For this, it is especially urgent and important to gather the research teams and forces of travertine/tufa around the world to investigate the natural travertine/tufa deposition mechanism and scenic mechanism, to study the damage degradation, and to explore the research and development of environmental conservation technology in the current process of travertine/tufa landscape conservation and sustainable development.

World Alliance for Research and Conservation of Travertine/Tufa Natural Heritage (WAT), jointly initiated by 22 organizations from Asia, the Americas, and Europe, discusses the relationship between global environmental change and karst action, as well as the ecological conservation methods and technologies of travertine/tufa and the conservation management research of the World Natural Heritage. In this short article, we emphasize the importance of travertine/tufa resource conservation and propose four initiatives for travertine/tufa research aimed at guiding further research and promoting international cooperation to achieve sustainable development of the world's travertine/tufa resources.

2. Establishment of a shared database for travertine/tufa research

Travertine/Tufa resources deserve global cooperation for multidisciplinary research and conservation(Klaić et al., 2018). From the perspectives of travertine/tufa geology(Fouke, 2011), hydrology(Carucci et al., 2012), biology(Wang et al., 2019), hydrochemistry(Pasvanoğlu, 2013; Sironic et al., 2017), ecology environment(Li et al., 2014) and heritage conservation(Altunel and D'Andria, 2019), etc., carry out

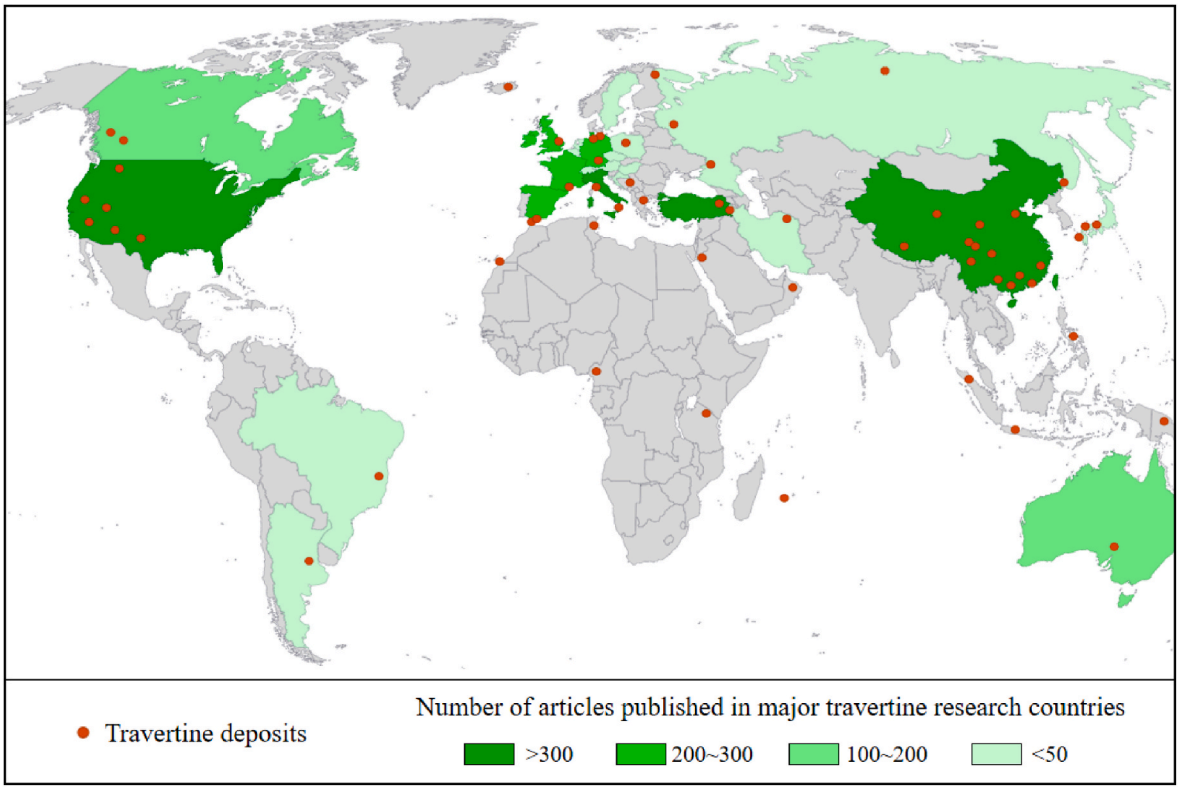

Fig. 1. The distribution of travertine/tufa in the world and the number of articles published in major travertine/tufa research countries.

investigations on the distribution, characteristics, and causes of travertine/tufa resources, and jointly build a shared database for world travertine/tufa resources research. This provides scientific support for the conservation and utilization of travertine/tufa resources, as well as a reference for more in-depth work of the majority of travertine/tufa researchers.

3. Create a linkage platform for travertine/tufa resource conservation

As a unique geological body in the karst system, travertine/tufa constitutes a geology-environment-biology system that is an important site for carbon cycle research(Walter et al., 2020) and an important information carrier for paleoclimate(Martin-Bello et al., 2019), paleoenvironment(Alexandrowicz et al., 2018), and special geological events (Gradzinski et al., 2014). Enhanced international collaboration can effectively promote researchers to view travertine/tufa issues from a global scale and multidisciplinary intersectional perspective. WAT can promote direct dialogue between travertine/tufa researchers and travertine/tufa scenic spots around the world, and exhibit all-around cooperation and sharing around travertine/tufa scientific research, tourism, management, science popularization, etc., to build international cooperation and linkage platform for the vast number of travertine/tufa researchers.

4. Construct travertine/tufa ecological conservation technology reserves

The superimposed effects of human activities, biological actions, and geological disasters on the travertine/tufa are increasing(Liu, 2017; Megerle, 2021). It is recommended to concentrate the global travertine/tufa scientific research forces to carry out technical research, jointly carry out continuous research on travertine/tufa ecological restoration and conservation technology, and provide technical reserves for the ecological conservation and sustainable development of travertine heritage. This will provide a world paradigm and scientific basis for the preservation, protection, evolution, and later restoration and conservation of travertine heritage.

5. Lead the construction of world travertine/tufa culture

Travertine/Tufa landscape is an important heritage and ecological wealth endowed by nature to human beings. Relying on the existing key travertine/tufa natural resources, it is suggested to speed up the deployment and preparation of “field observation stations” and “research centers” on a global scale, and build a series of world travertine/tufa natural sample banks. At the same time, we should create an international main position for travertine/tufa scientific research and popular science, actively create a travertine/tufa cultural atmosphere, and guide the development of travertine/tufa culture. In this way, more people can participate in the cultural exploration and resource protection of travertine/tufa around the world.

6. Prospects

The conservation and sustainable development of the world’s travertine/tufa resources require the participation of all parties. WAT is a non-profit social organization formed by global universities, research institutes, and travertine/tufa natural heritage management units based on the principles of voluntariness, equality, integrity, and win-win. The purpose of WAT is to concentrate global travertine/tufa scientific research forces and to share databases and ecological conservation methods and technologies around travertine/tufa landscape heritage protection, resource development, cultural tourism, etc. It also aims to reach a consensus on industry, academia, and talent in international travertine/tufa research and conservation, and focus on the cooperation between industry, academia, and research. It is to better study and conserve the world’s travertine/tufa natural heritage on a global scale.

The travertine/tufa in the world is more concentrated between 30° and 50° north latitude, with abundant resources and various forms. The research and protection of travertine/tufa resources requires the participation of more researchers. Taking biology, minerals and water as the object, around the four perspectives of ecology, geology, landscape and climate, it relies on the cross-integration of many disciplines such as sedimentology, ecology, isotope chemistry, and hydrochemistry. In this way, researches on 7 directions of travertine/tufa deposition and its co-evolution with organisms, environmental geology, ecological conservation and climate inversion are carried out (Fig. 4). At present, its sedimentary genesis and classification, biological characteristics,

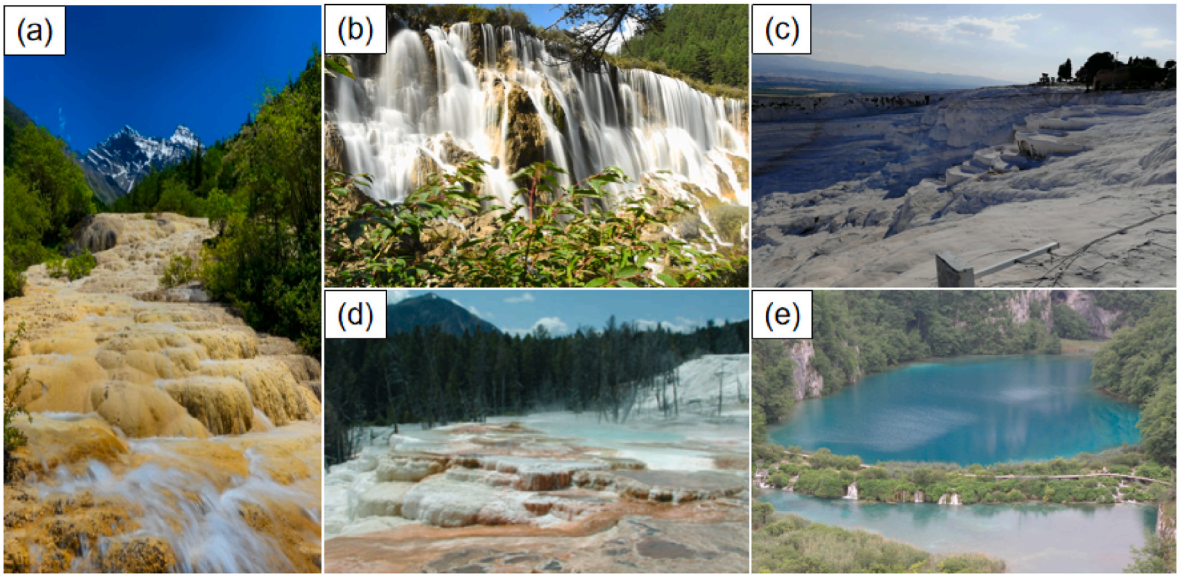

Fig. 2. World Travertine Natural Heritage Landscape
(a: Huanglong, China; b: Jiuzhaigou, China; c: Pamukkale, Turkey; d: Mammoth Hot Springs, Yellowstone National Park, the U.S.A.(Fouke, 2011); e: Plitvice Lakes, Croatia(Ivkovi et al., 2020)).

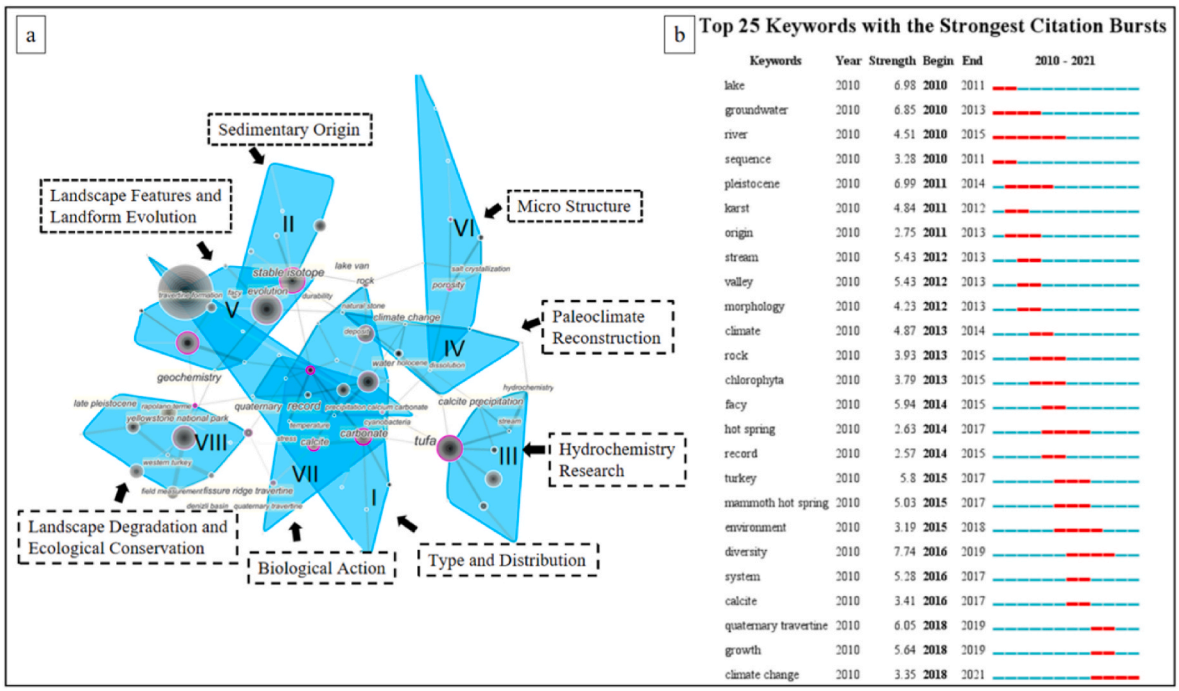

Fig. 3. Overview of travertine/tufa research directions.

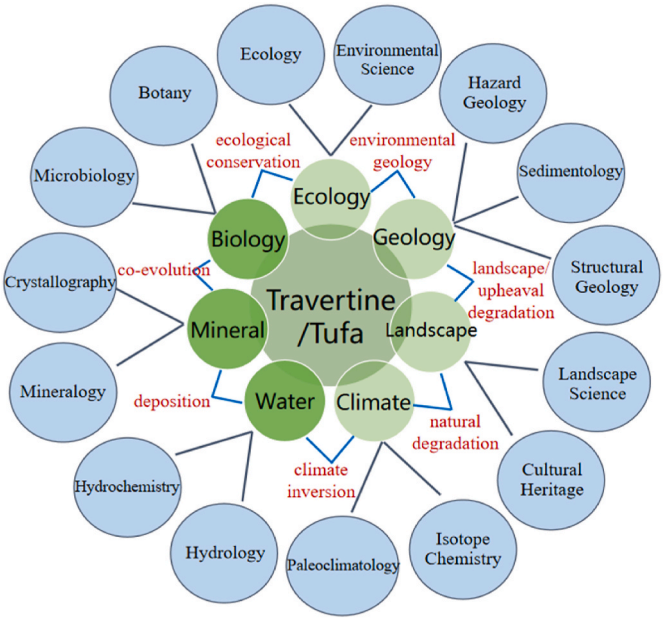

Fig. 4. Interdisciplinary research on travertine/tufa.

geology, and hydrology have been deeply studied. In the next step, researchers should do more work on travertine/tufa's contribution to global climate change, paleoclimate effects, carbon cycle and carbon storage, and degradation and conservation. To better decode the many scientific information contained in travertine/tufa, and to protect and continue the travertine/tufa landscape, it is imperative to strengthen multidisciplinary and cross-border cooperation.

World natural heritage is the commonwealth of all mankind, not only carrying the spiritual and cultural value of mankind but also related to the ecological security of the earth. It is necessary to carry out world karst research cooperation and protection at a new height and cooperate to explore the new future of travertine/tufa landscape and world natural heritage. The establishment of WAT is a landmark event, and it also indicates that the research and protection of travertine/tufa and karst in the world have entered a new stage. Let experts with common interests all over the world unite, and we will join hands to make more contributions to the research and protection of the world's travertine/tufa, a precious treasure of nature.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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