Notes from Abroad

International workshop on conservation and management of Taroko National Park, Taiwan

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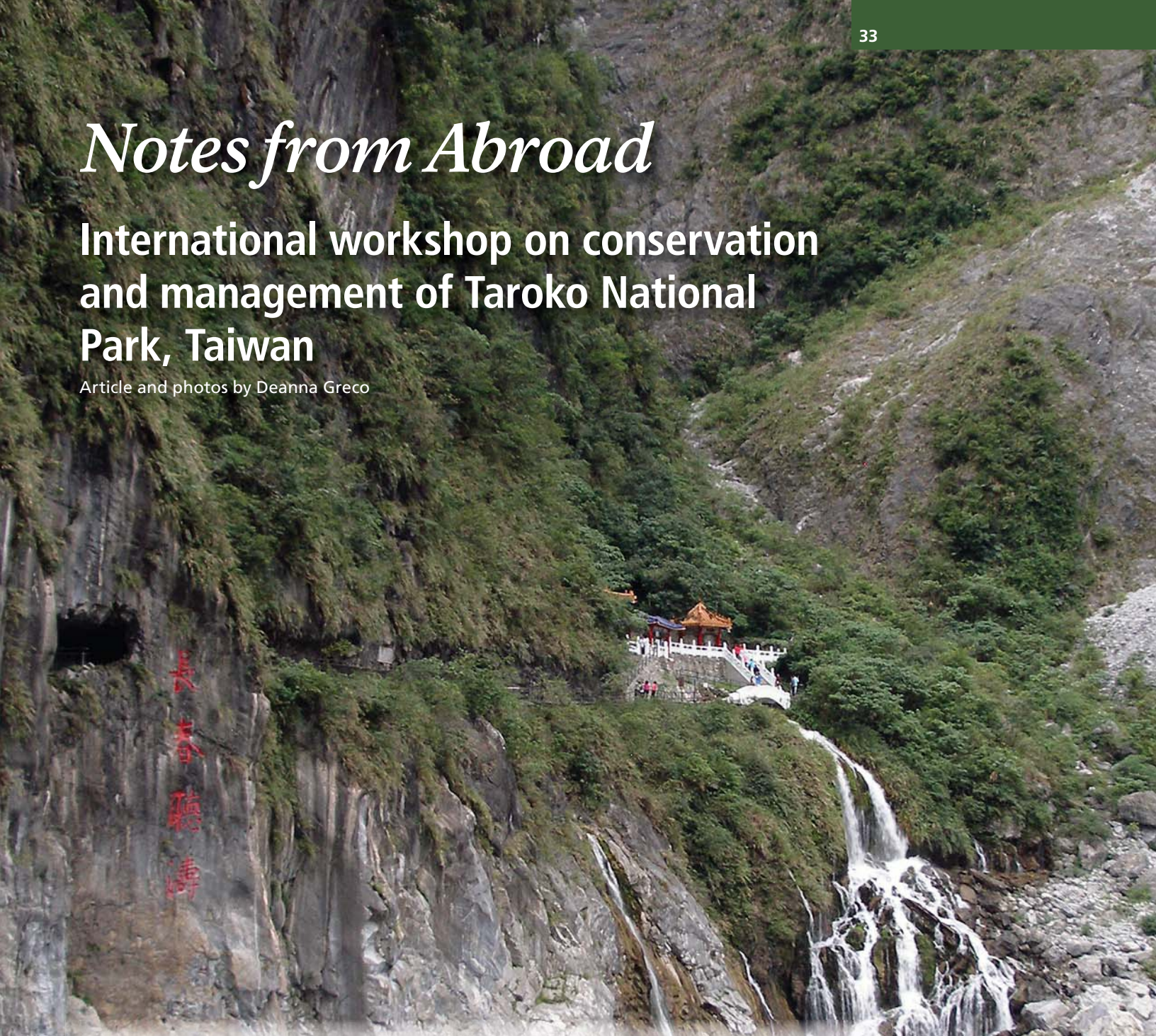

TAROKO NATIONAL PARK IS A RUGGED mountain landscape in central Taiwan that was established in November 1986 as this country's first national park (fig. 1). This beautiful area features a deep, scenic gorge that is very popular as a tourist destination. Tectonic activity, coupled with the local geology and climatic variables such as typhoons, has produced an environment in the gorge that is extremely dynamic. Thus the natural processes of landslides and rockfalls have collided with the social values and human uses of the area. Millions of people come to Taroko annually for its scenic beauty and recreational opportunities, and the multitude of landslides and falling rocks have resulted in safety concerns for visitors.

With Taroko's 25th anniversary approaching in 2011, the park enlisted the support of 20 experts from around the world to study management issues relating to geohazards and conflicts between recreational uses and landscape conservation. Specifically, Taiwan Parks requested the assistance of the U.S. National Park Service (NPS) to investigate geologic conditions in the park, make recommendations for improving visitor safety, and provide guidance on geomorphic restoration. In June 2009 I was contacted by the NPS Office of International Affairs to see about my interest and availability for this assignment. At the time I was employed as a geologist in the Geologic Resources Division and, because I had worked in a number of U.S. national parks on the

Figure 1. Taroko National Park, Taiwan.

very issues that the Taiwanese were seeking assistance with, they invited me to participate. They also enlisted the help of another NPS employee, Mike Martin, a hydrologist with the Water Resources Division.

Mike and I flew to Los Angeles in October and then on to Taipai, Taiwan. We were greeted by our Taiwanese contacts and interpreters and whisked away to Taroko National Park. There we met up with a team of experts from Australia, China, and the United States, as well as a range of experts from Taiwan. Over a span of 20 days, I participated in a series of field site visits, seminars, workshops, and group discussions designed to elicit international perspectives on the management, planning, administration, and restoration of Taroko National Park.

Taroko's geologic setting and the challenges it presents

Around 4 million years ago, predominant deposits of marble along with strata of gneiss and schist began rising out of the ocean when the Eurasian tectonic plate collided with the Philippine plate. As what would become the Central Mountain Range of Taiwan uplifted, the Liwu River eroded into the rock, gradually creating a deep gorge. Because marble is hard and does not erode easily the process resulted in the near-vertical-walled valley known today as Taroko Gorge. The first 12 miles (19 km) of Taiwan's Cross-Island Highway follow this 2,000-foot-deep gorge. The road is heavily used for transportation and also serves as the route for one of the nation's premier tourist attractions. The natural hazards associated with this section of road are found around a series of tunnels and the adjacent gorge walls.

Subjected to frequent seismic activity, the rock comprising the gorge walls is highly deformed and prone to failure. That the area has a tendency to get annual typhoons that can average more than 3 feet (0.9 m) of rainfall within a short duration presents no surprise that the gorge undergoes a cycle of severe geomorphic responses. The heavy rainfall initiates rockfalls and landslides and leads to widespread flooding, and cascading water spills onto the roadway from the adjacent cliffs. As a result, damage to vehicles and infrastructure is very common.

Of more serious concern is the not uncommon occurrence of injuries and fatalities from rockfall. Managers have attempted engineering solutions and awareness programs to mitigate the hazard. The current safety measures, including providing visitors with hard hats, have not solved the problem. In the year prior to our visit, three rockfall events resulted in injuries to visitors. In 2005, rockfall killed one and wounded 10. Approximately three months after our trip, a Chinese tourist was killed by a falling rock while boarding a tourist bus at the Tunnel of Nine Turns. Local officials were obviously concerned for the health and safety of park visitors, but added that reports of deaths caused by falling rocks would result in enormous damage to the reputation of Taiwanese tourism.

Field trips, meetings, and individual assignments

The first week of the trip comprised mostly meetings. Team members made presentations on a variety of topics, ranging from architectural features of park buildings and geologic hazards to the development of recreational opportunities such as founding of a mountaineering school to be hosted by the park. Intermingled between the presentations were field excursions, the majority of which consisted of an entourage of 10–15 people of various abilities, attire, and knowledge of the outdoors. Once my Taiwanese counterparts were convinced that I could handle myself in the backcountry, they sent me out with two of the park's rangers. They requested that I look at an aboriginal trail that was being considered for upgrade and hiking use and wanted my opinion and recommendations based on how trails are developed in U.S. national parks. The assignment turned out to be a challenge, requiring a combination of bushwhacking through jungle vegetation, rappelling down short steep cliffs, and hand-over-hand roped climbing to make our exit. Compared with earlier field trips with the large groups, this was a welcome change, as I enjoyed being with a small group of park staff. Interestingly, in terms of skill and personality the Taiwanese rangers were very much akin to NPS backcountry rangers.

We were shadowed by a documentary film crew for the duration of our time in Taiwan. At first this was

Figure 2 (right). Hard hats and rockfall reduction canopy on Tunnel of Nine Turns Trail.

Figure 3 (far right). Large fracture in pillar at west entrance of Tunnel of Nine Turns.

intimidating, but after a few days I forgot about the cameras, got to know the crew, and made friends with them. We often worked 12- to 14-hour days. Between jet lag, language barriers, and the sheer volume of work, the assignment was very stressful at times. For the purposes of drafting a report and recommendations we decided to distribute the workload, concentrating on the most pressing issues and making assignments based on areas of expertise. I was tasked with assessing three different areas of the park: Tunnel of Nine Turns, Swallow Grotto, and quarry sites.

Spectacular scenery coupled with big problems: The Tunnel of Nine Turns (Chiucyudong Trail)

The Chiucyudong Trail is part of the original Cross-Island Highway constructed from 1956 to 1960. To alleviate traffic concerns involving pedestrians and vehicles, a new tunnel was constructed in 1996. After completion, the Tunnel of Nine Turns was converted to pedestrian-only use. This enables visitors to enjoy the spectacular beauty of this part of the gorge without having to interact with automobiles and buses (fig. 2). This 1-mile trail is one of the most frequently visited sites in the park and takes visitors through what many consider to be the most spectacular scenery in Taroko Gorge.

On either end of the tunnel, a small parking lot serves as a drop-off/pickup area for shuttling visitors to and from the site. While vehicular traffic is not an issue on the tunnel trail, both ends of the tunnel are very congested and this problem only worsens during holidays. Tour buses are often lined up to drop off or pick up walkers. The buses waiting to pick up visitors on the east side of the tunnel often block an entire lane of traffic through the tunnel on the Cross-Island Highway, slowing traffic and increasing vehicular exposure to rockfall.

During inspection of the Tunnel of Nine Turns we noticed faults, joints, and folds in the marble, indicating that the rock is inherently unstable. The rock in the tunnel is highly fractured, and continued rock failures are noticeable from the scattered rock fragments on the trail surface. We also witnessed seepage, which can be an indicator of weak points in the rock. At the western bus drop-off location, a large fracture in the asphalt shows potential for slope failure. Additionally, a big fracture in the support pillar at the beginning of the tunnel shows signs of imminent collapse (fig. 3).

Past rockfalls are also evident in the numerous pit marks on the asphalt trail surface, the dented trail handrails, and the boulders scattered on the slope below the tunnel. Large rockfalls occur less frequently and can often be attributed to typhoon and earthquake activity. Often these large rockfall events are acknowledged only when they impact trails or other park facilities. Many more small rockfalls occur and usually go unnoticed.

Since the Tunnel of Nine Turns is one of the most popular destinations in the gorge, the massive volume of pedestrian traffic on the trail increases

Figure 4. Rock bolts and metal netting at Swallow Grotto west entrance.

the likelihood and potential for injuries and even fatalities. The park has installed several protective canopies, and a policy of encouraging hard hat use by visitors provides some defense against small rockfall–related injuries (see fig. 2). However, for any rock larger than a golf ball, these measures only marginally provide any real protection and could actually be a detriment since visitors may develop a false sense of safety and tend to pay less attention to their surroundings.

The hazards continue: Swallow Grotto (Yanzihkou)

The Swallow Grotto Trail runs about 0.3 mile (0.5 km) to its end at the Jinheng Bridge and is the next logical stop for visitors after the Tunnel of Nine Turns. It affords views above the Liwu River and hot springs scattered along the lower parts of the cliff walls. The trail is separated from the highway by a concrete divider and a two-lane tunnel that allows visitors to walk the trail without dealing with traffic. This area too is very congested with buses lined up waiting to drop off and pick up visitors.

Though the hazard is less severe than that of the Tunnel of Nine Turns, the geologic setting of this trail is quite similar, with exposed joints and folds in the rock and fractured marble. Rocks have pitted and marred the asphalt surface here. The park has responded with standard engineering solutions, but unfortunately these have been ineffective. For example, the metal netting installed with rock bolts at the entrance of the trail is insufficient to prevent rockfall from landing on the roadway (fig. 4).

Restoration potential with hiking opportunities: The quarries

The last area we investigated was a large quarry complex developed by an Australian company for concrete aggregate (fig. 5). The road leading up to the quarry follows a steep mountain creek and has developed gullies about a foot deep. According to park staff the creek was much smaller before the quarry was developed. The increased runoff caused by the road and the quarry has amplified the rate of erosion, down-cutting and widening the creek. The road also has acted as a pathway for nonnative plant infestations in the watershed, with numerous species growing along this corridor.

The quarry walls are terraced and average approximately 30 feet tall, with the upper wall reaching a height of about 50 feet. These walls are fairly stable with the exception of those on the northern side, which are highly fractured, weathered, and most prone to failure. The lower quarry area was once the main processing site. Piles of crushed rock are still present and this site bisects the upper drainage of the creek. The steep slopes have led to massive erosion features emerging from the lower processing area down the hillside and onto the old roadbed.

Figure 5. High walls of the quarry, looking to the east.

Engineering or simplified solutions to complex problems

We consolidated our recommendations for all three sites in a report of findings and suggestions for mitigation and restoration. For the Tunnel of the Nine Turns and Swallow Grotto, both of which have very similar hazards, the prudent approach outside of developing costly engineering solutions would be to reduce the number of visitors using the trails. The sheer volume of visitation, coupled with the rockfall hazard, presents odds that injuries and fatalities will continue to be an issue for the park. Additional efforts at implementing a better transportation system, conducting educational outreach on geologic hazards and the need for restricted access, along with a more controlled trail experience, would help decrease the hazard.

Despite the multitude of afflictions owing to Mother Nature at Taroko National Park, the quarry is relatively safe from a geologic perspective. The site has great restoration potential; however, full restoration to natural contours would be very expensive. Additionally, actions required for full restoration would denude the site of its current vegetation and could potentially increase sediment yields in the watershed until large woody vegetation could stabilize the area. Though we provided a range of alternatives, the simplest solution would be the installation of erosion control measures such as stair-step structures and rolling dips at the old processing site to help reduce surface runoff and increase sediment capture.

The simplest solution also presents an opportunity: convert the old quarry road into a loop trail and provide a picnic area. The lower quarry area provides spectacular views of the Pacific Ocean. Making the old road into a trail and connecting it to the Cingshui Cliffs Trail would produce a hike with outstanding vistas. From there, a trail that continued to the top of the ridge would offer a challenging activity and rewarding view not only of the Pacific but also of the Cingshui Cliffs, and provide for a hiking loop. Additionally, trail development could help to spread out visitor use, away from congested areas of the park.

Conclusions from "Great Crayon"

During the trip my Taiwanese hosts asked me to give a presentation on management planning for the "Great Crayon." It took me a few days to realize that they had used language translation software that converted "Grand Canyon" into "Great Crayon." In the process of researching the presentation, I came across a UNESCO World Heritage Site document naming Taroko Gorge for consideration as a worldwide natural protected area. This information compared Taroko Gorge to the Grand Canyon.

Ironically, less than a year after traveling to Taiwan I took a new position at Grand Canyon National Park as the Physical Science Program manager. Every day I now face challenges similar to those of park managers at Taiwan's oldest national park, namely difficult management decisions related to the area's geology and the potential for erosion. Both of these parks receive almost 5 million visitors per year, and because the park environments are so dynamic, altering human behavior is one of the few management options available. By applying best management practices that include restricting access to the most hazardous areas, improving transportation systems, and offering alternative hiking opportunities, managers can achieve a safer environment for park visitors. Often our best approach is to understand and respect the natural processes at work and adapt management as new techniques and information come to light.

About the author

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