Restoration of Skull Ice Cave, Lava Beds National Monument

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Abstract

Lava Beds National Monument lies on the northern flank of the Medicine Lake Volcano in northern California. Lava flows emanating from multiple volcanic vents cover the landscape under the high-elevation desert ecosystem at 1,219 to 1,707 meters (4,000 to 5,600 feet). Numerous lava tubes and lava tube caves formed in these flows. One of these lava tube caves, Skull Cave, a lava tube ice cave, has become a popular attraction for visitors since the monument was established in 1925. Commercial development and heavy visitation in the cave has resulted in accumulation of sediment and larger material on its well-developed ice floor and along the main upper-level trail. Mitigation and restoration measures include removal of approximately 862 kilograms (1,900 pounds) of sediment and rock from the surface of the ice floor, rehabilitating the main trail leading up to and continuing through the upper-level of the cave, and remodeling existing stairway structures. The renovations have improved the condition of the ice floor and dust mitigation measures now limit dust production and transportation caused by foot traffic.

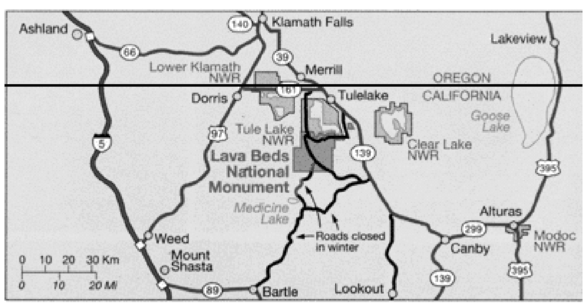

Figure 1. *Lava Beds National Monument location map.*

Background

Lava Beds National Monument is located along the California–Oregon border in northeastern California (Figure 1). The 18,842-hectare (46,560-acre) National Monument has the largest known concentration of lava tube caves in the 48 contiguous United States. The monument lava flows originated from a variety of volcanic vents and created lava tubes that stretch for miles under the landscape. Some of these lava flows reached the southern shoreline of a Pleistocene and Holocene lake, now called Tule Lake, that covered much of the Klamath Basin. Others flowed over the prehistoric landscape until they cooled and became frozen rivers of basalt. The flows formed extensive networks of lava tubes, jumbled aa lava flows, lava lakes, sag basins, and inflation plateaus. The diversity of the cave environments created between 1,100 and 62,000 years ago is comparable to the vast number of caves present. Field reconnaissance has located 436 lava tube caves and other lava tube features within the monument. The mapped caves total over 46 kilometers (27 miles) of underground passage to date with much more to be surveyed. The surrounding high-elevation desert that makes up the northern flank of the Medicine Lake Volcano lies at the juncture of the Sierra–Klamath, Cascade, and Great Basin Provinces. This region supports a patchwork of bunchgrass, sage, and juniper in the lower lying areas, while in the higher elevations ponderosa and lodge pole pine communities predominate. This diverse region of northern California encompasses an awe-inspiring landscape with elements of all three major geographic provinces.

Water is a scarce natural resource in this semiarid environment. There are no surface water sources present within Lava Beds National Monument. However, seasonal rains and winter snow melt replenish ice caves within the monument and provide critical sources of water for wildlife. Ice levels in these caves are measured several times annually to monitor the fluctuation of the ice from season to season and year to year.

Skull Cave was discovered in 1892 by E.L. Hopkins, one of the early settler-explorers in the area. On the earliest recorded visit to the cave, Hopkins, with the help of the Stonebreaker brothers from Alturas, California, made it to the lower level of Skull Cave where he found the bones of numerous antelope, bighorn sheep, mountain goats, and two human skeletons. It is assumed that the animals and humans fell to their death while attempting to gain access to ice and water deposits present in the lower level. The cave was aptly named after these remains.

As a premier attraction in Lava Beds National Monument, Skull Cave receives an average of 13,000 visitors per year.

Skull Cave has one of the largest main tubes in the monument at 137 meters (450 feet) long, 18 to 24 meters (60 to 80 feet) high, and 9 to 20 meters (30 to 65 feet) wide. Total length of the cave is over 305 meters (1,000 feet) of surveyed passage. Developments for visitor convenience in Skull Cave include a main upper-level trail that was initially constructed of basalt rock stairs and silty, pumice-rich soil trail tread fill, apparently all made during the Civilian Conservation Corps era of the early 1930s. A series of four metal stairways lead down to a well-developed ice floor on the lower-level of the cave.

The Cave Research Foundation conducted a sedimentology investigation in Skull Cave from 1989 to 1992. The study characterizes cave sedimentology in terms of depositional rate, depositional process, and provenance (source of sediment) (Tinsley, Miller, and Johnson; 1992). Results indicated that the main source of sediment accumulation throughout the cave was from the trail-tread material in the upper level of the cave. This material was being transported throughout the cave by visitor foot traffic. The heaviest deposition occurred in the vicinity of the main trail. Remediation measures proposed by the authors of this study were incorporated into the rehabilitation plan and restoration activities for Skull Cave.

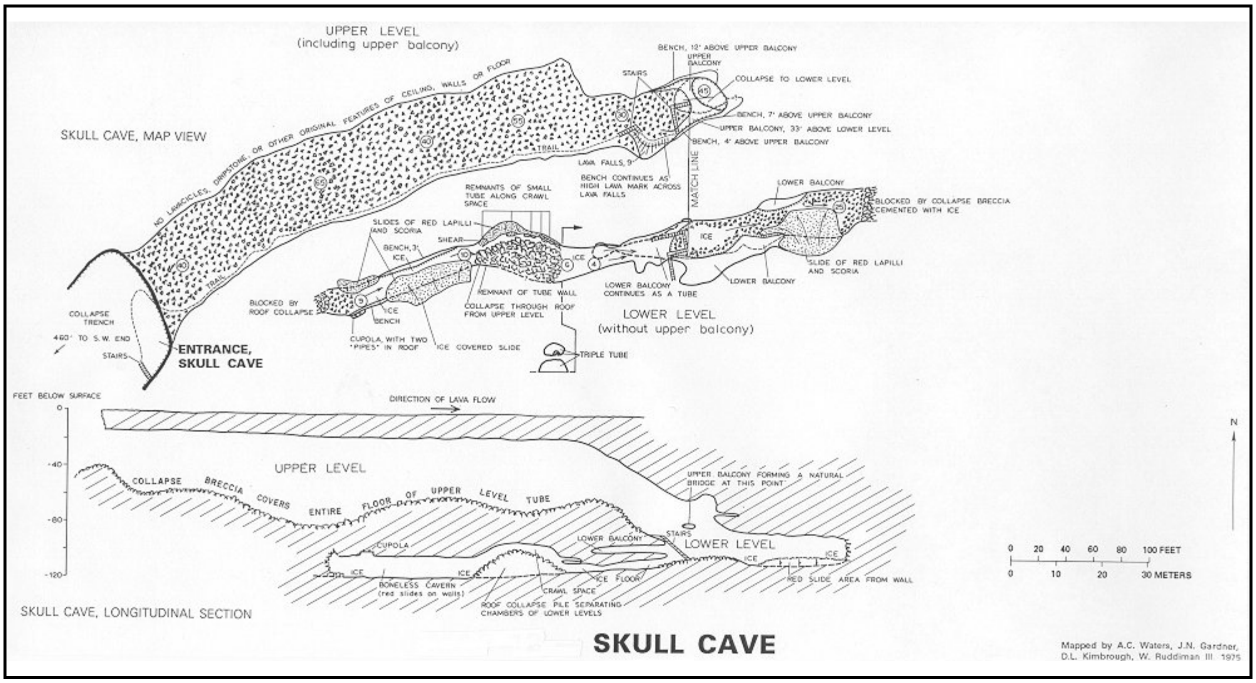

Figure 2. *Skull Cave Map (from A.C. Waters, J.M. Donnelly-Nolan, and B.W. Rogers, 1990)*

Restoration was initiated in Skull Cave to mitigate the impacts of increased sedimentation from foot traffic. Impacts to the cave during many decades of use included dust accumulation on the upper and lower levels of the cave, trail degradation at the entrance of the cave, and impacts to the quality of the ice floor at the lowest level of the cave.

The initial stages of this project included redesigning existing stairways, constructing a gate at the ice floor, and installing an interpretive viewing platform in front of the gate on the lowest level. After the construction and renovation phase, the ice floor behind the gate was thoroughly cleaned. A new native lava rock trail tread was installed on the upper level trail of the cave, which covered the entire trail surface. A dust removal project focused on dust accumulations along the main trail was completed after the installation of the new trail tread.

Stairway Restoration and Viewing Platform/Gate Construction

During the first stage of the project, four stairways were refurbished. The original 47 steps that accumulated dirt and debris on three of the stairways were replaced with open mesh metal steps on stairway frames that allowed dirt and debris to filter through the stairs (Figure 3).

Since March 1999 a gate has served to eliminate foot traffic on the ice floor. The ice floor appears to be recovering from many decades of foot traffic and vandalism. The future quality of the ice floor in Skull Cave will depend on educational interpretive displays and limited access to the ice floor.

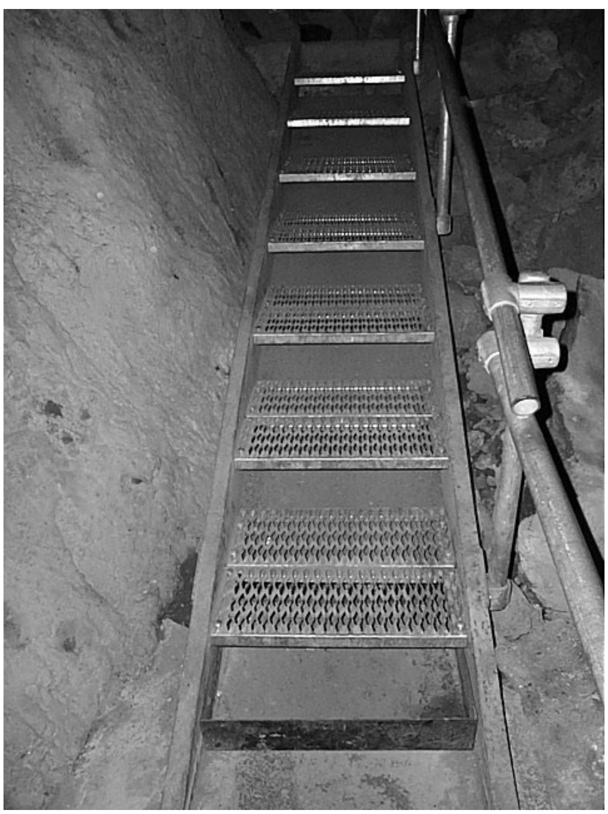

Figure 3. *New stairs in Skull Cave made of galvanized steel with ½-inch mesh. Also notice the steel tray under the structure and catchment trough at the base of the stairs (photo by Kelly Fuhrmann).*

An interpretive viewing platform was built in front of the gate to provide access for visitors to view the ice floor (Figure 4). This platform also provides an area for displaying interpretive signage explaining the processes of ice formation and cave conservation practices. A tarp was affixed under this platform to catch debris from foot traffic.

During the summer of 1999, accumulated rock and dust debris was removed from the ice floor. The cleaning of the ice floor involved removing 816 kilograms (1,800 pounds) of rock and 45 kilograms (100 pounds) of sediment from the ice floor. After all the larger debris was removed by hand picking, the surface of the ice was washed by sponging with chlorine-free water to remove remaining sediment from most of the ice in an attempt to restore it to a more pristine condition. With the addition of new ice, one can now see 20 centimeters (8 inches) into the ice floor, where before an opaque film of sediment in and on top of the ice obscured any view into the floor.

The lack of visitor traffic on the ice floor has allowed the cleaned ice to remain clear of debris from foot traffic and carelessness and prevented unnatural increases in ambient air temperatures from body heat in the ice floor chamber. New ice has begun to accumulate on top of the cleaned ice. Ice level monitoring has revealed the accumulation of 5.8 millimeters (0.23 inches) of new ice from February 1999 to February 2001 (Figure 5).

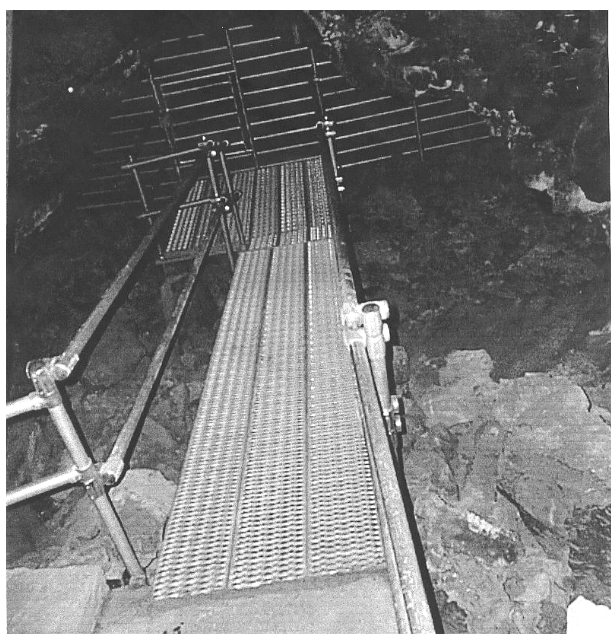

Figure 4. *Viewing platform and gate in lower level of Skull Cave. The gate spans the entire passage width of four meters (14 feet)(photo by Kelly Fuhrmann).*

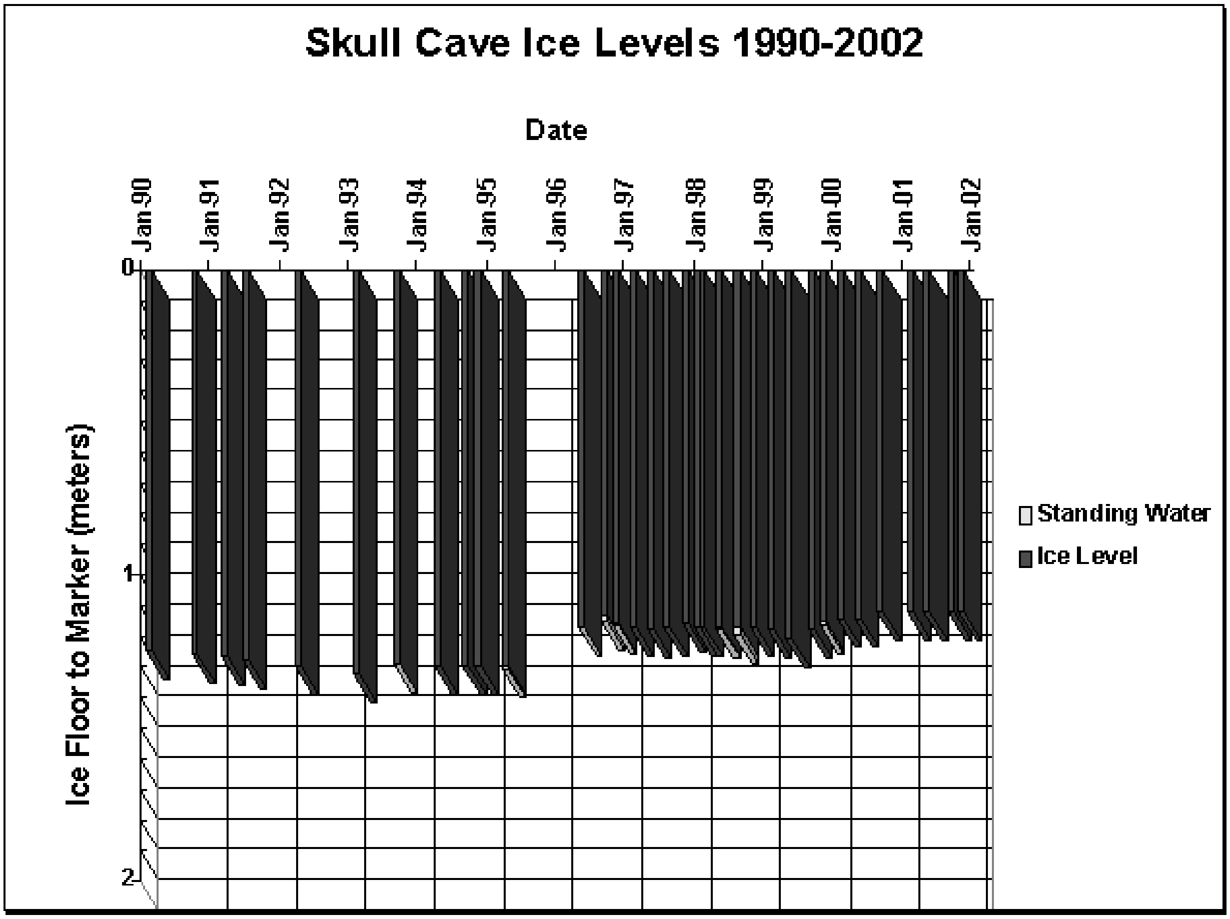

Figure 5. *Ice levels in Skull Cave 1990 to 2001.*

Figure 6. *Dust impact along the trail in the upper levelof Skull Cave.*

Trail Tread Restoration

Dust accumulation originating from the original dirt trail tread was impacting the upper and lower levels of the cave environment. The accumulation of dust along side the trail on the upper level of the cave had coated both breakdown and historical writing (Figure 6). An effort was made to remove this dust from the trailside rocks using water and light scrubbing during the summer of 1999. The cleaning revealed many historic writings covered up by dust deposition. However, traffic on the dirt trail tread continued to produce dust that was deposited on the same cleaned rocks. The cleaning process was repeated during the summer of 2001 to remove the dust that was deposited before the new trail tread was installed.

The installation of 84 square meters (900 square feet) of new trail tread on the existing upper level trail in Skull Cave was completed during the summer of 2000. To mitigate dust accumulations produced from visitor traffic on the main upper-level trail, flat lava rock was mortared in place over the entire length of the existing dirt trail tread. A local source was chosen as a supplier for this lava rock to provide local material that was compatible with the color and texture of the existing basalt rock in the cave.

Photomonitoring of the main upper level trail and ice floor was initiated before the start of the restoration project. The commitment to preserve the ice floor in Skull cave has resulted in the improved state of the ice floor as witnessed in the photographs. Continued monitoring in Skull Cave will determine the trends of ice levels and ice quality.

The following photographs (Figures 7 to 10) shows the inner ice floor from 1961 to November 2000. They depict the ice floor before heavy usage, the accumulation of 38 years of debris, and the restored ice floor in 1999.

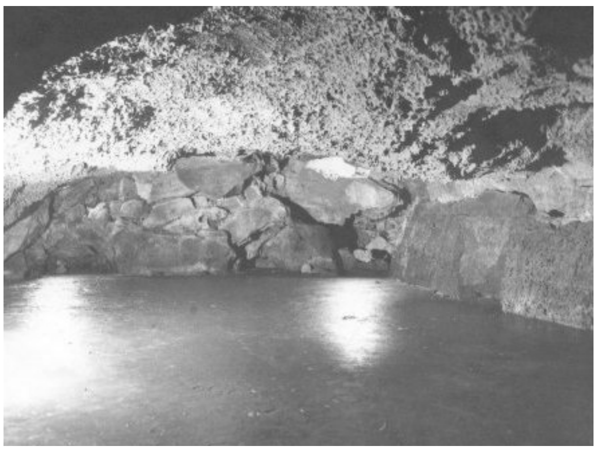

Figure 7. *View of the inner ice floor looking towards the back of Skull Cave in 1961. (National Park Service photograph)*

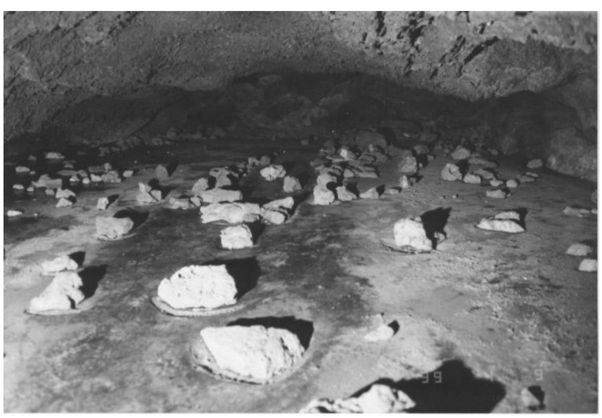

Figure 8. *View of the inner ice floor in Skull Cave. This photograph was taken just before cleaning started in April of 1999. It shows heavy accumulation of debris consisting of breakdown and dust mantle carried onto the floor by visitors to the cave. (Photo by Kelly Fuhrmann)*

Figure 9. *Same view of the inner ice floor as Figure 8 after clean up of nearly 862 kg (1,900 lbs) of debris and dust by the end of October 1999. (Photo by Kelly Fuhrmann)*

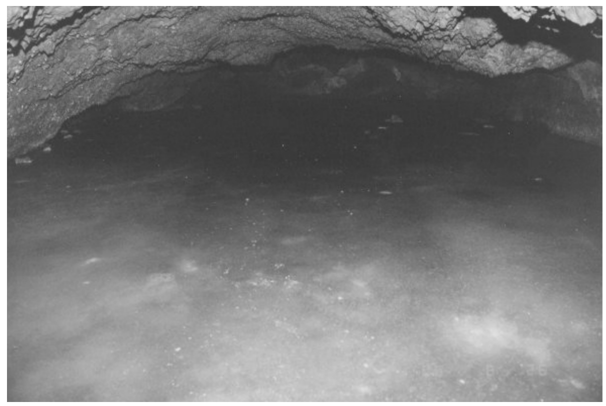

Figure 10. View of the inner ice floor in Skull Cave in June 2000. Note new ice layer on the floor. (Photo by Kelly Fuhrmann)

Upper Level Trail Construction

The upper passage trail was reconstructed by covering the original dirt trail with sand. Flat lava rock slabs were then laid on top of the sand. Dry mortar was added to the spaces between the lava rock and then water was used to set the dry mortar. This phase of trail construction was completed by September 2000. The following photographs (Figures 11 to 14) show both before and after views of this reconstruction process.

Surface Trail Construction

The surface trail leading into Skull Cave consisted of lava rock covered with gravel that had migrated down onto the trail from the trail head. This material proved to be a major source of dust and soil tracked into the cave on visitor's shoes.

***Figure 11**. View of the upper level trail with the original trail tread. (Photo by Kelly Fuhrmann)*

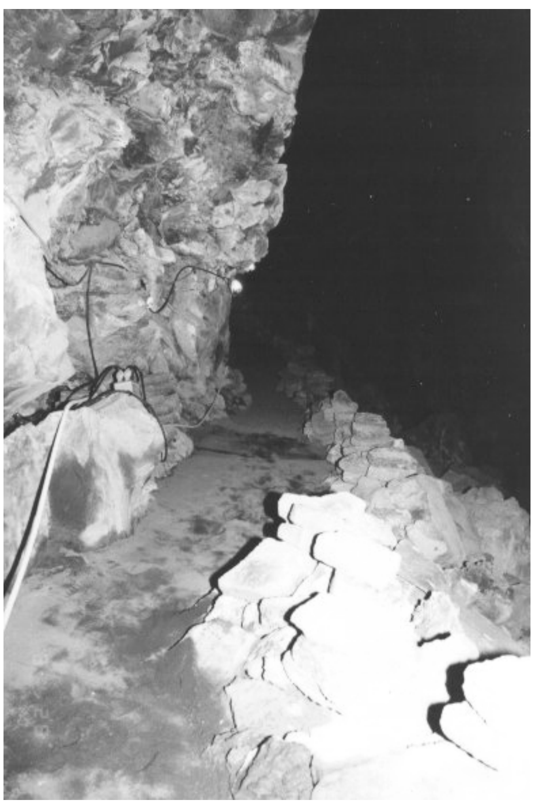

***Figure 12**. A basalt sand base was added over the original trail tread material. (Photo by Kelly Fuhrmann)*

***Figure 13.** Park Service maintence employee placing lava slabs into basalt sand substrate. Lava rock was chosen to closely match existing breakdown and cave wall colors and textures. (Photo by Kelly Fuhrmann)*

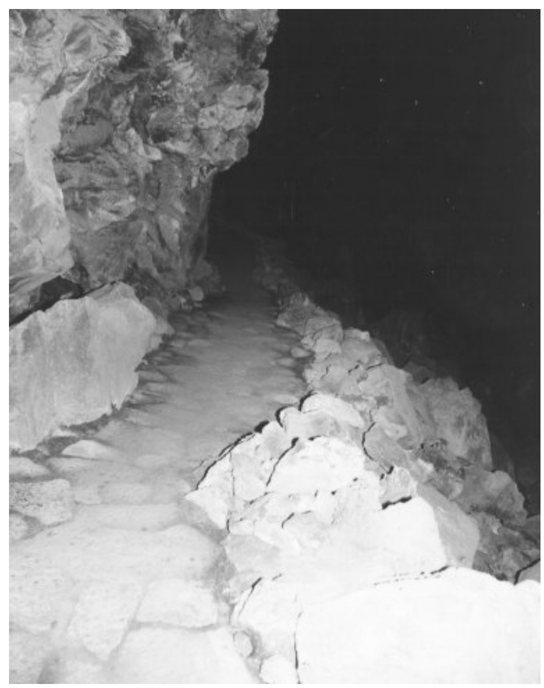

***Figure 14**. Dry and wet mortar was packed into spaces between slabs. The dry mortar was then wetted to cement the basalt slabs in place. (Photo by Kelly Fuhrmann)*

Figure 15. *This photo, taken in June of 2000, shows the trail leading down into the collapse sink entrance of Skull Cave. This nearly 30-meter (100-foot) trail leads to the cave entrance just out of the picture to the upper right. The trail in the foreground is approximately a meter (three feet) wide. Note sagebrush (*Artemisia tridentata ssp. tridentata*), desert sweet (*Chamaebatiaria millefolium*), and rabbitbrush (*Chrysothamnus viscidiflorus*) plant community in and around the cave collapse. (Photo by Kelly Fuhrmann)*

Figure 16*. Photograph taken in August of 2000 from the same location as Figure 15. All loose debris was removed, new basalt lava slabs added, and the trailhead renovated. (Photo by Kelly Fuhrmann)*

Conclusions

Restoration of the upper level trail and lower passage main ice floor was accomplished in Skull Cave in Lava Beds National Monument, California, in 1999 and 2000. Large amounts of debris and dust were removed from the ice floors by hand. The main trail leading into the cave was resurfaced with slabs of lava that were cemented into place. These renovation activities and the limited access to the ice floors have improved the condition of the ice floors. These actions have also led to a dramatic reduction in dust and debris in the cave. After a period of over a year the ice floors have improved dramatically from the conditions observed in photographs from 1999 and exceeded conditions observed in photographs from 38 years ago.

Since the completion of work inside the cave, a slight redesign of the parking lot trail head entrance to the cave has also been completed. Photo-monitoring, ice level measurements, and temperature and relative humidity conditions will continue indefinitely. In addition, dust accumulation and sediment studies are also continuing.

Acknowledgments

This project was a cooperative effort completed by the divisions of Maintenance, Resource Management, Fire Management, and Interpretation at Lava Beds National Monument and the Cave Research Foundation.