An update on fracture character in stability tests.

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Rutschblock and Compression tests are stability tests commonly used by avalanche practitioners to evaluate instabilities in the snowpack. Past research (i.e. Föhn 1987, Jamieson 1999) has shown that as the number of taps for the compression test (or the loading step for the rutschblock test) increases, slab avalanching becomes less likely. Indeed, as shown in Figure 1, all skier-tested slopes where the compression test score was in the easy range were triggered, while only 19 out of 51 (37%) slabs released on slopes with an average score in the hard range. Similar numbers are found for the rutschblock test, with a frequency of skier-triggering of 100% for RB1 and 28% for RB6.

An ideal stability test would have a frequency of skier-triggering of 0% for the last loading step. This is clearly not the case for the compression test nor the rutschblock test. Of course we could keep tapping on our shovel until our hands are numb and hope to find a high enough loading step, but this is not practical. Instead, practitioners and researchers have been looking for ways to improve the interpretation of the stability test results by incorporating a qualitative description of the character of the fracture in the weak layer.

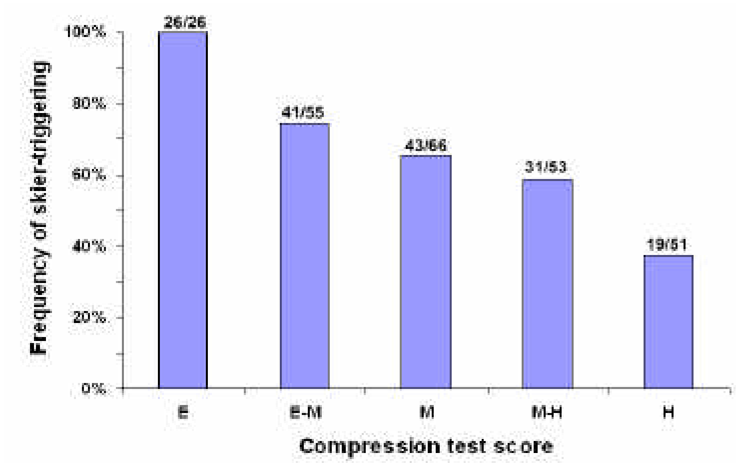

Figure 1: Frequency of skier triggering by average compression test score for 251 skier-tested dry slabs. From 2003 ASARC database, winters 1996-2003, Columbia Mountains, British Columbia, Canada.

Field workers have been distinguishing fractures involving collapse from other fractures for many years now. Since 1981, the Canadian Avalanche Association's Guidelines for Weather, Snowpack and Avalanche Observations (NRCC 1981 & 1989, CAA 1995 & 2002) have assigned a special code (STC) for shovel tests that resulted in noticeable collapsing of a layer and "settlement" of the overlying block when the shovel is inserted. The 1995 and 2002 editions of the guidelines note that sudden failures that result in distinct lines ("pops") are more often associated with avalanches than test results with rough or indistinct fractures. Avalanche professionals are well aware that some types of fracture have to be distinguished from others. This is exactly what the current research is aiming for; a systematic description of fracture character in stability tests to improve the interpretation of the results.

In Switzerland, a rating system for the type of release and quality of the fracture plane in rutschblock tests is used. The type of release is described as whole block, below the skis or only an edge and the fracture quality is either clean, partly clean or rough (Schweizer and Wiesinger 2001). Unfortunately, no data from this descriptive system has been presented thus far.

In North America, two fracture classification systems for stability test results are currently in use. In the United States, Birkeland and Johnson (1999) introduced a three level shear quality description: Q1 is a "clean, fast shear", Q2 is an "average shear" and Q3 is an "irregular or dirty shear". At the 2002 ISSW in Penticton, Johnson and Birkeland summarized six years of shear quality data from stability tests. Comparing the data with somewhat subjective "signs of instability" in the area of the test (southwest Montana and northwest Wyoming) they reported improved interpretation of stability test results, particularly for those tests with high scores. A stability test with a high score and with a clean Q1 shear is more likely to be related to signs of instability than a same test result with an irregular Q3 shear.

In a 1999 article on the compression test, Bruce Jamieson outlined a four level description of fracture character, used by researchers of the University of Calgary and some field workers in Canada: Progressive Compression (PC), Thin Planar (TP), Sudden Collapse (SC) and non-planar Break (B). Five winters of stability test data with the four level description of fracture character were analyzed and presented at the 2002 ISSW in Penticton (van Herwijnen and Jamieson 2002). Over 6000 classified fractures from compression and rutschblock tests showed that the weak layer crystal type plays an important role in the fracture character. Most fractures in weak layers composed of precipitation particles, decomposed fragments and rounded grains, as well as surface hoar crystals, were thin planar fractures. Weak layers composed of depth hoar, or large well developed facets, are more likely to produce a collapsing fracture.

Unfortunately, no significant difference in fracture character was found between the stability tests performed on slopes that were triggered and slopes that were not. Even for stability tests with high scores, the incorporation of the fracture character did not seem to improve the interpretation of the stability test result. However, a smaller number of stability tests performed on whumpf sites revealed that sudden collapse was the usual fracture type for this type of slab release.

Table 1: Descriptive classification of fracture character in stability tests.

Fracture Character	**Code**	**Fracture Characteristics**	**Typical Shear Quality**
Progressive Compression	PC	Fracture usually crosses column with single loading step, followed by gradual compression of the layer with subsequent loading steps.	Q2
Resistant Planar	RP	Fracture requires more than one loading step to cross column and/or the block does not slide easily on the weak layer.	Q2
Sudden Planar	SP	Fracture suddenly crosses column in one loading step and the block slides easily on the weak layer.	Q1
Non-planar Break	B	Irregular fracture	Q3
Sudden Collapse	SC	Fracture crosses column with single loading step and is associated with noticeable vertical displacement.	Q1
No Failure	NF		

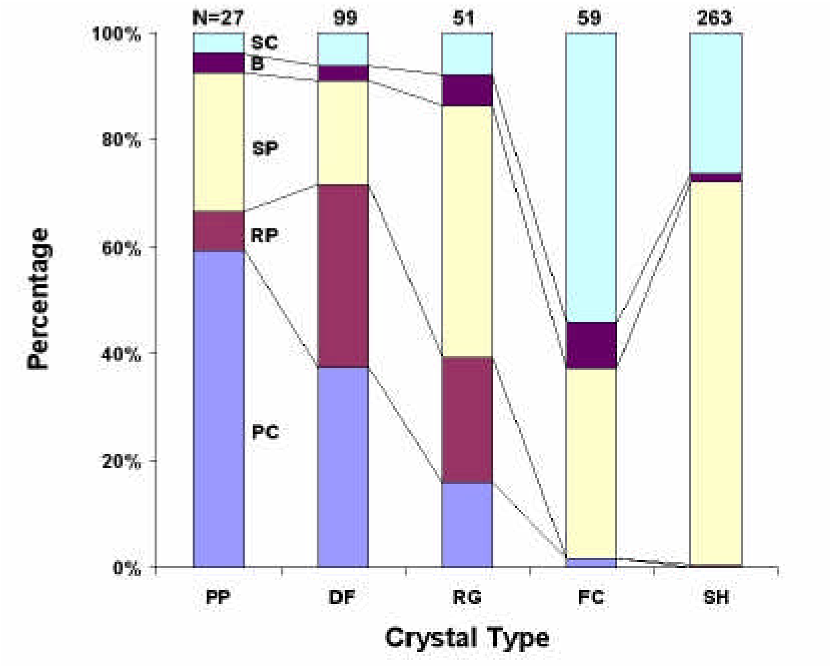

Figure 2: Fracture character from compression tests by grain type for precipitation particles (PP), decomposed fragments (DF), rounded grains (RG), faceted grains (FC) and surface hoar (SH). From 2003 ASARC database, winters 2002-2003, Glacier National Park and Blue River area, British Columbia, Canada.

In the fall of 2002 we decided to refine the fracture characterization system. Of all the classified fractures of the previous five years, 55% were characterized as Thin Planar. This category was too broad and was divided into two new fracture categories: Sudden Planar (SP) and Resistant Planar (RP) (Table 1). This new fracture classification system was used last winter by field workers of the University of Calgary in Blue River and in Glacier National Park. After one winter, the first results are encouraging.

The weak layer crystal type is again important for fracture character in compression tests, as can be seen in Figure 2. While thin planar fractures dominated the previous data set, the distribution is broader. Weak layers of decomposing fragments and surface hoar crystals used to have the same main fracture character (TP). With the new classification system, failures in weak layers of decomposing fragments usually exhibit PC (37%) and RP (34%). Surface hoar layers on the other hand are mainly associated with SP fractures (72%). Again, layers of faceted grains often fail with a sudden collapse (54%). Sudden fractures (SP and SC) account for 97% of the fractures in persistent weak layers (surface hoar or facets). As shown in Table 1, sudden fractures would likely be classified as Q1 in Birkeland and Johnson's shear quality rating. Progressive compressions are mainly observed in shallow storm snow layers. It is the leading fracture character for layers composed of precipitation particles (59%) and decomposing fragments (37%). Unfortunately, we have insufficient data from Rutschblock tests with the revised scheme.

After only one winter, it is hard to evaluate the validity of the new characterization system, however the results are promising. The new fracture characterization scheme is easy to learn and does not require a lot of experience to obtain consistent results. The limited data we have on skier-tested slopes, including whumpfs, show that the fraction of SP fractures for stability tests performed on slopes that released (16 slopes) is substantially greater than that for stability tests performed on skier-tested slopes that did not release (6 slopes).

In Figure 3 the percentage of compression test results for each fracture character is shown for skier-triggered slopes and for slopes that were skier-tested but not triggered. On skier-triggered

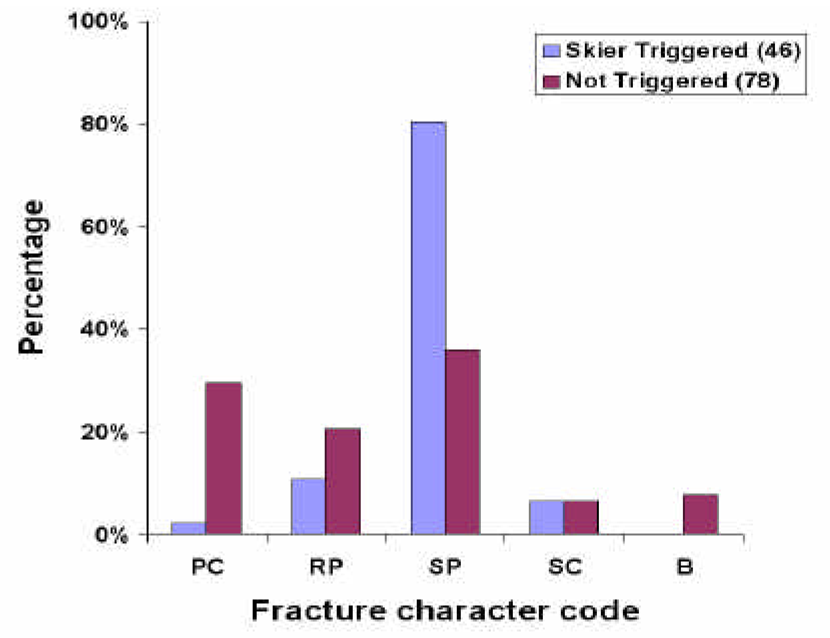

Figure 3: Fracture character in compression tests for skier-tested dry slabs. From 2003 ASARC database, winters 2002-2003, Glacier National Park and Blue River area, British Columbia, Canada.

slopes, 80% of fractures were characterized as SP, 10% as RP and only 2% as PC. On skier-tested but not triggered slopes, only 36% of the fractures are now characterized as SP. However, 20% of fractures are now classified as RP and the number of PC fractures has increased from 2 to 29%. Unfortunately the number of tests performed on skier-tested slopes is very limited. Only 23 slopes were skier-tested. Nevertheless, the data seem to indicate that SP fractures are more often associated with avalanching than PC and RP fractures.

The reason for this is probably that fracture character gives a qualitative description of the fracture propagation propensity through the weak layer (Johnson and Birkeland, 2002). PC and RP fractures are usually gradual fractures, meaning that the fracture progresses over several loading steps. On the other hand, SP fractures are fast fractures that happen as a result of one single loading step. This could indicate that fractures propagate more easily through weak layer that produce SP fractures, and therefore these are more likely to be the failure plane for slab avalanches. This is consistent with the Observation Guidelines (CAA, 1995, 2002)

We will continue to use this fracture characterization next winter, which will hopefully be a more "normal" winter. More data will be collected, and a trend will emerge. The goal is to create a classification system for fractures that is easy to apply and improves the interpretation of stability test results. Essentially we are trying to quantify experience in such a way that information exchange and the transfer of knowledge about snowpack tests is made easier.

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Birkeland, K.W., R.F. Johnson. 1999. The stuffblock snow stability test: comparability with the rutschblock, usefulness in different snow climates, and repeatability between observers. *Cold Regions Science and Technology*, Vol. 30 (1-3), pp. 115-123.

Canadian Avalanche Association. 1995, revised 2002. *Observation Guidelines and Recording Standards for Weather, Snowpack and Avalanches*. Canadian Avalanche Association, Revelstoke, BC.

Föhn, P.M.B. 1987. The rutschblock as a practical tool for slope stability evaluation. *International Association of Hydrology Science Publication*, 162, pp. 223-228.

van Herwijnen, A.F.G., B. Jamieson. 2002. Interpreting fracture character in stability tests. *Proceedings of the International Snow Science Workshop*, Penticton, B.C. (JR Stevens, ed.), pp. 508-513.

Jamieson, J.B. 1999. The compression test - after 25 years. *The Avalanche Review*, 18 (1), pp. 10-12.

Johnson, R.F., K.W. Birkeland. 2002. Integrating shear quality into stability test results. *Proceedings of the International Snow Science Workshop*, Penticton, B.C. . (JR Stevens, ed.), pp. 514-520.

Schweizer, J., T. Wiesinger. 2001. Snow profile interpretation for stability evaluation. *Cold Regions Science and Technology*, Vol. 33(2-3), pp. 179-188.