USING LARGE COLUMN TESTS TO SUCCESSFULLY FORECAST PERSISTENT DEEP SLAB AVALANCHES IN THE CENTRAL SIERRA NEVADA

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ABSTRACT: Forecasting of Persistent Deep Slab avalanches presents a unique and at times difficult problem for Backcountry Regional Forecasters, Guide Services, Highway Avalanche Mitigation Programs, Ski Area Avalanche Mitigation Programs and other avalanche forecasting operations. The addition of the Extended Column Test (ECT) and the Propagation Saw Test (PST) to the Avalanche Forecaster's toolkit has allowed for successful forecasting of Deep Slab avalanches. USDA Tahoe National Forest Sierra Avalanche Center (TNF-SAC) avalanche forecasters have created a framework for identifying when persistent weak layers are likely to contribute to deep slab avalanche problems under future loading conditions, often as much as two weeks in advance of the avalanche cycle. Using problematic near crust facet (NCF) layers observed during different winters, TNF-SAC forecasters were able to successfully forecast when these near crust facet layers would lead to deep slab avalanche problems. Signs of impending deep persistent slab conditions include: near crust facets (NCF) in the top 1.2 m of the snowpack, no current avalanches within the TNF-SAC forecast area, consistent ECTN results on these NCFs, and PST (End) results with less than 50% cut lengths. We present two case studies outlining the successful use of this deep slab avalanche forecasting framework.

KEYWORDS: Avalanche Forecasting, Persistent Deep Slab, Propagation Saw Test (PST), Extended Column Test (ECT), Sierra Nevada

1. INTRODUCTION

Significant loading events combined with persistent weak layers create deep slab avalanche cycles in the Central Sierra Nevada Mountains. These deep slabs most often fail on a near crust facet (NCF) layer. Some fail during or just after significant loading events as naturally triggered avalanches and some fail in response to a human trigger that loads the slope where the deep slab resides. These avalanches are often size D3 to D4, often travel farther than expected, fracture across wider areas than expected, and have been associated with avalanche fatalities in the area. Since the weak layer that these avalanches fail on exists well below the snow surface, observations such as test slopes, some specific snowpit tests, ski cuts, and cornice drops often prove unreliable or can give backcountry users a false sense of stability. Forecasters at the TNF-SAC have begun to identify a reliable way to forecast these deep slab avalanches using a combination of Extended Column Tests (ECT), Propagation Saw Tests (PST), and detailed snowpit and weather observations. This paper will outline this method and provide two case studies that support the efficacy of the method. While the framework has been successfully used to reliably predict deep slab instabilities up to two weeks prior to the event(s), data and testing are insufficient to fully vet this deep slab forecasting framework. Much of the data is anecdotal. As such it remains in the "beta" stages.

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2. FORECASTING METHOD

2.1 Layer identification

The persistent weak layer(s) or potential persistent weak layer(s) are identified. In the Central Sierra Nevada near crust facets (NCF's) represent a common persistent weak layer (PWL). Identifying and recognizing the weather events likely to create this PWL is the first part of the persistent deep slab forecasting framework. The following pattern often yields a NCF layer in the Central Sierra Nevada Mountains:

- A rain or warming event occurs that forms a wet layer of saturated snow on the surface.
- This wet layer refreezes and is covered by less than 30cm of new snow.
- A dry period ensues during which the snowpack remains cold, allowing a steep temperature gradient to form around the crust layer, promoting faceting around that crust. (This is the most common regional weather pattern for NCF formation, but others do occur.)

2.2 Field work

After weather conditions that might produce a PWL have occurred, detailed snowpit observations are used to track the layer's development or lack thereof. In many cases ECT and Compression Test (CT) tests combined with snow grain observation can identify these layers. Track these NCF layers using the ECT and PST.

- If the layer remains less than 1.2 m below the surface, use the ECT to test the layer. If the ECT yields ECTP results, the layer could still remain active and may indicate a current persistent slab problem.
- If the layer remains less than 1.2 m below the surface, the ECT yields ECTN results, and no avalanche activity is occurring in the region, then this layer may have become dormant.
- A PST can then be used to help determine if this layer can reactivate with future loading. If PST (End) results occur with cut lengths less than 50%, observations indicate that the PWL could re-activate under future loading.
- If the PWL is buried more than 1.2 m below the surface, PST's can be used to monitor the layer. If PSTs yield PST (End) results with cut lengths less than 50%, observations indicate that the PWL could re-activate under significant future loading.
- If ECT's yield ECTN results, PST's yield cut lengths greater than 50% and no avalanches are occurring on the layer, observations have shown that these layers will remain dormant under future loading.

2.3 Identify significant loading events

- Careful monitoring of weather forecasts and models will identify significant loading events.
- Follow up with crown profiles to identify the failure layer.

2.4 Verification

After the deep slab cycle use detailed crown profiles to verify that the cycle occurred on the monitored PWL. Revert to the tracking step (2) to determine if this layer will continue to pose a threat under future loading conditions.

3. CASE STUDY 1: Spring of 2012

3.1 Persistent weak layer formation

A persistent weak layer of crusts and faceted snow formed in response to a warming event creating wet snow on the surface that was subsequently buried by a layer of cold snow. Cold dry weather persisted through most of February allowing these surface layers to facet. A storm buried this layer with ~35 cm of new snow between Feb. 12 and Feb. 16.

3.2 Monitoring

- During and immediately after the Feb. 12-16 storm, the NCFs showed unstable test results in both ECT's and PST's but no avalanches were reported on this layer.
- By Feb. 17 ECT's started to produce mixed results. PST's continued to end propagate with cut lengths less than 50%. No avalanches were reported on this layer.
- By Feb. 20 ECT results consistently showed ECTN, but PST's continued to end propagate with cut lengths less than 50%. No avalanches were reported on this layer.

Snowpit observations continued to document faceted grains in the layer.

- PST's continued to end propagate with cut lengths less than 50% even though no avalanches occurred on this layer, and snowpit observations continued to show faceted snow grains in this layer across most of the region until Feb 27.

3.3 *Loading: Feb 28, 2012 & March 17, 2012*

A significant winter storm impacted the area between Feb. 28 and March 2 and deposited ~92 cm of new snow on top of the snowpack in which the NCF layer was buried ~20-30 cm below the surface.

3.4 *Deep Slab Cycle:March 1-2*

This load allowed for sufficient instability for several large human-triggered deep slab avalanches and two avalanche fatalities. The avalanche crowns measured between 1 m and 1.5 m in depth.

3.5 *Continued tracking*

- After this storm, ECT's continued to consistently produce ECTP results until March 5. From March 5 - March 17 ECT's produced mixed results trending toward more ECTN results.
- Throughout this entire period PST's continued to show end propagation with cut lengths less than 50%, and snowpit observations continued to show faceted snow grains in this layer.

3.6 *Another Loading Event: March 12-19*

Another storm cycle that added 154 cm of new snow to the snowpack occurred from March 12 - March 19 and resulted in widespread natural deep slab avalanches with crowns between 1.5 m and 3m.

3.7 *Continued tracking*

After this storm and avalanche cycle, PST's gradually started to show cut lengths greater than 50%, and snowpit observations indicated that the deeply buried NCFs were rounding. No more avalanches occurred on this layer despite additional loading events during the spring.

4. CASE 2: December 2012

4.1 *Persistent weak layer formation*

Rain and snow Dec 2-5, 2012 placed a few inches of new snow between two rain crusts. A week of clear weather followed. By Dec 7, the snow crystals between and directly above the crusts had become faceted.

4.2 *Monitoring: Dec 14-24, 2012*

A series of storms, each with storm snow totals of less than 15 to 30 cm combine to bury the NCF layers ~60 to 100 cm deep in the snowpack. PST (End) results on the NCF layer transition from greater than 50% cut lengths to less than 50% cut lengths during this time period. Avalanche activity during this time period occurs only within storm snow. ECTP results are limited to within storm snow layers. No avalanche activity on NCF layers.

4.3 *Loading: December 22-27, 2012*

Large storm cycle deposits 80 cm to 120 cm of high density new snow. Rapid storm snow settlement and compaction of old rounded layers above the NCFs and and below the base of the storm snow occurs. NCFs now buried 1 m to 2.4 m deep in the snowpack depending on elevation.

4.4 *Deep Slab Cycle: December 22-26, 2012*

Natural avalanche cycle occurs within storm snow and on NCFs. Persistent deep slab avalanches on NCFs have crown heights of 1 m to 2.4 m.

4.5 *Continued tracking*

Snowpack above the NCFs gains significant strength. Slopes that did not avalanche during the storm cycle show significant difficulties in human trigger force transmitting to the depth of NCFs. Areas where the NCFs were less than 1.2 m deep transitioned to yielding ECTN results. Persistent Deep slabs removed from avalanche advisory on Jan 2, 2013.

5. CONCLUSIONS

Observations in the Central Sierra Nevada have shown the following conditions as a precursor to a deep slab avalanche cycle:

- PWL is present but yields ECTN results
- No avalanche activity occurring on PWL within the region
- PST (End) results at less than 50% cut length on PWL

These observations have shown this data pattern, often present for up to two weeks prior to the loading event(s), indicate that a deep slab cycle avalanche cycle is possible if these conditions persist until a significant loading event occurs.

CONFLICT OF INTEREST

The creation of this document was not supported financially or materially by the ISSW. None of the authors benefit financially from the production or sale of ISSW proceedings nor have they received any related grants or patents.

ACKNOWLEDGEMENTS

We would like to acknowledge Travis Feist and Steve Reynaud for their assistance in fieldwork data collection.

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