The potential role of the geosciences in contributing to the UN's Sustainable Development Goals

Murray Gray and Roger Crofts

ABSTRACT

In 2015, the United Nations adopted a series of 17 Sustainable Development Goals (SDGs) and 169 individual targets with the aim of achieving these within 15 years, i.e., by 2030. These ambitious goals include ending poverty and hunger, facilitating sustainable economic growth and social development, and protecting the environment. Using Gill and Smith (2021) as a major source, this paper outlines the potential role that the geosciences and geoscientists as geopractitioners can play in contributing to the achievement of the SDGs.

INTRODUCTION

In 2015, the United Nations adopted a series of 17 Sustainable Development Goals (SDGs; Figure 1) and 169 targets with the aim of achieving these within 15 years, i.e., by 2030. These ambitious goals include ending poverty and hunger, facilitating sustainable economic growth and social development, and protecting the environment. Although the geosciences were not included in the process of developing the goals, Gill (2017) produced a matrix showing how

Ouzoud Falls, M'Goun UNESCO Global Geopark, Morocco KASMII

Figure 1. The UN's 17 Sustainable Development Goals.

aspects of the geosciences could help contribute to achieving many of them. The aspects included agrogeology, climate change, energy, engineering geology, geohazards, geoheritage and geotourism, hydrogeology and containment geology, and minerals and rock materials. In effect, Gill was demonstrating the importance of geodiversity to sustainable development. This idea was taken further by the Geological Society of London in producing a poster that shows how the many geoscience subdisciplines relate to the SDGs (Figure 2). But the most important publication in this regard is the book edited by Gill and Smith (2021), which has a chapter on the relevance of the geosciences to each of the 17 SDGs plus a summary chapter. Using this book as a main source, this paper aims to summarize how the geosciences have the potential to contribute to achieving these important goals. Although this paper, and indeed Gill and Smith, use the terms *geoscience* and *geoscientists,* what are really required are *geopractitioners,* i.e., those who have knowledge and experience in achieving better environmental outcomes from their input, rather than a purely scientific approach. As we shall see, there are strong overlaps between many of the goals, which we discuss in order below. Unfortunately, the COVID-19 pandemic has made their achievement even more difficult.

1. NO POVERTY

The full title of this goal is to "End Poverty in All its Forms Everywhere." *Poverty* is often defined as "the lack of resources needed to ensure dignity and survival." The World Bank estimates that as of 2015, an estimated 736 million people were living in extreme poverty, surviving on less than US$1.90 per day, while 3.4 billion (about half the world's population) live on less than $2,000 a year. Poverty hinders people from reaching their full potential, reduces life expectancy, increases vulnerability to economic and environmental shocks, and threatens access to food, safe drinking water, sanitation, shelter, health care, and education. Although poverty is universal, extreme poverty is concentrated in sub-Saharan Africa and South Asia.

Geoscience can both contribute to poverty and be a potential solution. For example, spatial poverty traps can be created in landlocked nations or remote mountainous regions. Climate can influence crop growth and water availability, while natural hazards disproportionately affect the poor. On the other hand, the presence of natural resources has the potential to promote economic wealth or reduce poverty for all citizens. These resources may include minerals, fertile soils, water, and energy resources. One of

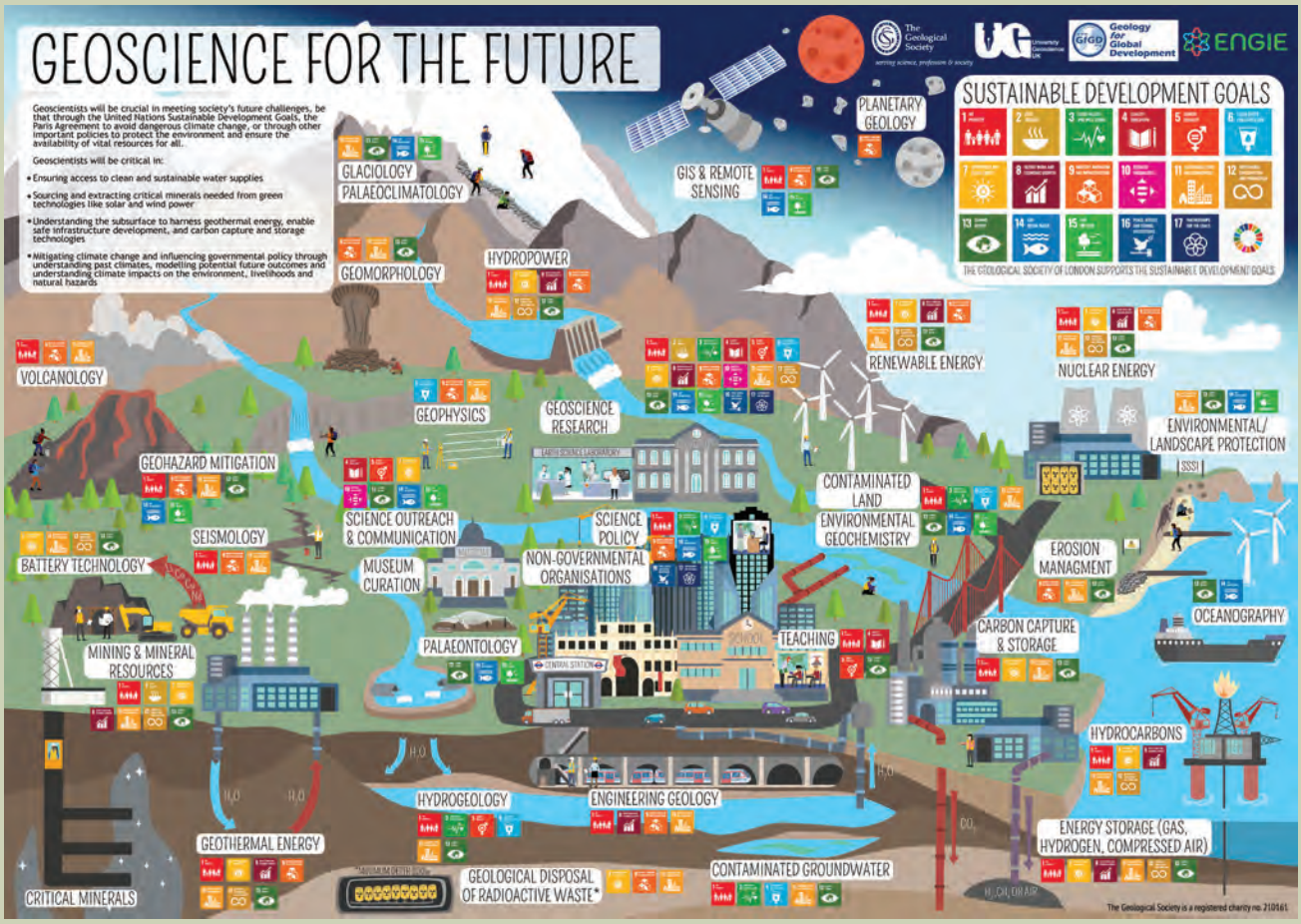

Figure 2. The Geoscience for the Future poster published by the Geological Society of London showing the 17 UN Sustainable Development Goals and the many geoscience subdisciplines related to the SDGs (https://www.geolsoc.org.uk/~/media/shared/documents/education%20and%20careers/Resources/Posters/Geoscience%20for%20the%20Future%20poster.pdf?la=en**).**

the ways to reduce poverty is to improve access to basic services and resources by identifying what and where the natural resources are—a particular skill of geoscientists—and then making use of these resources and managing them sensitively and sustainably, e.g., avoiding damage to water courses and groundwater. Geoconservation experts can help to identify and establish protected areas where the benefits of sustainable use of the area's natural resources are provided to local communities.

Sometimes geopolitical issues can influence the use of natural resources. For example, Afghanistan is a poor country, yet it has huge geological wealth that is as yet largely unexploited. This includes oil, coal, copper, gold, iron, and a huge range of gemstones. Geoscience and geoconservation experts have a responsibility to balance proposals for exploitation with protection of the resources and provision of benefits to communities.

2. ZERO HUNGER

Like poverty, and strongly related to it, hunger is concentrated in sub-Saharan Africa and South Asia, plus pockets in South and Central America. In 2017, the number of undernourished people reached 821 million, including 151 million children with stunted growth under the age of 5, with nearly 45% of child deaths being due to starvation. Increasing life expectancy, population growth, and rising incomes mean that food demand is increasing. Causes of hunger are diverse, involving both social and environmental factors, and may be exacerbated by environmental degradation and poor land management. Geoscientists can contribute to reducing hunger by advising on how to avoid soil degradation, improve soil structure/profiles, retain soil moisture, and sustainably manage land. These measures can contribute to improved agricultural productivity and resilience to environmental change. Of particular importance are the Land Care programs developed in Australia and delivered in countries

like Iceland, and nature-based solutions such as the United Nations University Land Restoration Training Program. In addition, terrestrial protected areas provide water and nutrients and thus can secure fertility of the land beyond their boundaries.

3. GOOD HEALTH AND WELL-BEING

The World Health Organization (WHO) defines health as "a state of complete physical, mental and social well-being and not merely an absence of disease." Good health requires a nutritious diet and is therefore related to SDGs 1 and 2, and also requires access to clean water, sanitation, good living conditions, and natural environments. It can also involve absence of exposure to toxins and infectious diseases, freedom from physical injury, and good access to healthcare. As previously stated, the COVID-19 pandemic has had a major impact on world health and the achievement of SDG3 and its targets is currently uncertain.

Geoscience can contribute to improving healthy environments, such as by understanding the origins and movement of pollutants through the environment. In addition, WHO (2021) has recently promoted the benefits of being out in nature. For example, increased contact with nature has been associated with lowering cortisol, blood pressure, and the risk of developing type 2 diabetes. Nature provides opportunities for stress reduction, physical exercise, and a physically active lifestyle; for restoration and relaxation; and for socializing with friends and family. Access to nature increases life satisfaction and happiness ratings (WHO 2021). Although frequently only green spaces or biodiversity are mentioned in connection with natural health benefits, they often come from access to diverse physical landscapes (Figure 3) or the physical exercise involved in hiking, hill walking, or rock climbing. There is increasing use of mobile geology and geoheritage apps and other new technologies that

Figure 3. A landscape in the West Coast National Park, South Africa.

give information and interpretation to visitors in the field, for example in the US national parks (Crofts et al. 2020). Geoconservation experts have a key role in helping to promote access to nature's special places, such as national parks and nature reserves.

4. QUALITY EDUCATION

Although access to education has been improving, there are still areas, particularly in sub-Saharan Africa, where children of primary school age are not in school or where girls are denied the right to any education. In its seven targets, SDG4 calls for inclusive, high-quality education; equal access for boys and girls; and education for sustainable development. According to Metzger et al. (2021: 87), geoscientists "possess vital and unique knowledge and skills that are essential to promoting sustainable development. These include multi-scalar spatial and temporal reasoning, systems thinking, interdisciplinary and collaborative problem-solving, and the ability to cope with uncertainty inherent in dealing with complex systems and incomplete data." Geoscientists also understand issues of deep time, climate change, land management, and resource depletion. Therefore, geoscience education in schools is particularly important. Geoconservation education can be added to school curricula so that children have a greater understanding of the whole of nature and its benefits for them. Though geology is not always included in the secondary curriculum, the geography curriculum usually does include many geoscience topics.

In 2008, UNESCO (the United Nations Educational, Scientific, and Cultural Organization launched the Earth Science Education in Africa Initiative, bringing together partners from universities, government agencies, and the private sector to direct projects and develop workshops with the aim of training the next generation of African geoscientists. The initiative, which concluded in 2015, included geological mapping training, geoscience education in schools, and increasing information on the health impacts of mining. The African Geoparks Network—part of a related UNESCO initiative, the Global Geoparks program—was created by the African Association of Women in Geosciences. Currently, there only two geoparks in Africa—M'Goun in Morocco and Ngorongoro Lengai in Tanzania—but the number is likely to increase in future.

5. GENDER EQUALITY

The full title of this SDG is "Achieve Gender Equality and Empower All Women and Girls." As Errami et al. (2021) point out, equality is a fundamental human right, but as with education, is sometimes denied to 50% of the population. SDG5 has targets of ending all forms of discrimination, violence, and harmful practices against women and girls everywhere; valuing unpaid care and domestic work; and ensuring equal opportunities for leadership roles, ownership of land and economic resources, and access to sexual and reproductive health. There has been progress on these issues in many countries and in the geosciences, but much remains to be done. Geoscientists need to take a stronger and more consistent role in promoting gender equality within their own ranks and in the realms in which they have influence. There are promising first steps to build on; of particular note are the Girls into Geoscience, African Association of Women in Geosciences, and Women in Mining Mongolia initiatives.

6. CLEAN WATER AND SANITATION

Access to clean water and sanitation is essential for health and social well-being. Diarrheal and other sanitation-related diseases remain a major cause of death in children under five. In sub-Saharan Africa, 50% of the rural population lacks basic water and sanitation services, with inadequate financing still being an issue. Water itself is very unevenly distributed around the world. In areas where rainfall is low, of major importance is understanding the groundwater resource in order to achieve climate resilient-water supplies. This is a field in which geoscientists can make a significant contribution through their understanding of the water cycle, issues of abstraction (withdrawal) rates, rainfall variation, climate change and likely recharge rates, groundwater flow, and the link between potential polluting activities at the surface and groundwater quality. In other words, whole catchment management and sustainable groundwater management is a key concept, one whose achievement is not helped by population growth and conflicts between countries over water abstraction and supplies. In addition, climate change and glacier loss are leading to reduced meltwater flows to some mountain communities, e.g., in the Himalayas. Developing the proposition of protected and conservation areas as the "water towers" to supply populations downstream remains an important and practical approach.

7. AFFORDABLE AND CLEAN ENERGY

SDG7 has the potential to contribute significantly to several of the other SDGs through enabling business, industry, agriculture, transport, communications, and healthcare to operate, as well as contributing to increases in living standards. Global primary energy consumption has been increasing since the Industrial Revolution, but has surged approximately 700% since 1950, largely through the use of coal, oil, and natural gas. Even so, in 2016 sub-Saharan Africa and South Asia had about 600 million and 200 million people, respectively, with no access to electricity. Even where local energy sources are available, many developing countries lack the infrastructure to develop their energy potential. There is also the issue of fossil fuel use and the global efforts to reduce it; many countries have the potential to develop renewable sources including solar, geothermal, and hydropower. Geoscientists can help to identify and design systems to use renewable energy sources in a nature-sensitive manner. For example, Icelandic geoscientists are helping to develop geothermal resources adjacent to the East African Rift Valley. Geoscientists can also contribute to the issue of the long-term storage of radioactive nuclear waste and identify opportunities for carbon storage and capture. Much will depend on finance and political will to exploit the existing resources.

8. DECENT WORK AND ECONOMIC GROWTH

Again, this SDG is strongly related to several others, because decent, well-paid jobs prevent poverty and hunger and lead to healthier, more fulfilling lives. Furthermore, strong, stable, and resilient economies are the key to sustainable development, inclusive social development and environmental integrity. The targets under SDG8 include a 7% annual growth in GDP in the least-developed countries, promoting sustainable tourism, and substantially reducing the proportion of youth not in employment, education, or training. The geoscience professions contribute substantially to economic growth by helping societies identify and develop their natural resources, including groundwater and minerals, that underpin economies and are essential to the manufacture of goods and provision of services. Geoscience is also a strong base for much sustainable (geo-) tourism in protected and conserved areas including, but not restricted to, UNESCO Global Geoparks.

9. INDUSTRY, INNOVATION, AND INFRASTRUCTURE

These 3 "i" topics are important in delivering jobs and developing the economic growth of SDG8. For example, in Africa poor transport infrastructure can add 30–40% to the cost of trading goods. Similarly, reliable energy supplies, water and waste infrastructure, and fast telecommunications are necessary for industrial expansion and economic growth. Resilient infrastructure and industrial facilities require a rigorous understanding of ground conditions, availability of suitable materials for construction, and surface geomorphological processes/hazards likely to affect the projects. As regards innovation, there is significant variation in the resources allocated to research and development across countries, and this needs to be addressed particularly across the Global South. Help from experts based in industrial countries, through for example Earth science societies, should be considered.

10. REDUCED INEQUALITIES

The full title of this goal is "Reduce Inequality Within and Amongst Countries." In other words, the aim is to reduce the gap between the richest and poorest, and hence this goal has a strong link to SDG1 and other goals by "leveling up" within and between countries. But this goal goes beyond economic inequalities to include social inequalities as well, because "income inequality reinforces social inequality and vice versa" (Moreano and Gill 2021). Thus, the goal's targets include ensuring equal opportunity and reducing "inequality of outcome, including by eliminating discriminatory laws, policies, and practices and promoting appropriate legislation, policies and action in this regard." As with SDG5 on gender equality, the main contribution geoscience can make to this goal is through introspection and self-reform—in this case, by making sure that poor people are not shut out of the benefits from intellectual advancements because of an inability to pay for access. Moreano and Gill (2021: 250) argue that in contributing to this goal, "Geoscientists may need to make changes to the systems that determine access to knowledge, education and tools. This could be in terms of geo-scientific data, publications arising from the analysis of that data or the training courses that enable effective professional practice. Geoscientists also need to think about how to foster equality through inclusive work environments and the

questions addressed in their research." Moreano and Gill also believe that tackling inequality requires pro-poor economic growth, redistribution of resources, progressive taxation and pricing, and removal of discrimination.

11. SUSTAINABLE CITIES AND COMMUNITIES

In 2018, 3.5 billion people or 55% of humanity lived in cities (Figure 4) and both these numbers are increasing due to rural-to-urban migration and population growth (Smith and Bricker 2021). Despite occupying only 3% of the land surface, cities account for over 70% of energy consumption and carbon emissions and are therefore major contributors to climate change. Smith and Bricker ask what the world's growing cities, particularly in the Global South, will look like in 2030. "Sprawling, chaotic slums—with poor health from uncontrolled emissions and impoverished food and water—or clean, healthy environments with data smart efficient transport systems enabling the flow of people and resources?" (Smith and Bricker 2021: 261). They therefore argue that SDG11 is a key global challenge. The role of the geosciences will be important in planning city growth; for example, in understanding ground conditions and groundwater aquifers, avoiding hazardous areas and undertaking risk assessments, identifying sources of building material, and avoiding the sterilization of mineral resources through building on top of them.

12. RESPONSIBLE CONSUMPTION AND PRODUCTION

Global demand for natural resources is rapidly increasing as countries seek to develop their economies and improve the living standards of their populations. Global material use tripled between 1977 and 2017, by which time it had reached 92 billion tons. Over half of this is in the form of low-cost construction aggregates rather than the more

Figure 4. Rio de Janeiro from Corcavado.

economically valuable metals, energy minerals, or gemstones. The lower-value minerals, because of their bulk, are generally used close to their source and have a crucial role to play in supporting local economies, particularly in the developing world (see Franks 2020). The ACP-EU project is an initiative of 79 African, Caribbean, and Pacific States (APC) with whom the European Union has a special trade relationship financed to the tune of €13.1 million by the European Commission and United Nations Development Program (UNDP) (Franks 2020). The aims of the initiative are to build capacity and improve the management of development minerals, including industrial minerals, construction materials, dimension stones, and semi-precious stones. Franks (2020) gives examples of projects and how they relate to the SDGs. Geoscientists clearly have a crucial role here in identifying future mineral resources, promoting their sustainable use and reducing the environmental impacts of mining. The geoconservation community could take the lead in developing protocols for good working practice in the development of natural resources.

Geoscientists also need to play a role in transitioning to a circular economy in which the use of primary resources is minimized by reuse and recycling of materials, thus also minimizing the disposal of material as waste. The recent *Circularity Gap Report 2020* (de Wit et al. 2020) showed that of the 100 billion tons of annual resource entering the global economy, over 75% is abiotic (e.g. minerals, ores, fossil fuels) but only 8.6% is recycled, down from 9.1% two years previously. As geoscientists, we therefore have a responsibility to future generations to provide expertise on how to use the earth's resources more sustainably than is done at present.

13. CLIMATE ACTION

"It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred" (IPCC 2021). This strong statement from the Intergovernmental Panel on Climate Change is mirrored by several climate-induced disasters in recent years, including flooding, hurricanes and storms, and wildfires. There are two complementary approaches to dealing with the effects of climate change—mitigation and adaptation in both of which geoscientists can play a role. Mitigation refers to actions taken to reduce emissions of greenhouse gases to the atmosphere, including the use of carbon capture and storage. Adaptation is the process of adjustment to the expected effects of climate change. These two approaches are complementary in the sense that increased mitigation makes adaptation both more likely and cheaper.

Geoscientists can play a role in climate action. In particular, they have unparalleled insight into climate and environmental change through the 4.6-billion-year history of Earth. They are therefore in a strong position to contribute to understanding the decoupling of human and natural causes of climate change. Geoscientists also play a leading role in promoting and developing the use of carbon capture and storage in sub-surface rock reservoirs; in developing renewable energy resources, including geothermal energy; and in understanding the impact of climate change on geomorphological processes and surface hazards. On this last point, geoscience has a clear role to play in the UN's Sendai Framework on Disaster Risk Reduction, which emphasizes climate change as a major driver of hazards and promotes international cooperation and early warnings in order to reduce mortality, damage to property and critical infrastructure, and economic loss.

14. LIFE BELOW WATER

This short title is somewhat misleading as the full title of SDG14 is "Conserve and Sustainably Use the Oceans, Seas, and Marine Resources." The fact that our oceans and seas cover over 70% of the planet and make up 97% of the water on Earth means that they are of immense importance to the functioning of the planet. They are complex ecosystems with significant biodiversity; play a critical role in regulating the earth's heat budget, with ocean currents transferring heat from low to high latitudes; and absorb carbon dioxide from the atmosphere, thus helping to mitigate human-induced climate change. On the other side of the climate coin, ocean floors and sub-surfaces are a source of oil and gas, along with a range of other minerals and aggregates. Elements can also be extracted from polymetallic sulfides (copper, lead, zinc, gold, silver), cobalt-rich crusts (cobalt, nickel, copper, tellurium, platinum, and rare earth elements) and manganese nodules (manganese, cobalt, copper, nickel, molybdenum, lithium and rare earth elements). Oceans and seas can also be used to generate renewable energy from wind, tidal and wave sources.

Protecting the oceans from pollution and degradation and promoting their sustainable use is therefore of vital importance to humanity. Unfortunately, the oceans have been deteriorating for many years through overfishing, plastic and other pollution, acidification, and heating affecting coral reefs. Geoscientists can play a role in many marine and coastal issues, including predicting future sea level rise and its impact on low-lying countries and communities, studying the rates and causes of coastal erosion (Figure 5), advising on the sustainable extraction of sea-bed minerals, and establishment and management of marine protected and conserved areas for both biodiversity and geoheritage, within and beyond countries' exclusive economic zones.

15. LIFE ON LAND

The aim of this SDG is to "protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation and halt biodiversity loss." Geoscientists can play a key role here in promoting the "Conserving Nature's Stage" approach (see Gordon et al., this volume). This uses the metaphor of biodiversity being the actors whose distribution is often largely dependent on the physical geodiversity of the stage. A wide range of abiotic habitats is needed to enable species to adjust their distributions, particularly as climate changes. Knowledge of geology, geomorphology, hydrology, and pedology can inform conservation and restoration programs, but requires better partnership between geoscientists and ecologists. Of particular note is the importance of input from geoconservation experts in the identification, designation, and management of protected areas (Crofts et al. 2020).

16. PEACE, JUSTICE, AND STRONG INSTITUTIONS

War, corruption, and weak institutions work against the delivery of sustainable development and the UN's SDGs. Therefore, SDG16 stresses the importance of delivering peace, justice, and strong institutions without underestimating the problems in achieving them, as recent events in Afghanistan and elsewhere

Figure 5. Coastal erosion and loss of dwellings, Hemsby, Norfolk, UK in 2013.

have demonstrated. Nonetheless, the targets under this SDG include significantly reducing all forms of violence and related death rates everywhere, substantially reducing corruption and bribery in all their forms, and ensuring responsive, inclusive, participatory, and representative decision-making at all levels.

Although these targets may seem distantly related to the geosciences many links do exist. Conflict can result in increased vulnerability to hazardous weather-related events or displace people into geologically hazardous areas, about which geoscientists can provide advice. An example is the 700,000 Rohingya refugees who fled to Bangladesh to escape persecution in Myanmar. The camps were affected by monsoon rains and landslides, which killed 170 people in 2017. In terms of fostering peace, geoscientists can promote collaboration for research and development of transboundary geological features and resources, such as aquifers, rivers, and mineral deposits. Geoscientists can ensure that geoheritage features and processes are recognized in existing peace parks, as in the transboundary peace parks in southern Africa. Geoscience institutions and organizations can play a role in promoting anti-corruption behaviors, good governance, inclusive decision-making, financial transparency, safe working environments, and high professional standards.

17. PARTNERSHIPS FOR THE SDGS

The final SDG aims to deliver the other 16 goals by working in partnership to achieve:

- Financial targets, mobilizing resources within and between countries, and tackling issues such as debt financing, debt restructuring, and investment priorities.
- Technology targets, bringing science, technology, and innovation to bear on achievement of the SDGs.
- Capacity building targets, focusing on international efforts to strengthen capacity in developing countries to achieve their own development objectives.
- Trade targets, aiming to increase exports from developing countries and access to markets.
- Systematic issues targets, promoting policy coherence, multi-stakeholder partnerships, and monitoring and measuring progress towards achieving the SDGs.

CONCLUSIONS

The 17 SDGs present ambitious and challenging targets but they have the potential to transform the global community, giving all people dignity, equality, and the resources they need to lead healthy and successful lives in a sustainable global environment. But many hurdles remain and the evidence so far suggests that in some regions we are decades or even centuries away from achieving some SDGs. Progress on some has been slow and new approaches, decisive actions, and willingness to act are needed to speed advances. Of particular importance to the geosciences is the "Geology for Global Development" charity that provides opportunities for geoscientists to develop their skills and capacity to help deliver the SDGs. Gill (2021: 466) argues that "geoscience is foundational to sustainability and an enabler of inclusive economic growth, human development and environmental protection." More specifically, geoconservation experts can provide input in the identification, development, and management of protected and conserved areas that provide the double benefits of conserving natural features and processes while securing basic resources of life for disadvantaged local communities to help to improve their standard of living and life chances. This kind of outcome is why the UN devised the 17 SDGs and why they are being implemented by countries around the world.

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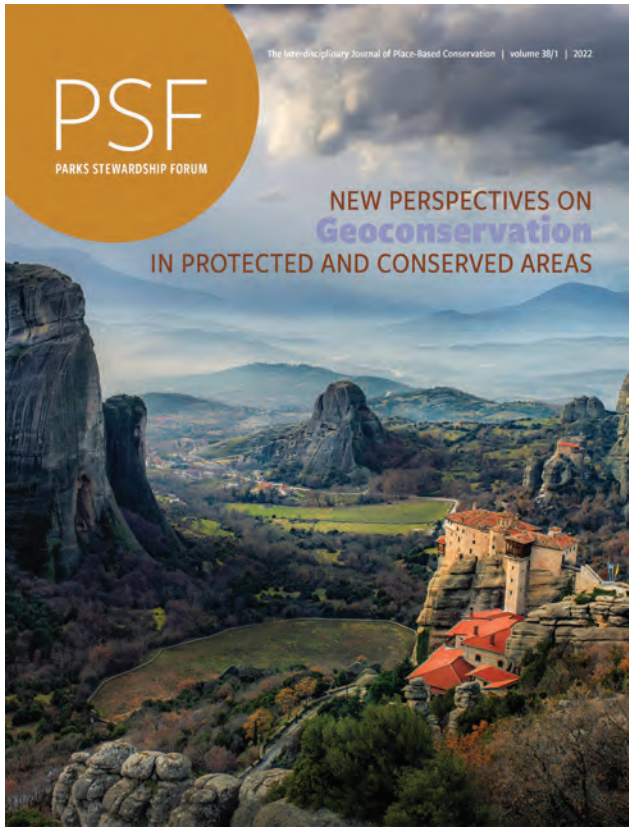

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