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Meteoric ^{10}Be, Fe_d, and Clay in Critical Zone Soils, Front Range, Colorado

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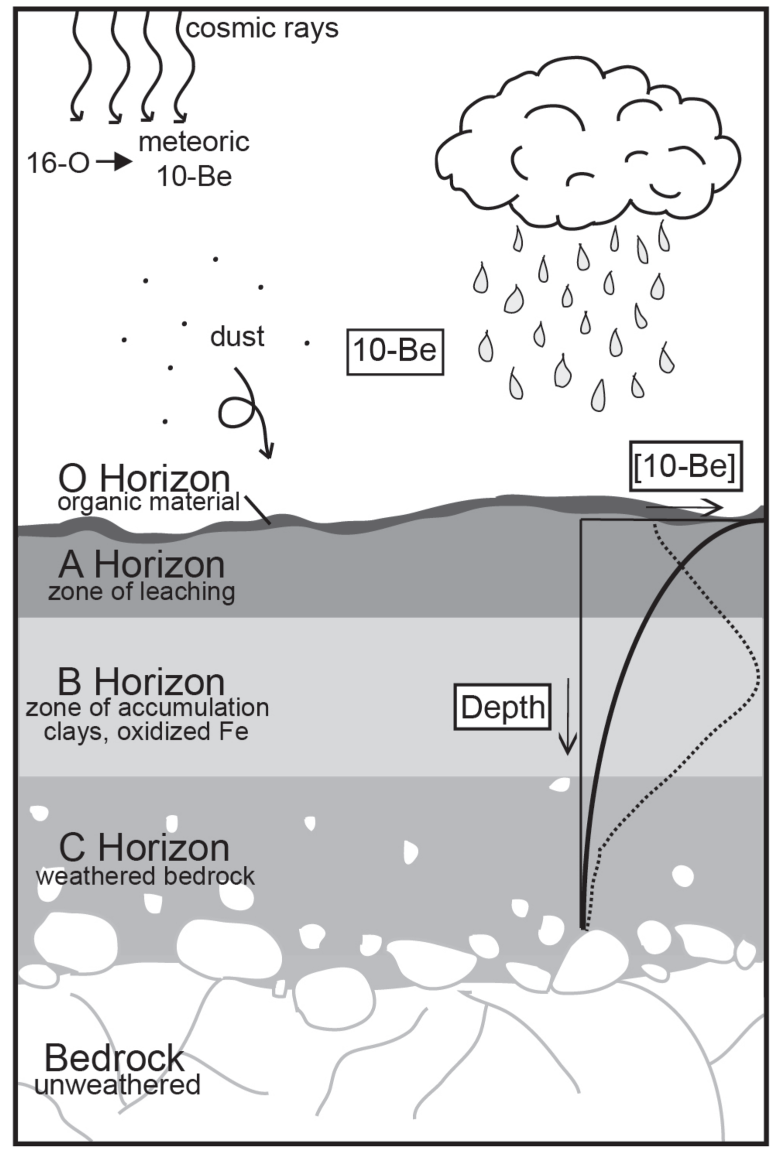
BACKGROUND INFORMATION

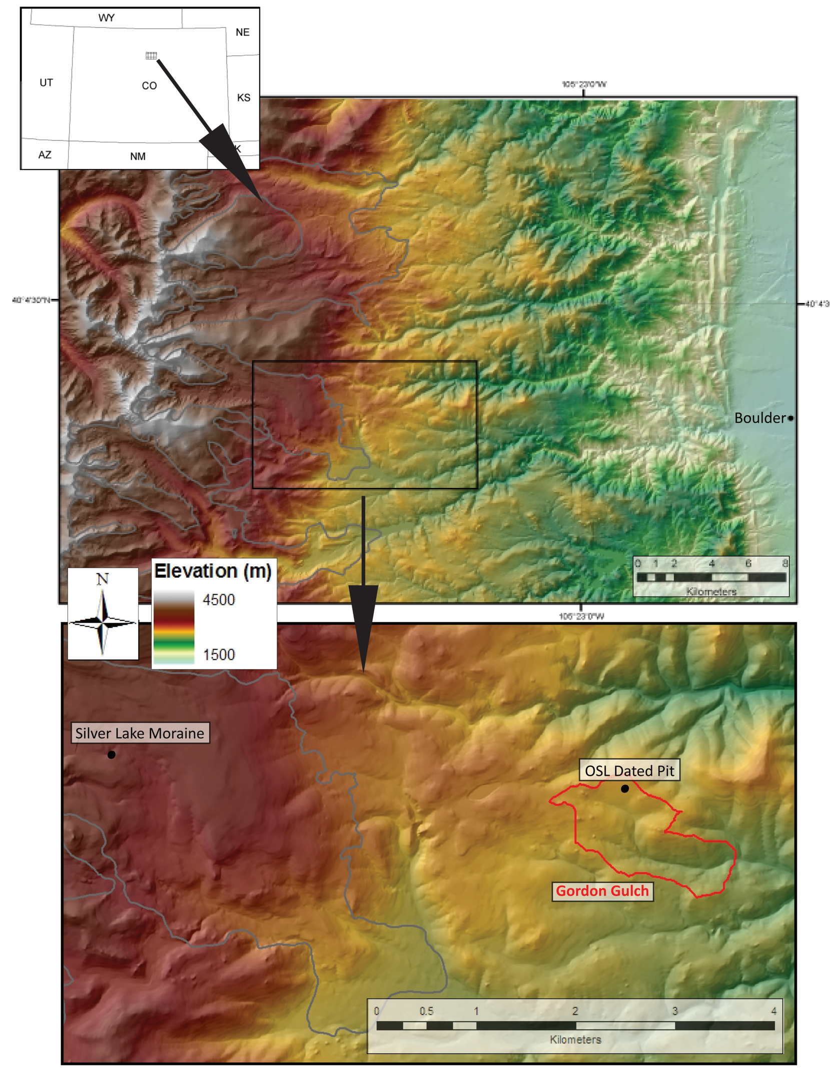
The critical zone is the zone within which meteoric water, atmospheric gases, soil, and bedrock interact, encompassing the zone of soil formation (Anderson et al., 2007). The concentrations of various pedogenic compounds at a given location indicate the degree of weathering that has taken place in the Critical Zone. Among the products of chemical weathering are secondary phyllosilicate minerals (clays) and iron (Birkeland, 1999). At stable sites, chronosequence studies have shown that the amount of pedogenic iron oxide and clay increase as soils become older (McFadden and Hendricks, 1985).

Meteoric ^{10}Be is a cosmogenic nuclide produced from oxygen and nitrogen in the atmosphere. It reaches the surface in rain water and dust and then binds to soil particles. As a soil profile evolves, so does its meteoric ^{10}Be inventory due to soil formation and mixing processes. Given a steady state hillslope, the peak concentration of meteoric ^{10}Be is expected in one horizon (Jungers et al., 2009). Concentration then decreases with depth, and the inventory is expected to increase downslope, creating a profile with a bulge. Given a young and eroding hillslope profile, the highest concentration of meteoric ^{10}Be will still be in a single layer but erosion prevents this concentration from moving to depths beyond near-surface (Graly et al., 2010). The geochemistry of soils provides useful insight into soil character and development, and when applied to steep, active hillslopes, aids in the analysis of evolving topography. The addition of meteoric ^{10}Be to soil analysis, combined with well-constrained delivery rates, allows for the dating of evolving soils and calculation of downslope soil transport.

This study examined hillslopes in Gordon Gulch, a 2.75 km² catchment with locally exposed bedrock and one of three focus areas of the Boulder Creek Critical Zone Observatory. Gordon Gulch is located downslope and to the east of the modern alpine environment and late Pleistocene glacial limit and generally upslope and to the west of the deeply incised landscape that characterizes the lower portion of Front Range rivers. Gordon Gulch may be affected by both upstream-migrating rejuvenation from the lower portion of the range and/or alpine environmental processes (i.e. periglacial activity).



ABOVE: Meteoric ^{10}Be is deposited by precipitation and/or dust and retained in soil.



ABOVE: Summary map of field area. Gordon Gulch is located between the glacial limit and the mountain front.

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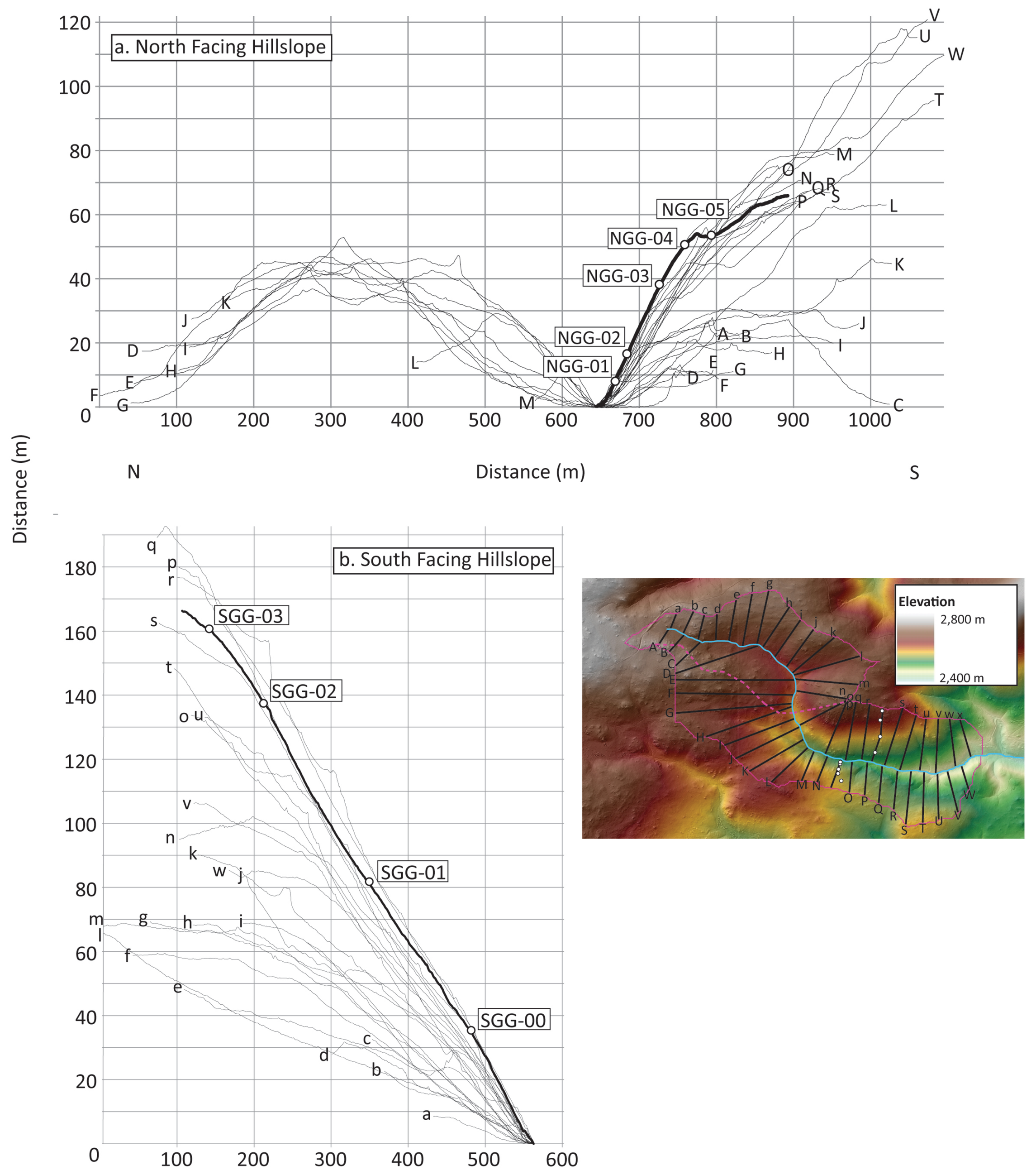
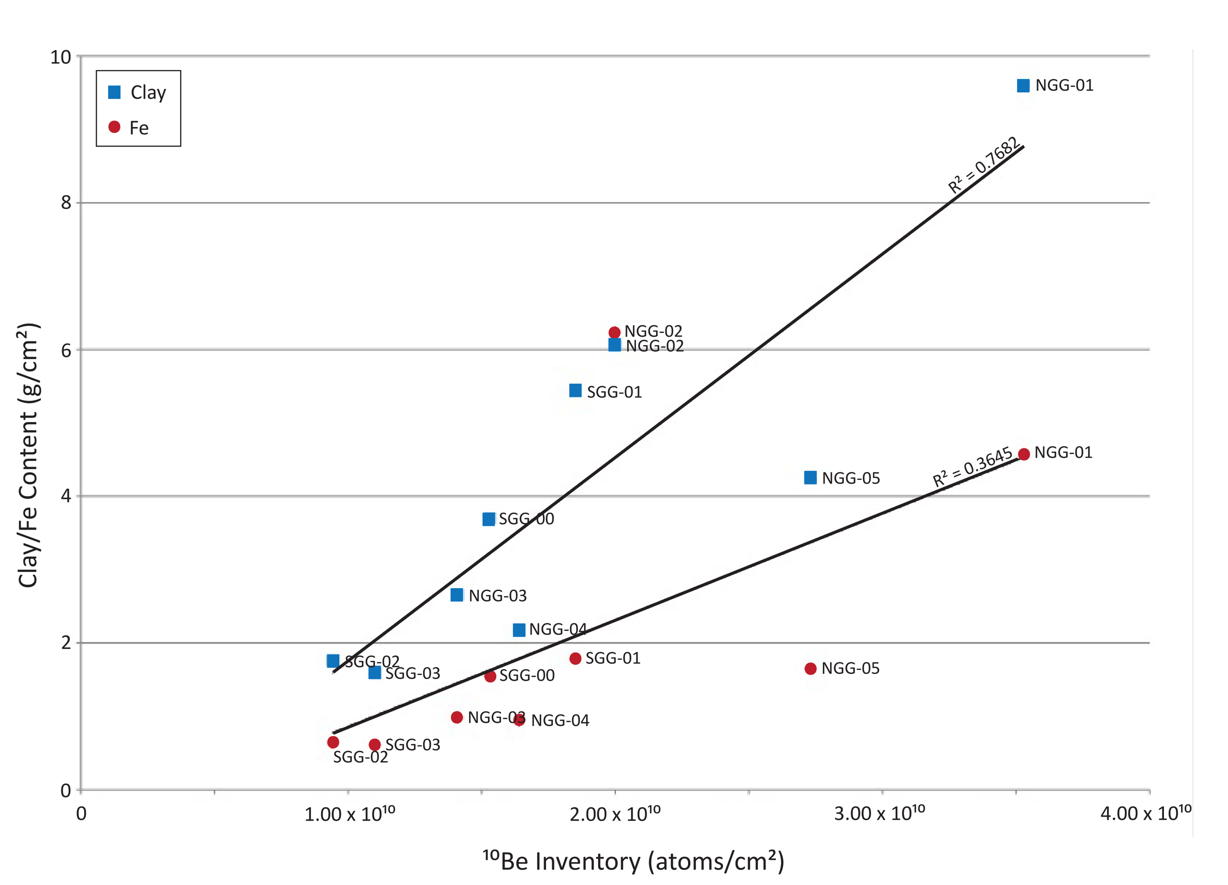
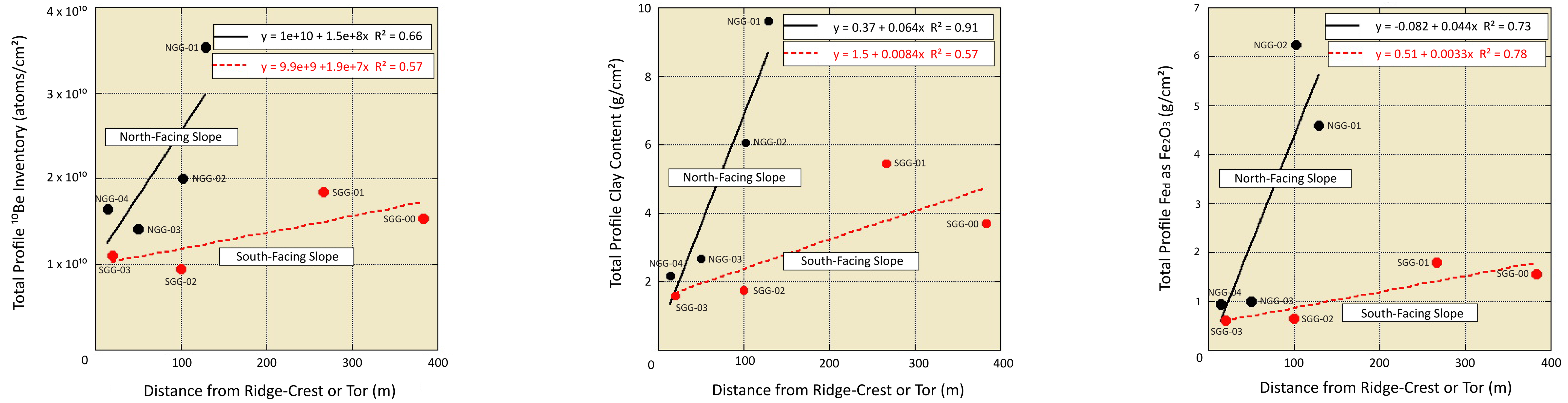


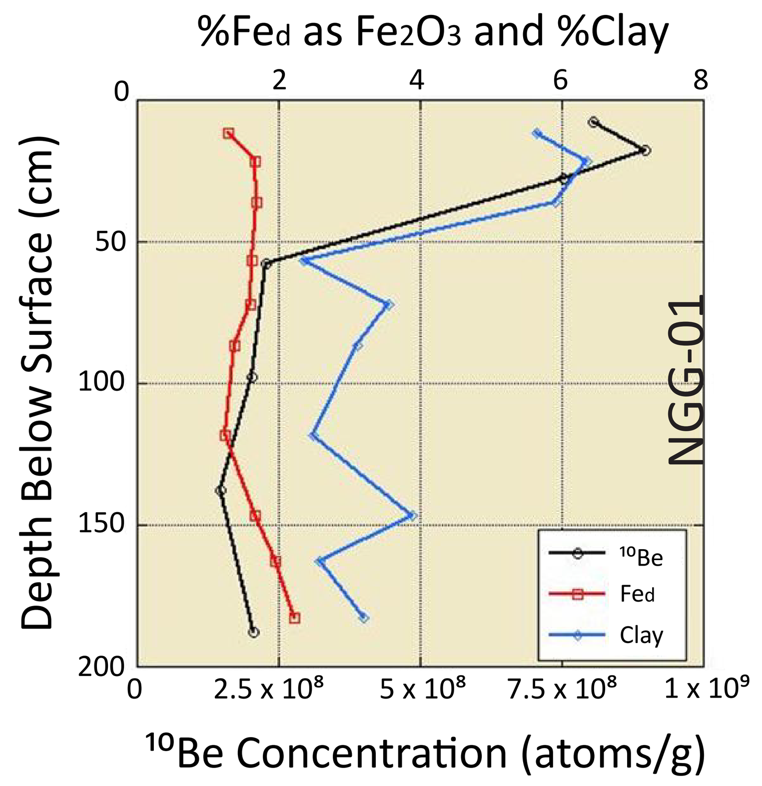
ABOVE: Profiles of the north- and south-facing hillslopes of Gordon Gulch extracted from ~1m resolution LiDAR digital elevation model (a and b). Profiles are labeled from west to east (downstream) beginning with "A" or "a". Transects in bold are the focus transects of this study. Open circles indicate locations of pits sampled for meteoric 10Be. Shaded relief map shows approximate location of transects with black lines. Dots indicate sample pit locations.

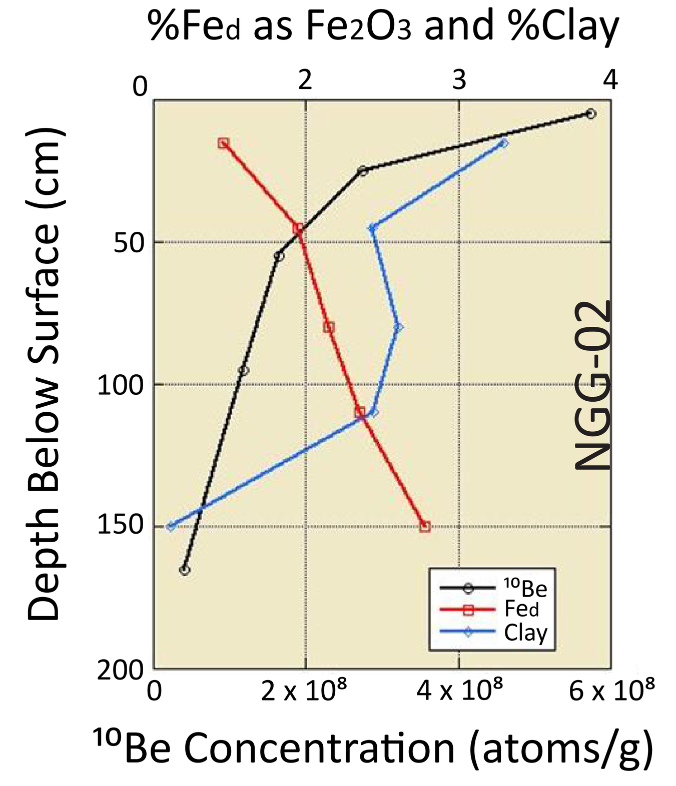


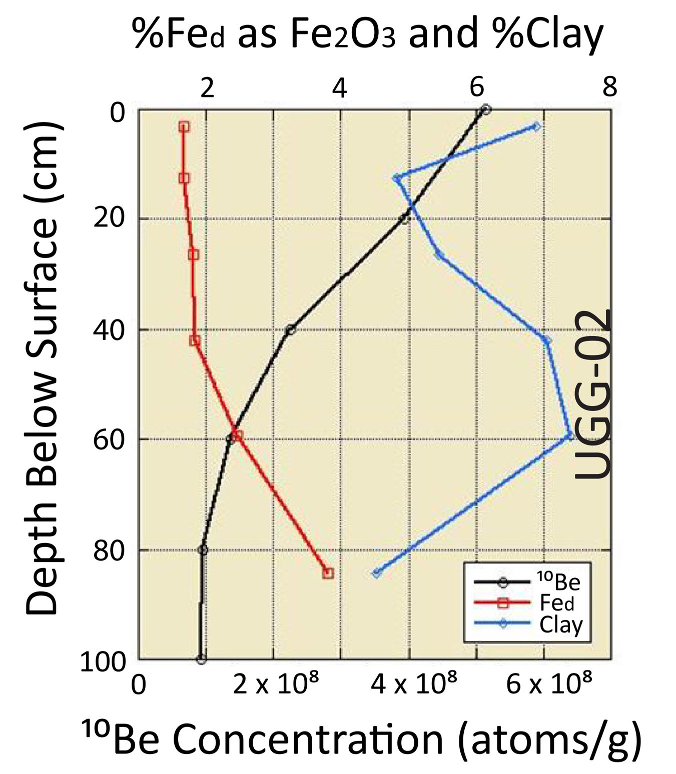
ABOVE: Chart showing the relation of ^{10}Be inventory to clay and Fe content for the sampled pits.



ABOVE: Graphs of meteoric ^{10}Be, clay, and Fed content vs. slope for both the north- and south-facing hillslopes.







ABOVE & LEFT: Graphs showing profiles with "excess" Fe and decoupling of ^{10}Be and Fe.

RESULTS

- The inventories of ^{10}Be, clay, and Fe genereally increase downslope on both the north- and south-facing hillslopes.
- NGG-02 contains anomalously high clay and Fe concentrations.
- The ^{10}Be inventory moderately-strongly correlates with clay content.
- The ^{10}Be inventory slightly correlates with Fe content, but a decoupling of ^{10}Be and Fe is seen in several profiles.
- Shorter and shallower north-facing hillslope, longer and steeper south-facing hillslope.

DISCUSSION & CONCLUSIONS

South-facing hillslope: younger soils and faster erosion

In Gordon Gulch, as regolith moves downslope toward the channel, soil profiles thicken and inventories of ^{10}Be, clay, and Fed increase, indicating that regolith is "older" downslope. Inventories of meteoric ^{10}Be, Fe_d, and clay in the Gordon Gulch catchment are all lower on south-facing hillslopes compared to north-facing hillslopes, indicating younger soils and faster erosion rates on the south-facing slope. Previous work assessing slope, vegetation, and hillslope length (Wyshnytzky, 2011) including LiDAR analysis of the catchment suggests the same.

^{10}Be and clay: a moderate-strong correlation

This correlation confirms previous work (Willenbring and von Blackenburg, 2010) showing meteoric ^{10}Be readily absorbs onto clay minerals. High concentrations of ^{10}Be and clay in the surface horizons, coupled with low Fe_d values, suggest a non-pedogenic, aeolian source of clay in the surface. This also suggests that a significant portion of the ^{10}Be inventory in study area soils may originate from dustfall.

^{10}Be and Fe: little correlation & decoupling

Depth concentrations of meteoric ^{10}Be to Fed show little correlation. The anomalously high total profile mass of Fe relative to clay and ^{10}Be inventory suggest Fe transport laterally along downslope flow pathways, perhaps mobilized by organic chelate-complexes in water flowing over a less permeable boundary, perhaps between Cox and hard saprolite horizons. Although saprolite was not seen in lower Gordon Gulch soils, the deeper pits of Gordon Gulch did not hit bedrock and therefore may not represent the entire soil column.

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