A POST-MITIGATION DEEP SLAB IN THE HOURGLASS COULOIR

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ABSTRACT: On the morning of January 1, 2026, Jackson Hole Mountain Resort saw its largest in-bounds avalanche of the season in an area called the Hourglass Couloir. This D3.5 deep persistent slab with maximum depth around 10 feet was especially significant as it was remotely triggered by a snowcat pushing snow off the summit of Rendezvous Mountain 24 hours after explosive mitigation work was performed in the area. This paper introduces this high-elevation northeast facing terrain that is permanently closed to skiers, the distinct avalanche hazard mitigation techniques utilized for this unique zone, and the mission the day before which attempted unsuccessfully to trigger this slab. Early-season snow and avalanche activity leading up to the event will be considered and studied; and finally, past research into post-mitigation release will be examined and how it may help to understand this avalanche. This paper does not attempt to answer the mysterious question of why this avalanche occurred, but rather examine possible contributing factors while looking back and learning from the event.

KEYWORDS: incidents and case studies, post mitigation release, deep slab instability, ski area, explosives

1. INTRODUCTION

Rendezvous Mountain, the home of Jackson Hole Mountain Resort (JHMR), is located in the Teton Range of the Rocky Mountains in a remote corner of northwest Wyoming. In 1966, an aerial tram was completed to the summit at 3185 meters (10,450 feet). The north side of Rendezvous Mountain is very precipitous, with large Dolomitic cliffs towering over Tensleep Bowl below. These cliffs are broken up by the famous Corbet's Couloir, the only area on this side of the summit that is open to the public for skiing above the bowl. 300 meters (1000 feet) to the north of Corbet's is the North Ridge of Rendezvous Mountain, where the Hourglass Couloir provides a steep and narrow passage through the cliffs (Figure 1). In Tensleep Bowl, the Jackson Hole Ski Patrol (JHSP) maintains a rope line for closing the Left Field area, only opening it on rare occasions when avalanche hazard reduction (AHR) has been performed on the North Ridge and the forecast and mitigation teams determine it is appropriate to open.

The North Ridge itself is a large alpine area facing northeast to east. Due to its aspect and location directly below the summit, this area receives snow very early in the autumn and can hold onto that early-season snow when other slopes melt in Oct/Nov. Because this area is permanently closed, it receives minimal skier compaction. These conditions make this area the perfect location to preserve persistent weak layers (PWLs), a situation which has been observed since the early days of JHMR (Krisjansons 1971).

Avalanche hazard reduction (AHR) is rarely performed on the North Ridge. Throughout storm cycles and during extended periods of snowfall this area is left alone, often for weeks at a time. Once high pressure returns and the JHSP is fully caught up with all other mitigation work on the mountain, they will consider an AHR mission on the North Ridge in order to open the bowl below for skiing. These missions usually consist of two teams: one above the cliffs and one below. The team above will typically begin the mission by deploying two large "sled bombs" on either side of the Hourglass Couloir. These specialty explosives consist of a mix of pentolite cast boosters and ANFO totaling 13.5-35 kg (30-75 lb), which is placed in a plastic sled and lowered with ropes into the starting zone. These types of charges have been used at JHMR since 1985, and are very effective at influencing a large area that is otherwise challenging to mitigate (Livingood et al., 1990).

Figure 1: Aerial view of the North Ridge of Rendezvous Mountain. All terrain above the cliffs is permanently closed.

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The use of these types of explosives on the North Ridge have historically produced the deepest crowns observed on Rendezvous Mountain: up to 4.5 m (15 feet).

The Tetons generally receive abundant snowfall and moderate temperatures, putting them in an Intermountain snow climate (Mock and Birkeland, 2000). Snowfall measurements at JHMR are conducted at four separate snow study plots. The nearest plot to the Hourglass Couloir is at Rendezvous Bowl (RVB; 2920 m, 9580 ft), .8 km (.5 mile) to the south of the summit. This site averages 10.7 m (420 in) of snow each season.

2. 2025/2026 WINTER WEATHER

2.1 Early Season

Winter 25-26 began early at the upper elevations of Rendezvous Mountain. Light but consistent snowfall began on October 5, and by the end of the month 81 cm (32" inches) of snowfall had been observed at RVB. In the first week of November, another 36 cm (14 inches) fell, and on November 11th this author observed a connected basal snowpack in place on the North Ridge (Figure 2). Snowfall diminished during the rest of November and upper elevation temperatures remained cold. The situation at mid and low elevations was less positive, and a planned opening day of November 28 was delayed due to lack of snow.

Figure 2: Snow on the North Ridge on November 11, 2025, as observed from the Aerial Tram.

2.2 December Storms

The month of December brought heavy snow and abnormally high SWE to upper elevations, and warm temperatures and rain to lower elevations. Beginning on Dec 4, a week of storms delivered 89 cm (34 inches) of snow with 14 cm (5.5 inches) SWE at RVB. This made for an average density just over 17% and a peak density of 27.1%, very uncommon numbers in the Tetons, especially in December. This storm also finished with one of the most significant rime events in recent memory on Dec. 10 while bringing heavy rain up to 2743 m (9000 feet), capping all upper and mid elevations slopes with a thick crust.

On December 8, AHR was performed by the JHSP for the first time of the season. Large slides were observed throughout JHMR, but the north side of Rendezvous Mountain may have been the most significant. Notable avalanches were easily triggered in Corbet's Couloir and adjacent areas of Tensleep Bowl, stepping down to basal snow layers while propagating large distances and connecting disjointed terrain features (Figures 3 and 4). On this day and throughout the rest of the month, no AHR work was conducted on the North Ridge.

Figure 3: This D2 avalanche in Corbet's Couloir with average depth 91 cm (36 inches) was triggered by cornice fall during mitigation work. Dec 8, 2025.

Figure 4: D2 avalanche from mitigation in Tensleep Bowl, average depth 102 cm (40" inches). The North Ridge can be seen in the distance. Dec 8, 2025.

A series of powerful storms returned to the Tetons December 16-28. During this period, a total of 1.67 m (66 inches) of snow fell at RVB containing 23.6 cm (9.3 inches) of SWE with an average density of 13.54%. During the late afternoon hours of December 19, a natural avalanche released on the North Ridge in close proximity to the Hourglass Couloir (Figure 5). This hard slab had an estimated average depth of 1.2 m (4 feet) with a maximum depth up to 1.8 m (6 feet). On Christmas Day, another significant rime crust developed in the early morning hours with rain once again reaching an elevation of 2743 m (9000 feet).

Figure 5: Natural hard slab on the North Ridge, Dec 19, 2025.

Total precipitation at RVB for December 2025 was the 3rd highest on record, with 38.4 cm (15.1 inches) of SWE received. This was 202% of average moisture and was exceeded only by the Decembers of 1996 (54.1 cm; 21.3 inches) and 2016 (40.9 cm; 16.1 inches). Average density of new snow for the month was 13.7%. Total snowfall was 2.67 m (105”) which was 129% of average. The average mean temperature for December 2025 at the Mid Mountain study plot (2493 m; 8180 feet) was -3°C (26.6°F), which is significantly warmer than the 41 year average (1974-2015) of -9.4°C (15°F). The warm temperatures and heavy precipitation resulted in a snowpack at the onset of 2026 with well above-average snowfall and snow depths at high elevations, and yet the lowest snow depth at the Base study plot (1984 m; 6510 feet) in its 32-year history. This unusual start to the winter of 2025/2026 mimicked patterns seen throughout the Intermountain region (SW MT, UT, ID, etc.).

3. HOURGLASS AVALANCHE

3.1 December 31 North Ridge Mission

With a break in the weather and all mitigation work completed throughout the rest of Rendezvous Mountain, it was decided that December 31 would be the first North Ridge mitigation mission of the season. No new snow had fallen in over 72 hours, and the morning dawned with light wind speeds and moderate temperatures on the summit (-1°C; 30°F) following a warm-up over the previous four days from -22°C (-8°F).

The teams began mitigation work by deploying two 14 kg (31lb) sled bombs on either side of the Hourglass Couloir. These were smaller than our typical size: around 23 kg (50 lb). In addition, a 4.5 kg (10 lb) charge was deployed in the Hourglass Couloir by attaching it to a rope and throwing it over the cornice above. These explosives all produced minor results up to R2-D2 and maximum depth of 40 cm (16 in), but were unable to trigger failure in the deeper weak layers (Figure 6). Following these shots, the upper team deployed additional hand charges on the North Ridge, while the lower team deployed a series of shots below the cliffs. These additional shots produced only R1-D1 slides with a maximum depth of 45 cm (18 in).

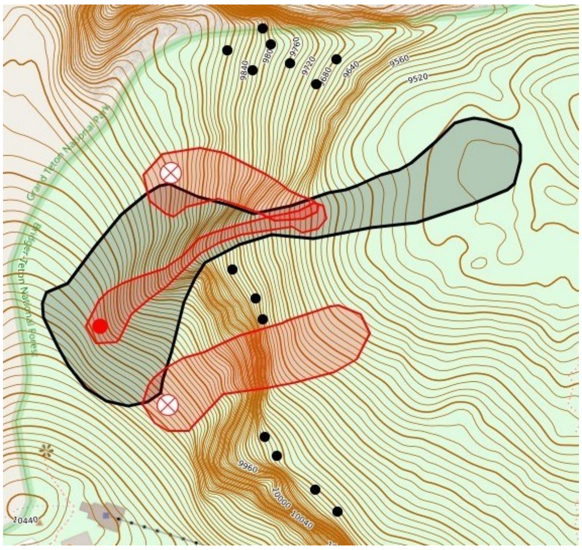

Figure 6: Black polygon is post-mitigation release triggered Jan 1. Red polygons represent avalanches triggered during mitigation Dec 31. Red & white x’s are 14 kg (31 lb) sled bombs. Red dot is 4.5 kg (10 lb) bomb dangled over cornice. Black dots are smaller shots.

3.2 January 1 Hourglass Avalanche

Though there are no groomed ski runs from the summit of Rendezvous Mountain, a snowcat is kept there to maintain the area around the tram dock. An operator began the first morning of 2026 by doing a large snow removal project at the summit. Standard procedure for this involves pushing snow near the north edge of the tram dock where it can fall onto the closed terrain below. At approximately 8:30am, members of the Mountain Sports School riding the tram reported seeing a large powder cloud in the area of Tensleep Bowl. The author was stationed at the summit and immediately walked onto the tram dock, from which the avalanche crown was clearly visible. At this hour, the only skiers on the upper mountain were members of the JHSP and it was confirmed that no one was near the avalanche site. A team consisting of two forecasters (including the author) and an exchange patroller from France proceeded down the low angle slopes of the North Ridge to get better observations of the slide.

Figure 7: HS-AKr-R3-D3.5-O/G. Red X's mark the locations of previous sled bombs. The structure above is an observation deck for summer guests.

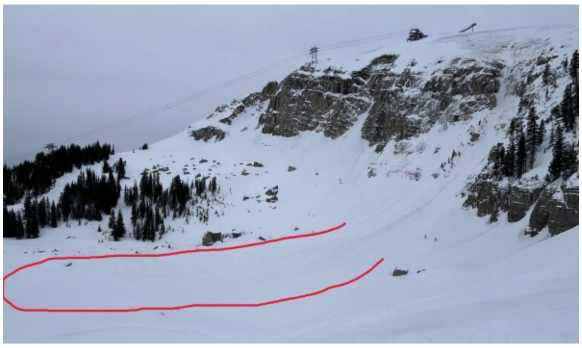

Figure 8: Runout zone highlighted due to poor visibility, with two skiers seen traversing into path.

Upon approaching the site, we first observed that while there was a large pile of snow that had been moved by the snowcat, there was no disturbance on the surface for at least 60 m (200 ft) above the crown line. It appeared no snow had traveled down far enough to have directly triggered the slide, thus we determined this was a remotely-triggered avalanche. Due to the size and variable nature of the crown, a formal crown profile was impractical. Crown depths averaged around 1.8m (6 ft) with a maximum depth of 3 m (10 ft). The bed surface consisted of small basal facets from Oct/Nov and ground. Within the crown, two distinct rime layers from Dec 17 and Dec 25 were easily identifiable, and the failure plane was well below. Slope angle at the crown averaged 34 degrees, but failure pulled back onto the ridge into terrain under 20 degrees (Figure 9). The crown was 140m (460 ft) wide and the slide ran 450 m (1475 ft). Runout zone was a bowl-shaped feature with an uphill at the terminus, depositing snow 3-6 m (10-20 ft) deep (Figure 8). Debris remained visible throughout the winter.

4. DISCUSSION

4.1 Deep Slabs

This avalanche follows many trends which have been previously identified regarding the characteristics of deep slab avalanches. While the difficulty of forecasting for and triggering these slides increases the deeper these layers are buried, when they do finally release, the potential is there for large and destructive avalanches (Marienthal et al., 2014). Previous work characterizing deep slabs in the Tetons identified that these events are larger, harder, and tend to occur more frequently in December and January (Comey and McCollister, 2008). As of that 2008 study, only 6.9% of these slides in the Bridger-Teton Avalanche Center database had failed on the ground, adding to the significance of this event.

Figure 9: Crown pulled back onto ridgeline with slope angles under 20 degrees.

In 2016, Wright et al. looked at historical deep slab cycles in the Tetons, and found that they could often be identified by two dominant trigger mechanisms: loading or temperature change. Temperature poses an interesting situation in this case: the morning of mitigation work followed a four-day warming trend, from -22°C (-8°F) to -1°C (30°F), yet failure occurred after 24-hours of stable temperatures. The more obvious marker which likely contributed to the triggering of this avalanche is loading. Typically, this comes in the form of precipitation and/or wind. In this case, the loading came from a snowcat pushing tonnes of dense, settled snow onto the upper low-angled slopes of the North Ridge. This heavy loading in a very short time was enough to cause failure in the basal weak layer, which rippled downhill to the steeper slopes below, remotely triggering the post-mitigation release.

4.2 Explosives

The weak layer involved in this avalanche was a known entity, causing large avalanches on nearby slopes both naturally and with explosives (Fig. 3, 4, 5). Despite this, explosive work was unable to affect this layer on Dec 31. Why were we unsuccessful in our mitigation?

It is sometimes said that the key to explosive mitigation is using the right explosive, of the right size, at the right time, in the right location. Maybe we put our sled bombs in the wrong locations. Sleds are inherently difficult to position, as gravity takes over and they trend downhill wherever the fall line takes them. The eventual crown line basically extended from one bomb crater to the other (Figure 7). Maybe if we deployed shots more to the middle we would have had different results? However, the middle was the deepest part of the slab; shouldn't it be easier to trigger the avalanche from thin areas? Or were the shots simply *not big enough* to cause failure?

In both cases, our sleds carried 14 kg (31 lb) of pentolite and ANFO. This is smaller than our more traditional size of 23 kg (50 lb), with charges up to 35 kg (75 lb) or more being used historically. The smaller size was a decision of the explosive team that day, who were testing a theory that our shots were usually bigger than they needed to be. Had we used bigger bombs that day, would the results have been different?

Timing the shot differently would be a challenge. Due to operational constraints, mitigation on the North Ridge is only possible in rare instances and never during large storm cycles. If we could mitigate this terrain more often, would we have had different results? Traditional practices would suggest so.

This leaves the type of explosive. Historically, the sled bomb has been the preferred shot for this terrain and has had good results. When Livingood wrote his paper presenting the sled bomb to the avalanche community in 1990, he noted no post-mitigation avalanches had been observed in areas where they had been used. 36 years later, we believe this is the first such example at JHMR. But could there be a better option? For decades, experiments have shown the increased effectiveness of aerial explosives detonated above the snow surface (Gubler, 1977; Juergens, 1984; Binger et al., 2006; Bones et al., 2012). In the case of the Hourglass, the only practical way to perform a large "air blast" would be through the installation and use of Remote Avalanche Control Systems (RACS). While this may indeed be the most effective way to mitigate this terrain, the low-occurrence of mitigation work and the low-priority nature of opening the terrain below make the necessary capital investment unlikely.

What could we have done better with our explosive work on December 31? The simplest answer is to use bigger explosives or put them in different places. However there is a more interesting question, one that triggers its own cascade of thoughts and questions: is it possible that our explosives *were* effective in *weakening* the snowpack, putting it in a state of increased instability and rendering it more likely to fail later?

4.3 Post-Mitigation Release

Post-mitigation avalanches (PMRs), which fail after mitigation measures have been completed and when there has not been any subsequent snowfall, have long been the bane of all ski patrols. Explosive use is the most common mitigation technique, and also often referred to as a test for the snowpack. While explosives generally perform this test well (based on the low occurrence of PMR), they can provide a false-stable result, and their effectiveness in determining the stability of deep slabs remains particularly questionable (Pratt, 1984). Despite this, explosives are currently the best tool we have for evaluating and mitigating these slabs, but we must accept them for what they are: an excellent but poorly understood and, most importantly, imperfect stability test (Savage 2010). It is very important for all avalanche professionals to remember that testing and hazard removal are different things (Ferrari, 2010). Just because the *test* indicated stability does not necessarily mean that the *hazard* has been fully removed. On the contrary, it is possible (though unlikely), and has long been theorized, that explosives could actually increase the hazard of slopes (for a limited time) which do not otherwise fail.

In 1984, Pratt performed a study which looked at differential creep rates present around explosive craters, and whether this phenomenon may contribute to post-mitigation release. He found that the snow grains in the crater will creep downhill more slowly than the surrounding snow due to the immediate sintering effect of the explosive, thus resulting in two opposing creep rates. He hypothesized that this increased the strain in the snowpack, leading to instability. Pratt suspected several hours to a day is required for maximum strain build-up, after which the snowpack undergoes self-stabilization and instability decreases. Could this phenomena have been present on the Hourglass that day, contributing to the crown line being present in the area between the two bomb locations while leaving those sites intact?

In 2006, Birkeland et al. focused on slopes which *collapsed* during explosive work but did not produce an avalanche (In our case, it is unknown whether or not the slope collapsed). They observed that while some people believe post-collapse slopes are safer, others treat the slopes with *more* caution, sometimes applying additional explosives or waiting 24 hours before opening those slopes. Their experiment concluded that the shear strength of fractured areas decreased dramatically immediately following the collapse, then increased over time, suggesting that fractured slopes may in fact be more unstable after the fracture.

More research is clearly needed on this topic to better understand the phenomenon of PMR. A more modern update to Pratt's snow creep model may help us understand if the differential creep rates surrounding a bomb crater actually increases instability in the snowpack. In the case of an arrested collapse, what role does depth of weak layer play, and what about different types of weak layers, or slab types? Do deep slabs remain in this heightened state of instability longer than slabs higher in the snowpack? Many questions remain unanswered, however this past work suggests that it may be possible the Hourglass Couloir had been rendered less stable *for a time* after our mitigation work did not produce the desired result.

It is important to note here that any potential for explosives to have a destabilizing effect on a snowpack is admittedly unlikely. PMRs are exceedingly rare, and with U.S. ski areas using approximately 100,000 explosives each winter, if they commonly weakened the snowpack and made it more susceptible to triggering, PMRs would be much more common (Baugher et al., 2023). Regardless, when avalanche workers are faced with an area that was forecast to slide with explosives but didn't, to quote Birkeland, "taking a little extra care around these slopes seems like a good idea."

5. CONCLUSION

The avalanche which occurred in the Hourglass Couloir on January 1, 2026, was a significant event in the operational history of Jackson Hole Mountain Resort. Its sheer size was noteworthy though not historic. However, when also considering its status as a PMR 24 hours after explosive work, and the unique nature of the trigger (remotely triggered by snowcat), the picture becomes one of a truly remarkable avalanche. As was said that day by an Avalanche Hazard Reduction Leader with 40 years of experience at JHMR, "I've been waiting my whole career for that to happen."

6. ACKNOWLEDGEMENTS

It is a rare blessing to have an opportunity to learn from a PMR in which no one was hurt or killed. We're not always so lucky. The authors would like to thank the forecaster team at Jackson Hole for their professionalism and mentorship, and to all patrollers of the JHSP. Two boards upon cold powder snow, what else does a man need to know? One final acknowledgement goes out to Steve Haas, who died in an avalanche in the Hourglass on February 10, 2003, and to all those who still refer to it as the Haas Couloir.

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